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In the Matter of the

Ontario Power Generation Inc.

Applicability of the Darlington New Nuclear Project environmental assessment and plant parameter envelope to selected reactor technology

Commission Public Hearing

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Exposé oral

Mémoire de l'Institut de radioprotection du Canada

À l'égard d'

Ontario Power Generation Inc.

Applicabilité de l'évaluation environnementale et de l'enveloppe des paramètres de la centrale à la technologie de réacteur sélectionnée pour le projet de nouvelle centrale nucléaire de Darlington

Audience publique de la Commission

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Canada

Radiation Safety Institute of Canada
Institut de radioprotection du Canada

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Review of the applicability of the Darlington New Nuclear Project environmental assessment and plant parameter envelope to Ontario Power Generation's selected reactor technology

for

Canadian Nuclear Safety Commission
(Reference: Form number: *PFP 2023 DNNP-03*)

by

Radiation Safety Institute of Canada

Radiation Safety Institute of Canada
Institut de radioprotection du Canada

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Submitted to:

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1 Introduction

1.1 About the Radiation Safety Institute of Canada

Founded in 1980, the Radiation Safety Institute of Canada (RSIC) is an independent, national organization dedicated to promoting and advancing radiation safety in the workplace, in the environment, and in the community. Our commitment to the principle of “good science in plain language”® underpins everything we do. The Radiation Safety Institute of Canada is incorporated under federal statute as a not-for-profit corporation and is also a registered charity (number: 106861511RR001).

The Radiation Safety Institute of Canada offers a broad range of educational, technical, and scientific services to businesses, government organizations, health care providers, communities, and individuals across Canada and around the world. The Institute is known for the high quality and scientific integrity of its work, and the practical and helpful assistance of its staff. The Institute’s independent information service receives hundreds of calls and e-mails every year, for information and assistance on workplace radiation questions.

1.2 Project

The *Radiation Safety Institute of Canada* (Institute) applied for and received funding through the CNSC’s Participant Funding Program (PFP). In the first phase of the work, the Institute sought to address two objectives: (1) review of Ontario Power Generation’s plant parameter envelope (PPE), environmental impact statement (EIS), and related documentation, and conduct an analysis and (2) submission of a written report to the CNSC summarizing comments from the review of the EIS and PPE. The original version of the written report was submitted 20 March 2023 and RSIC experts subsequently participated in a discussion session with other interested parties and CNSC staff.

For the second phase of the review, the Institute commited to delve into the issues once again, with two main objectives: (1) review Ontario Power Generation (OPG) and CNSC staff’s Commission Member Documents and related documentation and comment on the applicability of the Darlington New Nuclear Project environmental assessment to OPG’s selected reactor technology and (2) summarize the findings and recommendations in a written report to be submitted to the Commission and participate at the Commission hearing either in-person or remotely. For this phase, the written report was to be submitted by 20 November 2023..

2 Second Stage Review of OPG and CNSC Staff Documents

The Institute was provided with a series of OPG and CNSC documents related to the Darlington New Nuclear Project (DNNP). Environmental assessments are, by their nature, wide ranging, with much of the material unrelated to radioactive material or to radiation dose. Given its mandate to *promote and advance radiation safety*, the RSIC's current review focuses on the aspects of the documents relating to radiation safety for workers and the general public.

Document CMD: 24-H2, dated 18 September 2023, points out that 8 of the original 198 parameters from the original plant parameter envelop needed further investigation once the BWRX-300 was selected as the reactor of choice, as the BWRX-300 could exceed the original bounding values for these 8 parameters. Of these 8 parameters, three are of particular interest for radiation safety:

(1) The minimum release height above the finished grade is lower for the BWRX-300 than for the bounding scenario reactors (i.e., this could lead to higher radiation dose to individuals living or working near the reactor, as a lower release point implies less dispersion of airborne contaminants)
(2) Airborne radioactive emissions to atmosphere are in different proportions for the BWRX-300 than the emissions assessed in the original environmental assessment (EA) (i.e., this could also lead to increased dose per unit of power produced)
(3) The volumetric activity of solid radioactive wastes generated by the operation of the BWRX-300 is in different proportions than that assessed in the EA (i.e., this could result in increased radiation dose hazards in initial handling and could add to costs or difficulty in long-term storage of radioactive waste)

OPG document N-REP-01200-10000-R006 (14 July 2023) "*Use of plant parameters envelope to encompass the reactor designs being considered for the Darlington site*" provides useful details to evaluate the affects of these three parameters and other aspects of the reactors which could impact radiation dose to workers or the public.

2.1 Background:

OPG provides information on their intensions with respect to new nuclear power plant installation at:

https://www.opg.com/powering-ontario/our-generation/nuclear/darlington-nuclear/darlington-new-nuclear/

OPG and its partners initially developed a" Plant Parameters Envelope" (PPE) in 2008. The PPE was developed to provide input to an Environmental Assessment (EA) for the Darlington New Nuclear Project (DNNP), as described in the Project Description for the Site Preparation, Construction and Operation of the Darlington New Nuclear Generating Station. The PPE was developed to assist in evaluating the safety and environmental effects of the multiple reactor designs being considered for the site at that time. PPEs have been previously used in the United

States to assist in obtaining regulatory approval for site preparation before a final reactor design was determined. In the case at hand, the final reactor design has been chosen (i.e., the BWRX-300), but this was not one of the original reactor designs considered within the PPE, so the PPE had to be revised to ensure that there would be no additional excessive siting or environmental issues caused by choosing a reactor outside the original scope. An environmental impact statement (EIS) document was then revised based on the addition of the BMRX-300 characteristics to the PPE.

The CNSC has offered an opportunity for interested stakeholders to bring information to the Commission regarding the PPE and EIS. The RSIC has responded to this opportunity through this review of the PPE and EIS documents.

3 Review of Plant Parameters Envelope (PPE) Document

The Institute has reviewed versions R005 and R006 of "*Use of Plant Parameters Envelope to Encompass the Reactor Designs being considered for the Darlington Site*". The PPE provides a "bounding envelope" of plant design and site parameter values used in licence applications and in environmental assessments. It should place upper bounds on any potential adverse interactions between operation of the nuclear power plants and the environment. As noted in this document's revision summary, the document was updated to include BWRX-300 plant parameters which were not bounded by the previous revision of the PPE, which had considered a different set of potential reactors being sited. Thus, the PPE should bound not only the original reactor technologies but also the selected reactor (i.e., the BWRX-300).

The PPE was based on inputs from the reactor vendors originally considered. The values in the PPE were generated, reviewed and verified using a Quality Assurance Program compliant with CSA N286.2-00 "*Design Quality Assurance for Nuclear Power Plants*." The limiting values for each of 198 parameters of interest were then tabulated. Once the BWRX-300 was selected as the reactor of choice, the PPE was reviewed to make sure that all parameters of the BWRX-300 fell within the original bounding envelop. Upon review, it was found that eight of the parameter boundaries needed to be adjusted based on characteristics of the BWRX-300. While only 8 of the 198 parameters were found to be limited by the BWRX-300, several of these could be of significant public concern.

4 Review of Environmental Impact Statement (EIS)

The Institute was provided with a copy of the "*Darlington New Nuclear Project Environmental Impact Statement Review Report for Small Modular Reactor BWRX-300*", document NK054-REP-

07730-00055 R000, which had been prepared by **Calian Nuclear** with their associated consulting team and submitted to **Ontario Power Generation Inc** in October 2022. It notes that the Plant Parameter Envelope (PPE) was used as the basis for the environmental assessment. As noted in the document, an original EI was conducted between 2006 to 2009. There are a couple of interesting issues regarding the original EIS and the current situation. First, the original EIS considered a completely different set of possible nuclear reactors to be sited. In addition, that original EIS considered up to four nuclear power reactors to produce up to 4800 megawatts of electrical generating capacity.

The document notes that "The BWRX-300 belongs to the same Light Water Reactor (LWR) family as the Pressurized Water Reactor (PWR) which was included as one of the reactors assessed in the EIS". Based on the information provided, it appears that the document was attempting to contend that, while generating significantly less electricity, the BWRX-300 could be considered "not fundamentally different" from reactor designs previously considered. This is a bit of a stretch, as vendors of SMRs like the BWRX-300 have taken considerable pains to differentiate themselves from conventional power reactors such as the four originally considered in the PPE. None of the four original designs were boiling light water reactors. All four original designs required a foundation no more than 13.5 m below ground level, while the BWRX-300 requires foundations extending 38 m below ground level. The emergency cooling system differs from the previous designs. In addition, in the BWRX- 300, heat produced by nuclear fission in the core heats up the surrounding cooling water, creating steam, which is *directly* used to drive a turbine, while in the previously considered PWRs, the reactor cooling circuit (primary cooling) is *separate* from the turbine circuit. Thus, with the BWRX-300, there is less apparent separation of steam line and active components. In contrast with the pressurized water reactors considered in the PPE, where the steam turbine is separated from the nuclear system, boiling water reactors pass radioactive water through the steam turbine, so the turbine is within the "radiologically controlled" area of the nuclear power station. One can consider radioactive contamination of the materials making up the turbine created by activation products a drawback of a boiling water reactor such as the BWRX-300.

Section 3.5 of the document lists a proposed project timeline. It is noted "The conceptual timeline for the BWRX-300 deployment is presented in Table 2 with an anticipated start in Q3/Q4 2022, approximately 12 years later than the original date". This project timeline indicates "site preparation" starting in 2022, which I assume did not occur.

The BWRX-300 parameters not bounded by the original PPE are discussed in the EIS document. Table 5 from the EIS is repeated below for information.

Summary of PPE Parameters Bounded by BWRX-300 Characteristics

PPE Line item	Description	Original PPE value	BWRX-300 value	Impacts to EIS conclusions
7.1.1	Maximum Short-term Rate of Water Withdrawal for Fire protection	39.4 L/s	127 L/s	None
7.1.3	Quantity of Water Stored in Fire Protection System	3.78E+06 L	4.00E+06 L	None
1.1.2	Foundation Embedment	13.5 m	38 m	None
9.4.2	Elevation (Normal Operation)	48.8 m	35 m	None
9.5.1	**Gaseous Radioactive Emissions (Normal)**	See note	See note	None
10.3.1	**Liquid Radioactive Emissions (Normal)**	See note	See note	None
11.2.1	**Solid Radwaste Volumetric Activity**	See note	See note	None
17.1.2	Spent Fuel Cask Weight	100 tonnes	113 tonnes	None
1.7.2	Importance Factor for Wind Load	1.15	1.0	None

Note: the radionuclides in gaseous effluents, liquid effluents, and solid waste are the same as in the EIS, but their proportion has changed.

A key radiation safety issue shown by the table above, in the PPE and in the EIS document, the BWRX-300 sources terms have higher levels of releases of certain isotopes than the other reactors considered.

For the initial review, details of the BWRX-300 airborne, liquid and solid waste source terms were not provided. However, for the second review, full, detailed source term information was provided in tabular format, which is appreciated.

4.1 Airborne release

The RSIC is aware that airborne releases of radioiodine are of concern to many members of the public living near Nuclear Power plants, given the provision of iodine pills to block thyroid uptake in the case of an accidental release. The total radioiodine Airborne Source Term, Single Reactor, is 1.93 x 10^{10} Bq for the BWRX-10, more than any of the other reactors considered, despite the BWRX-300 producing much less electrical power than any of the full-size reactors. It should be noted that the total airborne source term for the BWRX-300 is less than that of the other reactors, however. See table below.

Table I. Airborne source term scaled by net MWe of each reactor: data from Table 4.1. Note that the BWRX-300 has the highest amount of airborne radioiodine per MWe, but has less airborne emissions than other reactors when all radioisotopes are considered

Reactor	EPR	AP1000	ACR-1000	EC6	BWRX-300
MWe(net)	1580	1037	1085	686	300
Airborne Radioiodine (Bq/y)/MWe	9.53E+05	1.86E+07	1.47E+04	2.33E+04	**6.44E+07**
Airborne Total (without H-3)/Mwe	**1.12E+12**	3.95E+11	5.47E+10	5.44E+10	7.33E+10
Airborne Total (H-3)/MWe	4.22E+09	1.25E+10	**4.61E+10**	3.57E+11	3.23E+09

The BWMX-300 is to have a zero liquid effluent source term under normal operation, which is clearly a favorable scenario, particularly given normal public concerns about radioactive effluent reaching Lake Ontario.

4.2 Solid Waste

Note that the BWMX-300 will produce more solid radioactive waste per unit of electrical power than the other reactors considered (see table below)

Table II. Solid waste source term scaled by net MWe of each reactor: data from Table 4.5. Note that the BWRX-300 has the highest amount of solid waste activity per MWe

Reactor	AP1000	ACR-1000	EC6	BWRX-300
MWe(net)	1037	1085	686	300
total solid waste (Bq/y)	6.16E+13	1.48E+14	7.64E+13	4.92E+13
total solid waste per net electrical energy (Bq/y)/Mwe	5.94E+10	1.36E+11	1.11E+11	**1.64E+11**

4.2.1 Solid waste disposal

As noted above, the BWRX-300 produces more solid waste per unit of electrical energy produced than the other reactors considered. As noted in the in the 2022 PNAS article titled "Nuclear waste from small modular reactors", there are concerns that SMRs do not reduce the generation of geochemically mobile fission products from spent nuclear fuel and as a result will add to the management challenges of onsite dry storage of used fuel and disposal. These fission products have mobility issues and dose contributions for typical repository designs. The institute reviewed the EIS document under the sections mentioning solid waste storage and spent fuel management. The report indicates that the increased volumes of solid waste and higher activity generated by the BWRX-300 will be managed by earlier transportation of fuel, installing appropriate shielding designs and increasing the weight of the transport casks from 110 tonnes to 113 tonnes to fully manage the dose consequences. Given the suspected impact that the BWRX-300 fuel cycles will have on nuclear waste management and disposal we would suggest that a detailed breakdown of the design parameters be submitted for the used fuel storage facility, to improve the confidence on all safety concerns surrounding repository design integrity and to further assert that these issues will not affect the conclusion of the EIS.

5 Discussion

Both the PPE and EIS were reviewed. No critical radiation safety related issues were found, although it will be important to ensure that all airborne, liquid and solid wastes produced are handled appropriately to minimize dose to workers and the general public. It should also be noted that the review was limited to what was available for review, as some material was proprietary in nature.

It appears cumbersome to select 198 parameters to bound all possible environmental impacts of a group of reactors, including those aspects of an environmental assessment of most interest to the general public – that is, radiation dose to human subjects. In reality, it may be that only some parameters have any significant effect – it is difficult to know whether the 198 selected have covered all key parameters. It is also not clear which of the parameters are key and if there are large groups of parameters that are simply highly correlated with little independent effect on the environmental assessment. It also may understate the importance of any one parameter – for example, there were only a few parameters where the BWRX-300 was the reactor which provided the "bounding" value. If several of these parameters were key to determining environmental risks, however, this would understate the impact of the selection of the BWRX-300 on the overall PPE and overall environmental assessment.

Based on a review of the PPE and EIS, assuming all planned mitigation procedures are implemented, the BWRX-300 could be an acceptable choice within the confines of the presented PPE. The Darlington New Nuclear Project environmental assessment appears to the RSIC's reviewers to be applicable to OPG's selected reactor technology. Based on the PPE, the site is appropriate for much larger and more complex, full-scale nuclear power plants. The one proviso is that the selection appears to be a unit that releases slightly more radioactive material per unit of electrical power produced into the environment than larger potential units, which is an item which would always be of public concern.

6 References

N-REP-01200-10000 R006 *Use of Plant Parameters Envelope to Encompass the Reactor Designs*

Lindsay M, Krall et al (2022), Nuclear waste from small modular reactors, *PNAS*, Vol 199. No.23, https://www.pnas.org/doi/full/10.1073/pnas.2111833119, accessed on November 20, 2023

NK054-REP-07730-00055 R000 *Darlington New Nuclear Project Environmental Impact Statement Review Report for Small Modular Reactor BWRX-300* October 5, 2022

REGDOC-1.1.1, Version 1.2 Site Evaluation and Site Preparation for New Reactor Facilities

REGDOC-1.1.2, Licence Application Guide: Licence to Construct a Nuclear Power Plant

REGDOC-1.1.3, Licence Application Guide: Licence to Operate a Nuclear Power Plant

REGDOC-1.1.5, Supplemental Information for Small Modular Reactor Proponents

REGDOC-3.5.1, Licensing Process for Class I Nuclear Facilities and Uranium Mines and Mills