

DETAILS OF OM&A PROJECTS – NUCLEAR

1.0 PURPOSE

This evidence provides project listings and supporting information, including business case summaries, for planned project OM&A expenditures for Nuclear Operations.

2.0 OVERVIEW

A tiered reporting structure consistent with the OEB filing guidelines has been used to present the evidence for all OM&A projects which have budgeted expenses during the IR term.

- Tier 1 – Projects with a total cost of \$20M or more. Summary level information is provided (see Ex. F2-3-3, Table 1), as well as business case summaries for projects with expenditures during the IR term (Attachment 1).
- Tier 2 – Projects with a total cost of \$5M to \$20M, for which summary level information is provided (Ex. F2-3-3, Tables 2a, 2b and 2c).
- Tier 3 – Projects with a total cost of less than \$5M, for which aggregated information is provided (Ex. F2-3-3, Table 3).

For Tier 1 projects, Ex. F2-3-3, Table 1 provides information on eight released projects with a total project cost of \$20M or more. These include three ongoing projects from EB-2016-0152, one completed project, and four new projects. Further details on these new projects are provided in Section 3.0.

For Tier 2 projects, Ex. F2-3-3, Tables 2a, 2b and 2c provide information on the 34 released projects with total project costs between \$5M and \$20M. These include 15 ongoing projects from EB-2016-0152, 11 completed projects from EB-2016-0152 and eight new projects. Total cost of these projects is \$343.5M.

For Tier 3 projects, Ex. F2-3-3, Table 3 provides summary level information on the 38 projects with total project costs less than \$5M. The average cost of these projects is \$2.3M.

As per Ex. F2-3-3, Table 4, there are a total of nine projects categorized as Project Portfolio (Unallocated). These projects are currently in the project identification or project initiation phases, and detailed expenditure information by project is not available. OPG expects in conjunction with its asset management program (Ex D2-1-1), that some of these listed projects (or other projects yet to be identified) will move from the project identification and initiation phases into project definition or execution phase as part of the ongoing portfolio management process. None of these projects are currently forecast to cost more than \$20M.

3.0 PROJECT-SPECIFIC INFORMATION - TIER 1 PROJECTS

The following information relates to projects identified in Ex. F2-3-3, Table 1.

3.1 New Projects

There are four new Tier 1 projects undertaken since EB-2016-0152.

Project #83280 Darlington Annulus Spacer Life Management. The purpose of this project is to address concerns about annulus spacers' integrity that have been identified previously during the Fuel Channel Life Cycle Management Plan. Annulus spacers are designed to maintain a gap between pressure tubes and calandria tubes. If the gap is not maintained and the pressure tubes come into contact with the calandria tubes, blisters may form leading to potential pressure tube integrity concerns under normal operating conditions. This project will allow for additional experimental data to be collected and additional analysis to be performed, thereby establishing support of high confidence projections of annulus spacers' fitness for service for the purposes of ensuring Darlington units can safely operate until the start date when Darlington Unit 4 is scheduled for refurbishment. The total project cost is estimated to be \$29.3M with planned completion in December 2021.

Project #84415 Darlington Primary Heat Transport Motor Oil Seal Leak Repair. The purpose of this project is to coordinate the repair of six new Primary Heat Transport Pump motors during Unit 1 and Unit 3 Darlington Refurbishment outages. Oil seal leaks were identified on the new motors installed in Units 1 and 3 during the first routine inspection following their installation. Oil was observed pooling on the stator windings, rotor, stator coolers and motor

1 bus bars. Cleanup and repair must be performed at a properly equipped facility off-site.. The
2 total project cost is estimated to be \$47.4M with planned completion in July 2025.

3
4 Project #84484 Darlington Unit 0 Switchgear Refurbishment. The purpose of this project is
5 perform mid-life maintenance on Unit 0 (i.e., common services at Darlington) switchgear to
6 increase equipment and station reliability, and to address commitments made to the
7 Canadian Nuclear Safety Commission ("CNSC") in Darlington's Integrated Implementation
8 Plan ("IIP"). The total project cost is estimated to be \$21.3M with planned completion in
9 December 2028.

10
11 Project #84589 Darlington Station Periodic Safety Review. The purpose of this project is to
12 conduct a Periodic Safety Review ("PSR") in accordance with Canadian Nuclear Safety
13 Commission REGDOC 2.3.3 – Periodic Safety Reviews (Ex. A1-6-1) in preparation for the
14 submission of the Darlington license renewal application in November 2024. As per the
15 Darlington's License Condition Handbook, the conduct of a PSR is a pre-requisite for license
16 renewal application. A PSR involves an assessment of the current state of the plant and its
17 performance to determine the extent to which it conforms to applicable regulatory
18 requirements, modern codes, standards and practices, and identifies any factors that would
19 limit safe long-term operation. In performing a PSR, the licensee is required to conduct
20 comprehensive reviews, and develop an Integrated Implementation Plan that identifies
21 factors that would enhance continued safe and reliable operation to be carried out by the
22 licensee during the next license period. The total project cost is estimated to be \$27.0M with
23 planned completion in May 2024.

24 25 **3.2 Completed Projects (from EB-2016-0152)**

26 One Tier 1 project has been completed since EB-2016-0152.

27
28 Project #62444 Fuel Channel Life Management (OM&A) & Annulus Spacer Retrieval Tool
29 Project (Capital) was completed under budget (\$49.5M versus initial full release of \$54.1M).
30 The variance is attributable to contingency which was not used (-\$4.5M) and reduced labour
31 cost (-\$0.1M), offset by increased purchased services (+\$0.9M).

1 **3.3 Project Cost Variances**

2 There are no ongoing Tier 1 projects for which total forecast project cost variances currently
3 exceed 10%.

LIST OF ATTACHMENTS

Attachment 1: Business Case Summaries for OM&A Projects of \$20M or more

Note: Business Case Summaries included in Attachment 1 are marked “Confidential” or “Internal Use Only”, however, OPG has determined them to be non-confidential either in their entirety or with redactions as indicated.

Tab No.	Project Number	Business Case Summary (BCS) Title	BCS Approval Date
		ONGOING PROJECTS FROM EB-2016-0152	
1	80014	Fuel Channel Life Extension Project	Aug-2016
		PROJECTS NOT IN EB-2016-0152	
2	84415	Darlington Primary Heat Transport Motor Oil Seal Leak Repair	Jan-2020
3	84484	Darlington Unit 0 Switchgear Refurbishment	Jul-2020
4	84589	Darlington Station Periodic Safety Review	Feb-2020
5	83280	Darlington Annulus Spacer Life Management (ASLM)	Nov-2018

Type 3 Business Case Summary

To be used for investments/projects meeting Type 3 criteria in OPG-STD-0076.

Executive Summary and Recommendations

Project Information			
Project #:	Project # 10-80014	Document #:	N-BCS-31100-10009 R01
Project Title:	Fuel Channel Life Extension Project		
Class:	☒ OM&A ☐ Capital ☐ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others:	Investment Type:	Value Enhancing
Phase:	Execution	Release:	Full
Facility:	Nuclear	Target In-Service or Completion Date:	December-2020

Project Overview
DECISION REQUIRED The purpose of this submission is to request Board of Directors approval of the full execution release (Gate 3) of the Fuel Channel Life Extension Project in the amount of \$28.1 million, for a total release of \$69.3 million (including [REDACTED] contingency).
ISSUE The project was first approved in 2013 for \$105.8 million based on a Class 4 estimate (+50%, -15%). The project is now estimated at \$69.3 million (including [REDACTED] contingency) based on a Class 3 estimate (+20%, -15%). Board of Directors approval is required for projects exceeding \$40 million.
ANALYSIS OPG needs to continually update its assessments of degradation mechanisms on fuel channel components. These degradation mechanisms impact OPG's ability to demonstrate fitness-for-service of the units and continue to operate these units to planned end of life. Understanding of fuel channel component degradation mechanisms has been improved by the research and development work and technical assessments co-ordinated under the completed Fuel Channel Life Management Project. Plans, tools, and methodologies were developed for assessing technical confidence in the fitness-for-service of Darlington pressure tubes to 210,000 effective full power hours and Pickering to 247,000 effective full power hours. There is economic value in increasing the effective full power hour limits for both Darlington and Pickering. Darlington refurbishment requires that the three units with overlapping outages operate up to approximately 235,000 effective full power hours. Extended operation of all Pickering units to year end 2020 would require operation life of 261,000 effective full power hours. A separate project – Pickering Fuel Channel Life Assurance – is in progress to extend the life of the Pickering fuel channels to 2024. The project objective is to issue Technical Confidence Statements on fuel channel fitness-for-service to 235,000 and 261,000 effective full power hours for Darlington and Pickering units respectively. The Confidence Statements will be based on the results on a number of research and development topics that have direct impacts on constituent parts of fitness-for-service statements. The \$36.5 million reduction in the cost of the project is driven primarily by Bruce Power co-funding of the project (\$28.7 million) and reduced contingency [REDACTED] offset by increases due to scope changes (\$0.8 million) and vendor cost increases [REDACTED]. While the contingency is reduced due to the retirement of two risks, the remaining contingency is comparatively high for a Class 3 estimate due to a newly identified risk. The original estimate of \$105.8 million (including [REDACTED] million contingency) was based upon OPG funding the full extent of the research and development project managed by the CANDU Owners Group. Following the approval in 2013, Bruce Power agreed to co-fund of the programme, thereby reducing OPG's investment.

Type 3 Business Case Summary

Project #: Project # 10-80014
Project Title: Fuel Channel Life Extension Project, Full Release

Document #: N-BCS-31100-10009 R01

Project Overview

Specific contingency for acquisition of non-OPG ex-service pressure tubes [REDACTED] and cost escalation at Canadian Nuclear Laboratories [REDACTED] have been eliminated with the retirement of those risks. These reductions are offset by a small increase in general contingency [REDACTED] and a new specific contingency for co-funding risk.

Bruce Power reviews the value and continued funding of CANDU Owners Group projects annually. Since there is no guarantee that the later years of the project will be funded, a [REDACTED] million specific contingency, requiring Chief Nuclear Officer approval for use, has been set aside to ensure the project is completed.

The cost increase in scope is due to work on crack initiation recommended by an expert panel (\$4.2 million) offset by a reduction in the number of pressure tube burst tests (\$3.4 million).

Vendor cost increases are driven by research & development technical issues [REDACTED] and under-estimation of costs (\$5.5 million).

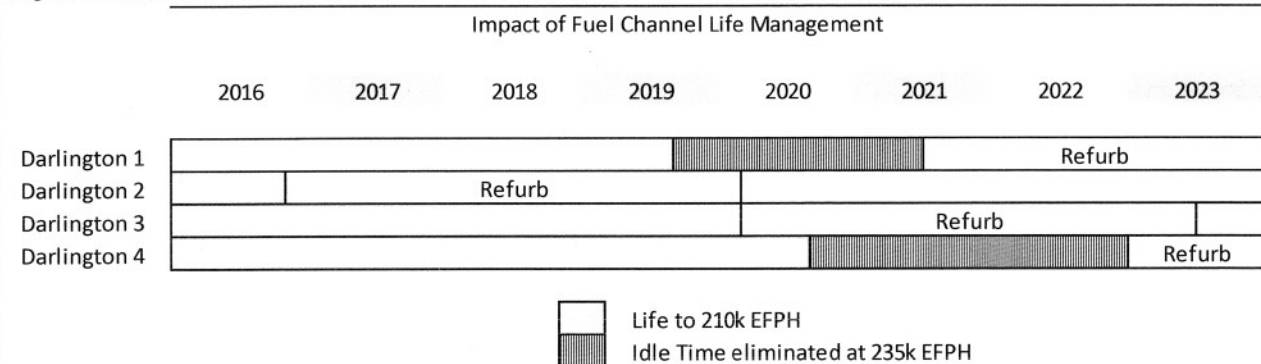
The end of the project is extended by 2.5 years in order to complete work that was deferred by the CANDU Owners Group and to allow more time for project close-out activities after the completion of research and development activities.

RECOMMENDATION / RESOLUTION

That the Board of Directors approve the release of an additional \$28.1 million for a full execution release of \$69.3 million (including [REDACTED] million contingency) for the Fuel Channel Life Extension Project.

Figure 1 shows the additional life which would be enabled by extending high confidence in the Darlington fuel channels fitness-for-service from 210k EFPH to 235k EFPH. The idle time avoided on the last 2 Darlington units to be refurbished is estimated at 50 months.

Figure 1: Impact of Fuel Channel Life Extension on Operating Times for Darlington



The value to the electricity system if the FCLE Project is pursued and successfully achieves high confidence in fitness-for-service of the fuel channels to 261k EFPH at Pickering and to 235k EFPH at Darlington is estimated at \$0.7B (PV 2016\$). The value arises from enabling the elimination of approximately 50 months of idle time on the Darlington units, which would occur if the planned refurbishment schedules is implemented, but fitness-for-service of the fuel channels beyond 210k EFPH were not achieved.

Type 3 Business Case Summary

Document #: N-BCS-31100-10009 R01

Project #: Project # 10-80014

Project Title: Fuel Channel Life Extension Project, Full Release

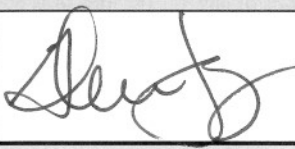
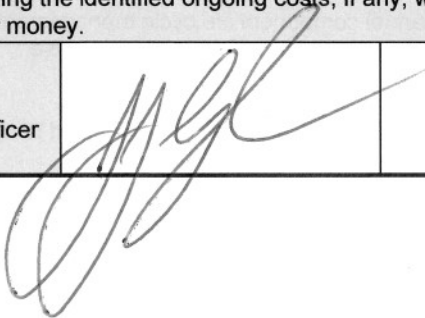
Project Cash Flows, NPV, and OAR Approval Amount									
M\$	2015 LTD	2016	2017	2018	2019	2020	2021	Future	Total
Currently Released	14.9	15.4	10.9						41.2
Requested Now	-		2.7	14.4	9.3	1.7			28.1
Future Required	-								
Total Project Cost	14.9	15.4	13.6	14.4	9.3	1.7			69.3
Ongoing Costs	1.0	0.3	8.0	31.6	57.6	14.4	7.5		120.3
Grand Total	15.9	15.7	21.6	46.0	66.9	16.1	7.5		189.6
Estimate Class:	Class 3				Estimate at Completion:				
NPV:	\$700M				OAR Approval Amount:		\$189.6M		

Additional Information on Project Cash Flows (optional):
Project Cash Flows, Estimate at Completion, and OAR approval amount show in the table above assumes co-funding by any other party. The Estimate at Completion does not include contingency of \$M.
Ongoing Costs are composed of Consequential costs and contingency Single Fuel Channel Replacements (SFCR):

\$M	To Enable 261k EFPH for Pickering	To Enable 235k EFPH for Darlington	Total
Consequential Costs*	39.9	56.4	96.3
Contingency SFCR (including material surveillance)		24	24
Total	39.9	80.4	120.3

*Consequential costs are composed of: material surveillance of pressure tubes and spacers beyond P1671 SFCR, Incremental station OM&A for fuel channel inspection and maintenance, incremental major components (Steam Generators) life cycle management costs, spacer material and ex-service spacer irradiation in High Flux Isotope Reactor, and potential additional burst tests to improve fracture toughness models at Heq<120PPM.

Note: This BCS assumes that OPG's partners in JP #4491 continue to co-fund the R&D effort at their current contribution levels. This assumption is based on COG JP #4491 partner approvals.

Approvals			
	Signature	Comments	Date
The recommended alternative, including the identified ongoing costs, if any, represents the best option to meet the validated business need.			
Recommended by (Project Sponsor): Glenn Jager, President, OPG Nuclear and CNO			27 July 2016
I concur with the business decision as documented in this BCS.			
Finance Approval: Ken Hartwick, SVP & Chief Financial Officer per OPG-STD-0076			179, 2016
I confirm that this project, including the identified ongoing costs, if any, will address the business need, is of sufficient priority to proceed, and provides value for money.			
Approved by: Jeffrey Lyash, President & Chief Executive Officer per OAR 1.11.11.1			Aug 10/16

Type 3 Business Case Summary

Project #: Project # 10-80014

Document #: N-BCS-31100-10009 R01

Project Title: Fuel Channel Life Extension Project, Full Release

Business Case Summary**Part A: Business Need**

As Darlington and Pickering reactors age, OPG needs to continually update its assessments of degradation mechanisms on fuel channel components. These degradation mechanisms may impact OPG's ability to demonstrate fitness-for-service of the units and, consequently, the success of continuing to operate these units to planned end of life (EOL).

Major degradation mechanisms can be categorized as follows:

1. Effect of Hydrogen/Deuterium ingress on pressure tube fracture toughness and impact on various fuel channel fitness for service assessments.
2. Pressure tube crack initiation by delayed hydride cracking (DHC), fatigue, or hydride region overload.
3. Mobility and integrity of annulus spacers, which carry pressure tube loads and prevent pressure tube/calandria tube contact.

Significant research and development (R&D) as well as improved assessment methodologies (eg. Probabilistic Core Assessment (PCA), Probabilistic Leak Before Break (PLBB) assessment, and Probabilistic Fracture Protection assessment) are required, to provide OPG with assurance that fuel channels will remain fit-for-service to the end of unit targeted service lives.

R&D work and technical assessments co-ordinated under the Fuel Channel Life Management Project (FCLM 10-62444), have improved the understanding of degradation mechanisms behind the aging of fuel channel components. Under this project, high confidence has been established in the fitness-for-service of Pickering fuel channels to operate to 247k EFPH. Together with the required R&D, inspection and maintenance activities, this enables continued operation of Pickering Units (EOL 2018-2020).

The FCLM project is now complete. The project results have established plans, tools, and methodologies to analyze inspection and surveillance data for assessing technical confidence in the fitness-for-service of Darlington pressure tubes to 210k EFPH and Pickering to 247k EFPH. A Long Term Darlington Life Management Plan for Inconel X-750 Annulus Spacers [1] was also prepared under the FCLM. This plan describes the fuel channel inspection and spacer R&D and material surveillance activities required to assess fitness-for-service of Darlington spacers and ensure that they remain fit-for-service to EFPH end of life target. This plan has been submitted to and accepted by the CNSC and is now included in the Darlington License Condition Handbook.

Economic value exists in OPG's ability to increase operational flexibility with respect to the sequencing and timing for the refurbishment of Darlington units. For example, unit refurbishment with no overlap between the first (D2) and second (D3) unit refurbishment outage requires the remaining three units (with overlaps of their refurbishment outages) to operate up to and beyond 210k EFPH. This would require demonstrating the capability of the last unit scheduled for refurbishment to be able to operate safely to approximately 235k EFPH. There is also economic value in the extended operation of Pickering units to beyond 247k EFPH. For example, extended operation of all Pickering units to year end 2020 would require operation life of 261k EFPH. This increased operational flexibility or opportunity for additional economic value is offset to some extent by the cost /risk of R&D activities.

Technical confidence in fuel channel fitness-for-service for Pickering and Darlington units to their end of life EFPH targets is required to mitigate business planning and regulatory risk. Technical confidence statements need to be based on the R&D results on a number of research topics that have direct impacts on the constituent elements of fitness-for-service statements.

BUSINESS COMMITMENTS NOT INCLUDED IN THE PROJECT:

OPG has the following commitments related to fuel channel component life cycle management beyond the FCLE project scope. These costs have been included in the economic assessment of this business case.

1. PT and Spacer Material Surveillance:

2 SFCRs are planned (P1951 and D1711 outages). The pressure tubes will be subjected to the material surveillance testing required by CSA N285.4. The conceptual estimate for these activities is \$12 M.

2. Incremental Station OM&A Costs for Fuel Channel Inspection and Maintenance

Includes 1 SFCR (P1951), 2 SLAR campaigns (P1751 and P1761), 1 PT-CT Gap inspection (P1961), Scrape sampling (P1961), for total estimated cost of \$19 M.

Type 3 Business Case Summary

Project #: Project # 10-80014
Project Title: Fuel Channel Life Extension Project, Full Release

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Part A: Business Need

3. Contingency SFCRs

The long-term spacer life management plan includes two contingent SFCRs at Darlington in 2018 (D1831 outage) and 2019 (D1941 outage). These SFCRs may be required to retrieve additional spacers for testing and examination if the results of earlier spacer testing and the subsequent spacer integrity assessments are unfavourable (i.e. long-term spacer fitness-for-service cannot be assured). Spacer material surveillance testing is estimated at \$2M per set of 4 spacers retrieved in a given outage, with a station cost of \$10M/SFCR, for a total estimated cost of \$24M.

4. Burst Test post-2017 for Fracture Toughness Model validation below 120 ppm [Heq]

There is a risk that additional Burst Tests from 2018-2020 may be required to validate the fracture toughness models for equivalent hydrogen concentrations [Heq] below 120 ppm. Assuming that 9 additional BTs are required, cost is estimated to be \$15 M.

5. Additional Life Cycle Management Cost of Other Major Components due to extended operations

Cost of P1951 Steam Generator water lancing is estimated at \$4.2M.

6. Spacer Material Surveillance

P1711 Spacers and the 24 spacers retrieved from Darlington Unit 2 during Refurbishment unit will be sent for testing and examination. Cost estimate is \$15M.

7. HFIR Irradiation post-2017

The HFIR irradiation program is planned through 2021 but only funded through 2017 (up to the dose that is equivalent to 225 KEFP in a Darlington reactor). Based on the HFIR irradiation strategy in the current long-term spacer life management plan, the estimated funding requirement beyond 2017 is \$13 M.

The total cost estimate for spacer material surveillance and testing listed (Items 6 and 7) is \$28M.

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Project Title: Fuel Channel Life Extension Project, Full Release

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Part B: Preferred Alternative: Execution of Fuel Channel Life Extension Project

Description of Preferred Alternative

Upon completion of the project, OPG will have the plans, tools, and methodologies to acquire and analyze inspection and surveillance data to assess fitness for service of fuel channels to the targeted lives of 261k EFPH plus margin at Pickering and 235k EFPH plus margin at Darlington. This would enable OPG to achieve its business objectives for Pickering Continued Operations and the Darlington operating units during their pre-Refurbishment lives.

PROJECT SCOPE AND RELEASE STRATEGY

The FCLE project is being released and executed in two phases:

- Phase 1 partial release (2014-2017) was for the execution of R&D scope, Burst Tests, surveillance testing of the PTs from D1321 and B8J18 SFCRs, and Phase II of HFIR Irradiation work. Part of Phase I was deferred into 2016/2017.
- Phase 2 full release (2016-2020) will include the remaining BTs from the matrix logic, surveillance testing of the PT and spacers from P1671 (deferred from P1561) SFCR and continuation of HFIR program. The final results will be used to refine models and methodologies. The R&D work is planned for the full year of 2019 and hence, funds (\$600k) are required for the project management and close-out activities in 2020.

Progress to Date:

Major Deliverables Completed:

Fracture Toughness

- Completed fracture toughness tests on small specimens ex-service material.
- Completed two burst tests (BTs) on a hydrided pressure tube section.
- High pressure hydriding (HPH) of small and full scale specimens. A significant amount of discovery HPH work was performed to address technical issues with the hydriding process.
- Phase I Alternative Hydriding (Low Pressure Gaseous Hydriding or LPGH) process development complete.
- Completed surveillance testing of the PT from D1321 SFCR.
- Validated interim fracture toughness model and obtained CNSC acceptance to use the model to satisfy License requirements for fuel channel fitness for service.

Crack Initiation

- Completed fatigue crack initiation tests on unirradiated and irradiated PT material.
- Completed DHC initiation tests in unirradiated and irradiated PT material.
- Completed load reduction tests on hydride region overload crack initiation in unirradiated and irradiated material.

Spacers

- Darlington Unit 2 spacers were transported to ORNL, encapsulated, and inserted into the HFIR under the HFIR Phase III Irradiation Program. This was a first-of-a-kind activity at ORNL.
- Irradiation of ex-service spacers is ongoing in the HFIR.
- Ongoing development of spacer models
- Crush and fatigue tested Darlington and Bruce Power ex-service spacers for demonstration of fitness-for-service

Probabilistic Core Assessments /LBB/Fracture Protection

- Issued the technical basis on revised acceptance criteria for the maximum allowable frequency of pressure tube rupture, which will be implemented into Table C.1 of the CSA Standard N285.8 as part of the 2017 revision.
- Developing computer code on probabilistic evaluation of fracture protection and leak before break (LBB).

Regulatory

- Industry workshops with CNSC to provide R&D results and resolve regulatory concerns with new methodologies and models (eg. probabilistic leak-before-break and fracture protection)
- Regulatory submissions including those specified in the Darlington Long Term Spacer management plan.
- Disposition CNSC comments, concerns and recommendations.

Major Phase I work in progress:

- The work on developing an alternating hydriding technique needs to be continued to mitigate the risk of the HPH process failing to achieve the 150 ppm target. Phase II of this work package includes testing on unirradiated samples having full size pressure tube circumference and wall thickness. This work is currently funded solely by OPG. If this program proceeds to Phase III, it is expected that the other major partner in JP #4491 will fund the remaining work. Criteria for abandoning the HPH or alternate hydriding technique have been established. OPG does not plan to support both programs to completion.

Type 3 Business Case Summary

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Project #: Project # 10-80014

Project Title: Fuel Channel Life Extension Project, Full Release

Part B: Preferred Alternative: Execution of Fuel Channel Life Extension Project

Description of Preferred Alternative

- Complete two more Burst Tests by the end of 2016.

Project Scope under Phase 2 release:

1) **Complete 6 Burst Tests (BTs):**

More BTs are required to generate data on fracture toughness model at [Heq] concentrations greater than 120 ppm. The test specimens are hydrided irradiated pressure tube material sections. These tests are required to demonstrate fitness-for-service of pressure tubes material late in their operating life.

2) **High Pressure Hydriding (HPH):**

A procedure for hydriding pressure tube material to 150 ppm [Heq] is required to support burst tests that will provide further insight into pressure tube behaviour beyond current projected end of life projections (looking beyond our headlights).

3) **Spacer Models:**

Preliminary (Version 0) spacer models were established under the partial release. Further development/refinement of the empirical and structural models is required for Darlington tight fitting spacers. The final objective is achieving a reliable formal spacer model that can be used to assess fitness for service throughout the extended life of Darlington units.

4) **High Flux Isotope Reactor (HFIR) Irradiation Program:**

This release funds Phase I and II HFIR program activities to the end of 2017. Phase I (unirradiated optimized) and II (unirradiated non-optimized) spacers/spacer materials will be irradiated to the equivalent dose of roughly 100 and 82 kEFP, respectively. Specimens will be removed from the HFIR for testing and examination as per the Long Term Spacer Plan. Phase III ex-service spacer specimens will be irradiated to the equivalent dose of 245,000 EFP in a Darlington reactor. Phase III of the HFIR program is required to provide a look-ahead into spacer fitness for service late in Darlington life, supporting OPG business planning decisions that may be required during the execution of the Refurbishment project.

5) **Complete remaining work:**

Under this release, the remaining assessments required to demonstrate fitness-for-service during extended life operation will be completed. The bulk of assessments focus on PCA, LBB and fracture protection using new fracture toughness and crack initiation models.

Other Project Tasks:

- 6) Other R&D activities such as deuterium ingress experiments, assessment of tight fitting spacer movement, continuation of hydride reorientation stress, probabilistic core assessments etc.
- 7) Key submissions and ongoing dialogue with CNSC on fracture toughness, and spacer fitness for service, and new probabilistic assessment methodologies.
- 8) Project management activities including project close-out.
- 9) Allowance for discovery work, which may be determined by expert panel discussions or CNSC requirements.

Type 3 Business Case Summary

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Part B: Preferred Alternative: Execution of Fuel Channel Life Extension Project

Description of Preferred Alternative

Table 1 - Breakdown of the project work scope and estimates

Item	Phase I	Est. Cost*	This Release	Est. Cost*
		Status		Status
Inspection & Maintenance Scoping (Tech Service Contracts)	Complete majority of R&D, inspection and maintenance scoping including assessment of target end of life hoop stress, PT/CT contact. Pilot assessment of LBB and FP using new FT models.	Complete	Complete remaining assessment work for the extended operations, including PCA, LBB and FP assessment using new FT models	
COG Material Surveillance Testing	Complete surveillance testing of PTs from D1321 and B8J18 SCFRs (through COG JPs) and issue test reports.	D1321 Complete B8J18 i/p	Complete shipping and surveillance testing of PT from P1671 SCFR (through COG JP) and issue test reports.	
Core R&D	Complete 4 Burst Tests (BTs) for Fracture Toughness (FT) model validation for the extended end of life conditions (higher [Heq] and higher hoop stress)	2 BTs competed 2 more in 2016	Complete 6 (originally 10) BTs for FT model expansion to extended life conditions	
	Hydriding to achieve 130 ppm. High Pressure Hydriding (HPH), Electrolytic and/or low pressure gaseous hydriding (LPGH) techniques development	HPH: LPGH: In Progress	Hydriding to achieve 150 ppm (HPH) to simulate higher [Heq] in later life reactor conditions	
	High Flux Isotope Reactor (HFIR) Irradiation and Spacer Testing	In Progress	HFIR Irradiation of spacer material and testing of ex-service spacers (to end of 2017 only)	
	Interim Spacer models and Spacer Fitness-for-Service (FFS).	Complete	Development/refinement of the Empirical and structural models for the Darlington Spacer and FFS for extended life	
	Other related R&D activities (Hydride Reorientation, Chlorine Content etc.) including fracture toughness work and core assessments.	Complete	Other related R&D activities (Deuterium Ingress, Tight Fitting Spacer Movement etc.)	
Third Party Reviews	Key submission to the CNSC on FT and Spacer models	Not required	Key submission to the CNSC on Probabilistic Fracture Protection	
Other Work	COG Project management activities		COG Project management activities, project close-out etc.	
Crack Initiation R&D	Discovery work determined by expert panel and CNSC discussion	In progress	Discovery work determined by expert panel and CNSC discussion	
OPG Internals	OPG Project/Technical Oversight		OPG Project/Technical Oversight	
Total	Phase I		Phase II	

*The majority of R&D work is executed through COG Joint Projects, for which OPG's portion of the costs is shown.

Type 3 Business Case Summary

Document #: N-BCS-31100-10009 R01

Project #: Project # 10-80014

Project Title: Fuel Channel Life Extension Project, Full Release

Part B: Preferred Alternative: Execution of Fuel Channel Life Extension Project

Description of Preferred Alternative

Table 2 below explains the differences between FCLM (#62444) and this project (#80014) on the Core R&D scope items:

Item	FCLM Scope (Proj. #62444)	FCLE Scope (Proj. #80014)	Explanation
1. Fracture Toughness - Burst Tests	14 BTs has been completed with which Rev. I of the New Fracture Toughness (FT) models have been established.	The original test matrix recommended 17 to 50 BTs (including 6 from FCLM that will be credited towards the matrix). This BCS assumes funding for 10 additional BTs.	Additional BTs are required to test PT and spacer material with high [Heq], broader range of Chlorine concentrations and higher hoop stress conditions which would exist during the extended life. CNSC is closely scrutinizing the BT test matrix for granting acceptance of the new fracture toughness model.
2. Hydriding Techniques Development	High Pressure Hydriding target of 120 ppm [Heq]	Alternate Hydriding method has been included in parallel to HPH method for achieving 150 ppm [Heq].	HPH repeatability has been poor and may not achieve the target [Heq]. Alternative processes are required to support DNGS refurbishment planning. The very recent results from alternate hydriding at small scale have shown success.
3. Spacer HFIR Irradiation	HFIR piloting i.e. reactor set up, material procurement, shipping and testing of the samples removed from the first interval.	Irradiation (Neutron) cost of subsequent samples and ex-service spacers retrieved during SFCRs.	Oak Ridge National Laboratories (ORNL) did not charge for neutrons during FCLM scope which was considered R&D work. Significant neutron charges will now be levied for future OPG commercial orders.
4. Spacer Empirical & Structural Modelling	Initial development of the models	Refinement of the models and acceptance by CNSC	These models are required to predict the life of the DNGS tight fitting spacers.

PROJECT COMPLETION

Project is targeted for completion and close-out by December 2020. A PIR will be completed by December 2021.

Deliverables under this release (2016-2020):

Deliverables:	Associated Milestones (if any):	Target Date:
Confirmatory technical confidence statement for PNGS 261k EFPH		30/06/2017
Updated Spacer Engineering Structural Model		30/11/2017
Develop Hydriding Techniques to Achieve High [Heq] (up to 150 ppm)		29/12/2017
Technical Confidence Statement (235k EFPH for DNGS) if needed		30/06/2018
Confirmatory technical confidence statement for DNGS 235k EFPH		30/06/2020
Project Close-out		15/12/2020

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Part C: Other Alternatives

In this alternative, OPG would not fund the next phase of the FCLE Project and would complete only the scope of work included in the FCLM, which concludes in Q2 2016, and some of the R&D activities in Phase I of the FCLE project.

Discussion with CNSC on Fracture Toughness Models have indicated that significant additional testing and analysis maybe required, beyond what was performed under the FCLM Project, to validate the primary fracture toughness model used for fitness for service assessment for the later life conditions at Pickering (beyond 247k EFPH) and Darlington (beyond 210k EFPH).

This alternative would impair OPG's ability to make strategic decisions with high confidence that fuel channel components will remain fit for service to target service lives, and may incur idle times on operating units where fitness for service cannot be demonstrated due to overly conservative or invalid models and methodologies.

Alternative 2: Base Case – Achieve 210k EFPH for Darlington with Life Management of Darlington Units

NOT RECOMMENDED:

This alternative was considered but rejected. Given the current refurbishment schedule for the Darlington units, this alternative would imply either idle time of 22 months on Darlington Unit 1, and 29 months on Darlington 4 prior to refurbishment, or life management of these units during 2016 to 2021/2023 to mitigate this significant idle time threat immediately prior to refurbishment, or other mitigating activities such as SFCRs, or non-standard operating configurations in the most-at-risk fuel channels.

While the costs of the FCLE project would be saved as well as a portion of consequential costs, significant system economic value would be forsaken. This alternative would foreclose the option of operating the Darlington units for a longer period prior to refurbishment, if it were economical to do so.

Alternative 3: Delay Work – NOT RECOMMENDED - Do only R&D work to Achieve 225k EFPH for Darlington with Possible Life Management of Darlington Units

This alternative was considered but rejected. Given the currently contemplated Refurbishment Schedule for the Darlington units, this alternative would imply idle time of 7 months on Darlington Unit 3 and 18 months on Darlington Unit 4 prior to refurbishment, or life management of these units in the period 2014 to 2021/2022 to mitigate this significant idle time threat immediately prior to refurbishment or other mitigating activities, such as SFCRs or non-standard operating configurations in the most-at-risk fuel channels.

Alternative 4: NOT RECOMMENDED - Do Not Extend Pickering Fuel Channel Life Past 247 k EFPH, but Extend Darlington to 235k EFPH

The initial confidence statement for operating all Pickering units to the end of 2020 (247k EFPH) has already been issued. A confirmatory statement is expected in 2017. This alternative is not recommended as there is no additional cost except that identified as consequential cost. All R&D work is bounded by Darlington.

Part D: Project Cash Flows, NPV, and OAR Approval Amount

k\$	LTD	2016	2017	2018	2019	2020	2021	Future	Total
Currently Released	14.9	15.4	10.9						41.2
Requested Now	-		2.7	14.4	9.3	1.7			28.1
Future Required	-								
Total Project Cost	14.9	15.4	13.6	14.4	9.3	1.7			69.3
Ongoing Costs	1.0	0.3	8	31.6	57.6	14.4	7.5		120.3
Grand Total	14.9	15.4	22.7	56.4	76.3	12.7			189.6
Estimate Class:	Class 3				Estimate at Completion:				
NPV:	\$700M				OAR Approval Amount:		\$189.6M		

Additional Information on Project Cash Flows (optional):

Project Cash Flows, Estimate at Completion, and OAR approval amount show in the table above assumes no co-funding by any other party. The Estimate at Completion does not include contingency of [REDACTED]

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Ongoing Costs are composed of Consequential costs and contingency Single Fuel Channel Replacements (SFCR):

\$M	To Enable 261k EFPH for Pickering	To Enable 235k EFPH for Darlington	Total
Consequential Costs*	39.9	56.4	96.3
Contingency SFCR (including material surveillance)		24	24
Total	39.9	80.4	120.3

*Consequential costs are composed of: material surveillance of pressure tubes and spacers beyond P1671 SFCR, Incremental station OM&A for fuel channel inspection and maintenance, incremental major components (Steam Generators) life cycle management costs, spacer material and ex-service spacer irradiation in High Flux Isotope Reactor, and potential additional burst tests to improve fracture toughness models at Heq<120PPM.

Note: This BCS assumes another CANDU operator will continue to co-fund the JP #4491 R&D effort at 50% contribution based on approved COG JP #4491 confirmation.

Part E: Financial Evaluation

M\$	Preferred Alternative	Base Case	Delay Work	Alternative 4	Alternative 5
Project Cost	69.3	0	N/A	N/A	
NPV	700	N/A	N/A	N/A	
Other (e.g., IRR)					

Summary of Financial Model Key Assumptions or Key Findings:

The value to the electricity system if the Fuel Channel Life Extension (FCLE) Project is pursued and successfully achieves high confidence in fitness-for-service of the fuel channels to 261k EFPH at Pickering and to 235k EFPH at Darlington is estimated at \$0.7B (PV 2016\$). This value is based on the assumption that the Darlington units are indeed operated to 235k EFPH or to their planned refurbishment dates (whichever is earlier) and that the Pickering units are operated to the end of 2020 (261k EFPH allows all units to operate to at least the end of 2020). The estimated value is net of the estimated cost of implementing the FCLE project, as well as net of the estimated \$72 M (PV 2016\$) of consequential costs associated with longer operation and increased life cycle management work on both Darlington and Pickering.

Table 3: Summary of Value Enabled by Recommended Alternative Versus Do Nothing (No project)

	No FCLE Project	Implement FCLE project	Impact	Value \$B (PV 2016\$)
Pickering	High Confidence in 247k EFPH achieved. Units Assumed Operated to 247k EFPH with Life Mgmt Outages on Unit 7	Tools and methodologies established to determine technical confidence in 261k EFPH achieved. Units Assumed Operated to 261k EFPH or end 2020, whichever is sooner.	Would allow all Pickering units to operate until end 2020, and would eliminate life mgmt outages on Pickering Unit 7.	
Darlington	High Confidence in 210k EFPH achieved* and Units operated to 210k EFPH or start of refurbishment outages, whichever is sooner	Tools and methodologies established to determine technical confidence and Units operated to 235k EFPH or start of refurbishment outages, whichever is sooner	Would allow elimination of all idle time prior to start of refurbishment on all units, given current planning schedule. Also allows flexibility to start refurbishment of the first unit later if readiness issues arise.	0.7
Total Median Estimated Value				0.7

*Some additional funding above base programs and beyond the Fuel Channel Life Management Project would be required to achieve high confidence in 210k EFPH at Darlington.

Results of the economic assessment were tested for sensitivity to key inputs such as the assumed electricity value, the degree of success in achieving high confidence in additional fuel channel life, and therefore the amount of additional station operating life achieved, the cost of the FCLE project and the level of consequential costs.

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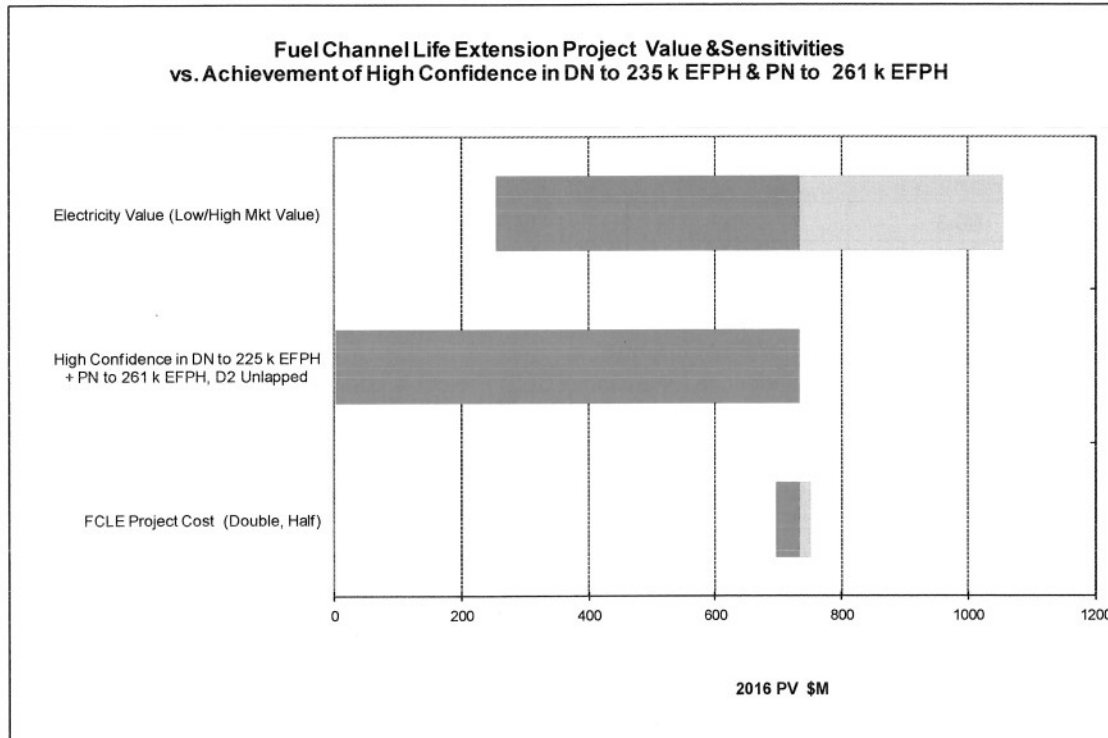
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Summary of Financial Model Key Assumptions or Key Findings:

In summary, the results indicate that, provided some additional life on Darlington is achieved, even if only to 225k EFPH, there would be a positive value to the electricity system, given the current planned refurbishment schedule (i.e. no overlap of the first two units to be refurbished), because of the reduction in idle time which is achieved.

The following tornado diagram shows the key sensitivity results.

Figure 1: Sensitivity of Value to Key Uncertainties



The following provides additional details on the sensitivity analysis:

- i. **Assumed Electricity Value:** The estimated value of FCLE is extremely sensitive to the assumed electricity value. In a high value regime the estimated value of eliminating potential idle time on Darlington and operating all of Pickering to end 2020 could be as high as approximately \$1.1 B (PV 2016\$). In a low value regime the value could be approximately \$0.3 B (PV 2016\$). A low priced regime could result from low or declining electricity demand growth (which could result, for example, from a prolonged economic slowdown) and low or declining gas prices, and /or high conservation which could result in a prolonged period of significant surplus base load generation.
- ii. **Length of Operating Life Achieved:** The value is sensitive to the additional fuel channel life which can be achieved with high confidence:
 - If the FCLE project were to enable the Pickering units to operate until end 2020, but only allowed Darlington to operate to 225k EFPH the value would be reduced by approximately \$700 M (PV 2016\$) to approximately \$0.0 B (PV 2013\$), as approximately only 6 months of idle time would result for the last unit refurbished, and this is off set by project costs and consequential costs..
- iii. **Project Costs:** The value is insensitive to FCLE Project Costs. An approximate doubling of these costs reduces the value by \$72 M (PV 2016\$) to approximately \$0.7 B (PV 2016\$). A halving of these costs increases the value by [REDACTED] [REDACTED] Given the magnitude of the consequential cost the value would also be insensitive to consequential costs.

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Part F: Qualitative Factors

The completion of the scope in the preferred alternative of this project is critical to the Continued and Extended Operations of Pickering, Refurbishment of Darlington. Since OPG operates the first CANDU units to be impacted by the fuel channel degradation mechanisms being investigated, our R&D findings may present financial opportunities when other CANDU units in the world are approaching their end-of-life.

Part G: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
Cost	There is a risk that the CNSC may require additional BTs (beyond the 10 included in the scope) to validate the cohesive zone fracture toughness model	Mitigate – Contingency has been included for moderate scope addition	Medium	Medium
Scope	There is a risk that additional BT request by CNSC increase the project scope.	Mitigate – OPG, Bruce Power and vendors setup workshop with CNSC to demonstrate adequacy, reliability and repeatability of data obtained from the existing scope.	Medium	Medium
Resources	A delay in project schedule may occur due to unavailability of specialized resources that cannot easily be replaced. Reasons for unavailability could be due to emergent, spin-off work and conflicting priorities threatening the project schedule and cost.	Mitigate – Obtain resource commitment from vendors. Prioritize project work; communication and negotiation within business units regarding FCLCP commitments and support.	Low	Medium
Technical	There is a risk that results of R&D or field inspection may not support operations to the targeted fuel channel lives (235k EFPH for Darlington and 261k EFPH for Pickering)	Mitigate – Phased release strategy and continuous assessments of the R&D and inspection results to minimize the cost of the project should this risk materialize	Medium	Medium
Schedule	There is a risk that technical complexity challenges the project team leading to delays in deliverables.	Mitigate – Identify challenges early through frequent Steering Committee meetings.	High	Medium
Schedule	There is a risk that lab equipment breakdown jeopardize the timeliness of the tests or produce poor results.	Mitigate – Oversight on testing procedure and effective commissioning program. Vendor's inventory includes critical spare parts.	Low	Medium
Schedule	There is a risk that lengthy internal reviews effecting OPG milestones and CNSC submissions	Mitigate – Spread reviews across qualified OPG staff, monitor vendor's report status	High	High
Scope	There is a risk that discovery work, indeterminate results or unexpected results impact on the project scope.	Mitigate - Provide oversight on COG R&D work and prioritize according to CNSC commitments. Use allocated funds if required.	Medium	Medium
Scope	There is a risk that unexpected scope cuts from the outage causing insufficient data to perform FC fitness-for-service assessments.	Mitigate – provide input to MCED on scope change recommendations	Medium	Medium
Cost	There is a risk that one of the funding partners drops out of JP or decrease their contribution.	Mitigate – Early alignment with funding partners	Low	High
Technical	There is a risk that the end of life Heq is underpredicted due to higher D-ingress when fuel channels exceed the limit for	Mitigate – Conduct scrape samples and update	Medium	High

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Part G: Risk Assessment				
Risk Class	Description of Risk	Risk Management Strategy		Post-Mitigation
	terminal solid solubility for hydrogen dissolution (TSSd).	models conservatively. Perform deeper scrapes and establish sample reliability model. Conduct experiments to determine material properties when fuel channels cross TSSd		
Technical	There is a risk that discrepancies between scrape and punch samples lead to higher than expected Heq at the outlet RJs.	Mitigate - Perform deeper scrapes and establish sample reliability model.		Medium High
Quality	There is a risk that insufficient pressure tube test material will be available. This may impair our ability to perform tests required to develop and validate fracture toughness models	Negotiate an arrangement that gives CANDU operators more control over ex-service materials		Medium Medium

Additional Risk Analysis:

Long term business risk to demonstrate fuel channel fitness-for-service (post project):
Management of fuel channel fitness-for-service must continue even after the completion of this project. As units age, CNSC is expecting that there would be sufficient inspection and surveillance data to support the projections that the units are safe to operate to their targeted service lives. An expansion of fuel channel inspection scope has been proposed to the outage organization with the potential for outage extension. A Darlington "Long Term Spacer Plan" has also been submitted to CNSC, stating OPG's plan to retrieve and test intact spacers from Single Fuel Channel Replacement campaigns in outages, as well as during Darlington's 1st Unit Refurbishment.

Part H: Post Implementation Review (PIR) Plan

Type of PIR Report		Target In-Service or Completion Date	Target PIR Completion Date	
Comprehensive PIR		December-2020	December-2021	
Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)
Expanded fracture toughness curves covering the hydrogen concentrations at extended life (above 120 ppm)	Fracture toughness models are valid to 120 ppm [Heq]	Expanded fracture toughness curves reflecting effects of hydrogen concentration, covering lower-shelf and transition temperature region	CNSC acceptance of the validity of cohesive zone and statistical fracture toughness models beyond 120 ppm	MCED
Engineering model to project Darlington Spacer life to 235,000 EFPH	Preliminary model available. Model projects FFS to approx. 200 KEFPH.	Model provides a high confidence prediction of spacer FFS to 235 KEFPH	Completion of CNE Review G4 in NK38-PLAN-31160-10000	MCED
Confidence in fitness-for-service of the Pickering fuel channels to 261k EFPH is established	Preliminary confidence statement issued	Confirmatory statement of technical confidence in fuel channel FFS issued	Document containing confirmatory statement issued in Asset Suite 7	MCED
Confidence in fitness-for-service of the Darlington fuel channels to 235k EFPH	High confidence statement in FFS to 210,000 EFPH issued	Level of confidence established and statement available	Statement of technical confidence in fuel channel FFS to 235,000 EFPH issued in Asset Suite 7.	MCED

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Project #: Project # 10-80014

Project Title: Fuel Channel Life Extension Project, Full Release

Part I: Definitions and Acronyms

ASRT - Advanced Spacer Retrieval Tool
BT - Burst Test
CT - Calandria Tube
EFPH - Equivalent Full Power Hours
FCLE(P) - Fuel Channel Life Extension (Project)
FCLM(P) - Fuel Channel Life Management (Project)
FT- Fracture Toughness
HFIR - High Flux Irradiation Reactor
HPH- High Pressure Hydriding
PM - Project Management
SFCR - Single Fuel Channel Replacement
SLAR - Spacer Location and Repositioning

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For Internal Project Cost Control

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 Project Title: Fuel Channel Life Extension Project – Full Release

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Appendix A: Summary of Estimate										
Project Number:	Project # 10-80014									
Project Title:	Fuel Channel Life Extension Project									
M\$	LTD	2016	2017	2018	2019	2020	20...	Future	Total	%
OPG Project Management	1.4	0.7	0.7	0.7	0.7	0.7			4.9	9.3
OPG Engineering (including Design)	0.9	0.5	0.5	0.5	0.5	0.5			3.4	6.2
OPG Procured Materials										
Design Contract(s)										
Construction Contract(s)										
EPC Contract(s)										
Technical Services										
Other Contracts/Costs										
Interest										
Subtotal										
Contingency										
Total	14.9	15.4	13.6	14.4	9.3	1.7			69.3	100

Notes			
Project Start Date	2014-01-02	Total Definition cost (excludes unspent contingency for Nuclear)	N/A
Target In-Service (or AFS) Date	N/A	Contingency included in this BCS (Nuclear only)	
Target Completion Date	2020-12-15 (FCLC Project Completion)	Total contingency released plus contingency in this BCS (Nuclear only)	
Escalation Rate	2.0%	Total released plus this BCS without contingency (Nuclear only)	
Interest Rate	5%	Total released plus this BCS with contingency (Nuclear only)	\$69.3M
Removal Costs	N/A	Estimate at Completion (includes only spent contingency for Nuclear)	

Prepared by:		Approved by:	
Name:		Name	
John Xiao		Kathy Charette	
Section Manager, FCLCP		Senior Manager, FCLCP	
Project Manager		Project Sponsor	
Date: July 21, 2016		Date: 21 July 2016	

Type 3 Business Case Summary

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Project #: Project # 10-80014

Project Title: Fuel Channel Life Extension Project – Full Release

Appendix B: Comparison of Total Project Estimates and Project Variance Analysis

Comparison of Total Project Estimates										
Phase	Release	Approval Date	Total Project Estimate in M\$ (by year including contingency)						Future	Total Project Estimate
			LTD	2016	2017	2018	2019	2020		
Definition and Execution	Partial	2013-11-11	41.2	37.6	26.5	0.6				105.8
Execution	Full	2016 Q3	14.9	15.4	13.6	14.4	9.3	1.7		69.3

Project Variance Analysis					
M\$	LTD	Total Project		Variance	Comments
		Last BCS	This BCS		
OM&A OPG Project Management	1.4	3.3	5	1.7	Extension of project timeline due to COG financial constraint and discovery work.
OM&A: OPG Engineering	0.9	2.1	3.3	1.2	Extension of project timeline due to COG financial constraint and discovery work.
OM&A: Permanent Materials	0	3.2	0	-3.2	No materials/tools are required.
OM&A: Design and Construction					
OM&A: Technical Services					
OM&A: Other Contracts/Costs					
Subtotal					
Contingency					
Total		105.8	69.3	-36.5	

Type 3 Business Case Summary

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Project Title: Fuel Channel Life Extension Project – Full Release

Appendix C: Financial Evaluation Assumptions

Key assumptions used in the financial model of the Project are (complete relevant assumptions only):

Project Cost:

1. Incremental Project Costs are [REDACTED] for the Preferred Alternative.
- 2.
- 3.

Financial:

1. Discount rate is 5% for regulated assets.
- 2.
- 3.

Project Life:

- 1.
- 2.
- 3.

Energy Production:

- 1.
- 2.
- 3.

Operating Cost:

- 1.
- 2.
- 3.

Other:

- 1.
- 2.
- 3.

Appendix D: References

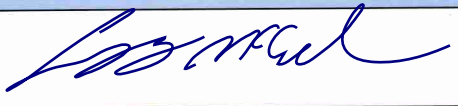
1. NK38-PLAN-31160-10000, Long Term Darlington Life Management Plan for Inconel X-750 Spacers.

Business Case Summary

Project #	16-84415	Controlled Doc #	D-BCS-33130-00006
Project Title	DNCS - PHT Motor Oil Seal Leak Repair		
Facility	Darlington	Investment Classification	Sustaining
Project Level (Scalability)	A	Financial Classification	☒ OM&A ☐ Capital ☐ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others: [if applicable]
Release: Gate and Project Phase	☐ Choose an item. G0: Initiation ☐ Choose an item. G2: Definition ☐ Choose an item. G1: Choose an item. ☒ Partial G3: Execution		
Estimate Class (overall project)	Class 3	Target Project Completion Date	Jul-2025

Recommendation
We recommend release of \$ 15,926K, including [REDACTED] of contingency. The Total Project Cost is estimated to be \$ 47,429K including [REDACTED] of contingency. This project will coordinate the material handling and repair of six (6) Primary Heat Transport (PHT) motors with identified oil seal leaks. This release will provide funding for two (2) PHT motors (3-PM3, 3-PM4) to be removed during the Refurbishment of Unit 3 for off-site repair of oil seal leaks, and returned for acceptance testing at Darlington. The motors removed from Unit 3 will be replaced with existing spare motors. A future release (Gate 3B) will request funding for the removal and repair of four (4) PHT motors from Unit 1. These motors will be returned to site spares inventory after receipt and acceptance testing. The two repaired motors from Unit 3 will be re-installed in Unit 1, together with two additional spare motors.

Investment Cash Flows									
\$K	LTD	2019	2020	2021	2022	2023	2024	Future	Total
Previous releases	-	-	-	-	-	-	-	-	-
Current request	-	29	3,287	11,246	1,317	42	5	-	15,926
Total released to date	-	29	3,287	11,246	1,317	42	5	-	15,926
Future required	-	-	-	-	8,251	15,270	7,511	471	31,503
Total Project Cost	-	29	3,287	11,246	9,568	15,312	7,516	471	47,429
Ongoing Costs	-								
					Gate:	G3	OAR Approval:	\$47,429 K	

Approvals	Signatures	Date
The recommendation, including the identified ongoing costs, if any, represents the best option to meet the validated business need.		
Recommended by: Project Sponsor Gregg McCabe Director, Station Engineering		2 DEC 2019
I concur with the business decision as documented in this BCS.		
Finance Approval: Barbara Kerr VP, Controllershship		January 29, 2020
I confirm that this investment/project, including the identified ongoing costs, if any, will address the business need, is of sufficient priority to proceed, and provides value for money.		
Line Approval per OAR 1.1: Sean Granville Chief Nuclear Officer		30-Jan-2020

Project #: 16-84415

Project Title: DNGS - PHT Motor Oil Seal Leak Repair

Document #: D-BCS-33130-00006

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OPG-FORM-0076-R006

Business Case Summary

EXECUTIVE SUMMARY – Project Overview

This project is to coordinate the repair of six (6) PHT motors during Darlington Nuclear Refurbishment Unit (DNRU) outages on Unit 3 (DNRU3) and Unit 1 (DNRU1). PHT motors perform the critical function of transferring heat from the fuel to the boilers for power generation or to a heat sink to provide cooling of the fuel.

Oil seal leaks were identified on new Unit 3 and Unit 1 PHT motors during the first routine inspection after their return to service. Oil was observed leaking and pooling on stator windings, rotor, stator coolers and motor bus bars. Cleanup and repair cannot be performed in situ or at site as it requires full motor disassembly.

While the total project costs include all costs related to the oil leak repairs, OPG is pursuing cost recovery from warranty claims from the manufacturer.

A risk assessment of the seal leak issue by OPG (NK38-CORR-33130-0794084) recommends that the problem be corrected early to preserve the life of the motors, before cumulative motor damage occurs. Oil leakage will degrade the motor stator winding insulation and increase motor operating temperatures resulting in premature motor failure, potentially leading to a forced Unit shutdown to replace the motor.

This recommendation was confirmed by an independent evaluation prepared by external subject matter experts - NK38-REP-33130-0796861: "Risk Assessment on New PHT Motors M01 to M06 Internal Oil Leaks".

This release will fund the following scope of work:

- 1) Disconnect and removal of two (2) PHT motors from Unit 3
- 2) Decontaminate and prepare for shipment
- 3) Transportation to and from the vendor's facility
- 4) Dis-assembly, repair and re-assemble
- 5) Factory Acceptance Test (FAT) and OPG acceptance
- 6) Site Acceptance Test (SAT) of motors upon return to Darlington
- 7) Installation of two (2) replacement motors in Unit 3
- 8) Design closeout for Unit 3
- 9) Development and approval of a Gate 3B BCS for the Unit 1 motors.
- 10) Technical oversight and project management.

A future release (Gate 3B) will fund the following work:

- 11) Commissioning, Turn-over and Close-out of the Unit 3 motors
- 12) Removal, repair and SAT of the four (4) leaking PHT motors in Unit 1
- 13) Install and commission four replacement motors during DNRU1
- 14) Design closeout for Unit 1
- 15) Project close-out

The key risks involved with this project are:

- Delay to Project schedule due to quality issues with first-of-a-kind (FOAK) oil seal leak repair may cause the refurbishment windows to be missed.
- Increase in Project cost due to troubleshooting motors on-site (OPEX due to quality issues during SAT).
- OEM Support/ Long Lead Materials Unavailable.
- There is a risk of discovery issues during inspection assessments of the repaired motors which may result in an increase in cost or delay to schedule.
- Vendor to accommodate concurrent repairs on two motors. Shop to confirm capacity to accommodate all 6 motors in the 2021 to 2024 time frame.
- Potential for contracting with unfamiliar vendors with little prior experience in PHT motor work.

Business Need

For Project Level A or B

There are 16 operating Primary Heat Transport (PHT) pump motors (4 per unit) at Darlington. As part of the PHT motor replacement project, 10 new motors were procured. Four new motors were installed in Darlington Unit 1, two new motors installed in Unit 3, and four new motors installed in Unit 2.

Project #: 16-84415
 Project Title: DNGS - PHT Motor Oil Seal Leak Repair
 Document #: D-BCS-33130-00006

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 OPG-FORM-0076-R006

Business Case Summary

Business Need	For Project Level A or B
Oil leaks from the drive-end (DE) bearing seals were discovered during the first internal inspections of the six new motors. Oil is leaking and pooling on the inside of the motor shroud covering the motors internal components, including the stator windings, rotor, stator coolers, bus bars, air baffles, auxiliary junction box and associated wiring. Additional issues include oil foaming in the non-drive end (NDE) oil reservoir (oil level not visible) and oil leakage at the NDE of the motor (oil on top of motor). The Objective of this project is to repair the 6 leaking PHT motors since they pose a mid to long-term operational risk to Unit 1 and Unit 3. The overall risk is significantly increased during the restart following a prolonged motor shutdown due to oil pooling and thickening. If the issues are not addressed, Darlington faces a risk of forced outages (in the 5 – 10 year time frame) or a delay to the DNRU3 and DNRU1 Refurbishment Return to Service (RTS) as a result of PHT motor failures. If repairs are delayed, the cumulative motor damage will reduce the service life of this critical equipment.	

Preferred Alternative:	Repair PHT Motors During Refurbishment Outages	For Project Level A, B or C
Description of Preferred Alternative Coordinate the repair of the six leaking PHT motors during the DNRU3 and DNRU1 outages. The repairs must be performed at a properly equipped facility off site. In the DNRU3 outage, the leaking motors 3-PM3 and 3-PM4 will be replaced with existing spare motors. The removed motors will be repaired off-site and brought back for site acceptance testing. (This release) In DNRU1 four leaking motors will be removed and sent off-site for repair. Once repaired, these motors will be returned for site acceptance testing. (Future release) Replacement motors for Unit1 will be the two repaired motors removed from Unit 3 and two spare motors. Scope of work includes: - Complete oil seal repair engineering (by vendor) - Motor removal, decontamination and transportation to and from Vendor's facility - Motor disassembly, oil seal repair, re-assembly per approved ITP, - Factory Acceptance Testing (FAT) - Site Acceptance Testing (SAT) upon receipt at Darlington - Motors Reinstallation and Commissioning - Engineering close-out Key Assumption: - Leaking Oil motors (M01-M06) can be repaired and returned to site as required per schedule (6-8 months). - OEM support (technical, parts, etc.) will be available to repair six (6) motors. - Spare motors will be available for installation in Unit 3 and Unit 1.		

Deliverables:	Associated Milestones (if any):	Target Date:
<i>Previous releases:</i>		
N/A	N/A	N/A
<i>Current release:</i>		
Award contract to construction vendor	Issue PO to Construction Vendor	15-Mar-2020
Award contract to repair vendor	Issue PO to Repair Vendor	15-Mar-2020
Remove motors in Unit 3 (3-PM3, 3-PM4)	DNRU3 Start of Installation	30-Sept-2020
Replace motors in Unit 3 (R7, R8)	DNRU3 Start of Installation	16-July-2021
Complete repair of Unit 3 motors (3-PM3, 3-PM4)	Delivery to Site after Repair	31-Jan-2022
<i>Future release:</i>		
Remove four motors in Unit 1	DNRU1 Start of Installation	01-May-2022

Project #: 16-84415

Project Title: DNGS - PHT Motor Oil Seal Leak Repair

Document #: D-BCS-33130-00006

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OPG-FORM-0076-R006**Business Case Summary**

Deliverables:	Associated Milestones (if any):	Target Date:
Replace defective motors in DNRU1	DNRU1 Start of Installation	04-May-2023
Complete repair of Unit 1 motors	Delivery to Site after Repair	31-Dec-2024
Project Closeout with Schedule Contingency	Project Closeout (PCM)	03-Jul-2025

Alternative 2:	Base Case – No Project	For Project Level A, B or Value-Enhancing
Not recommended as current PHT motor oil seal leakage issue will not be resolved. Continued operation with the oil leaks will not support safe and reliable continued operations of Darlington. This will pose production and safety risks going forward and will also expose the PHT pumps to the high risk of failure as a result of the degradation due to oil leakages especially during DNRU3 and DNRU1 RTS. Pros: • None Cons: • Failure of motors will lead to Unit 1 and Unit 3 forced outages (high generation losses) • A catastrophically failed motor may not be repairable (additional new motors may have to be procured)		

Alternative 3:	Delay the Project – Repair and Replace PHT Motors After Refurbishment Outages	For Project Level A or B
This alternative is not recommended. Defer PHT motor replacement and repair to scheduled outages after DNRU3 and DNRU1. This will increase the risk of a motor failure and a forced Unit outage, and will increase risk to DNRU3 and DNRU1 return to service schedules. A delay will mean missing the next planned opportunity for repair and extend the project completion date. Risks of delay: • Increased and more frequent maintenance to remove oil from inside the motor, • DNGS has a limited ability to remove oil from an installed motor • Increased oil viscosity may clog stator vents and coolers, increasing motor operating temperatures • Oil contamination on windings may lead to degraded rotor/ stator insulation and premature winding failure • Cumulative damage / fouling of internal parts such as (coolers, rotor, stator windings, bearing oil passages, etc) • Risk of premature motor failure and forced outage(s) Pros: • None Cons: • High Risk of motor failure upon DNRU3 and DNRU1 RTS • Motor replacements may affect outage critical path		

Alternative 4:	Procure New Motors for Replacement	For Project Level A or B
Replace deficient motors in Unit 3 and Unit 1 with six (6) new motors with the upgraded design. The alternative is not recommended due to the longer lead time and higher costs. Pros: • New Motors may have a longer operating life. Cons: • Long lead time to procure new motors • Significantly higher cost of new motors (approx. \$7M new vs \$4M each to repair; replacement costs are similar)		

Project #: 16-84415

Project Title: DNGS - PHT Motor Oil Seal Leak Repair

Document #: D-BCS-33130-00006

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OPG-FORM-0076-R006

Business Case Summary

Alternative 4:	Procure New Motors for Replacement	For Project Level A or B
Additional outages required or delay to refurbishment return to service		

Key Risk Assessment					For Project Level A, B or C
Risk Class	Description of Risk	Response Type/ Actions/Final TCD	For Additional Review	Residual Ranking	
Cost	There is a risk that further quality issues with repaired motors may lead to a delay in schedule for motor repairs (OPEX).	Mitigate: 1. Oversight of the motor refurbishment/repair process will be provided by OPG Projects and Centre of Excellence Engineering to address any technical concerns, and witness ITP hold-points per the PMP. 2. Motors' Centre of Excellence will be leveraged for expertise as required.	No	Low	
Schedule	There is a risk that OEM Support/ Long Lead Materials Unavailability will result in a delay in repair of motors and scheduled delivery on-site. Damage resulting from the oil leaks and continued running is more extensive than anticipated. There is a risk that some motors may require additional unanticipated work during repairs, or that repairs are delayed and completed late.	Accept: 1. Monitor the status of OEM support and long lead materials. 2. Scope and Schedule to be incorporated into RfP documents and vendor's contracts. 3. Ensure additional spare motors are available as contingency spare(s). 4. Motors' Centre of Excellence will be leveraged for expertise as required.	No	Medium	
Resources	There is a risk that the site support contractor may not be able to support multiple parallel activities (e.g. simultaneous removal, installation, testing, receiving and unloading motors and performing pre-requisites for replacement activities).	Accept: 1. Executing contract to be in place ahead of time for vendors to secure resources and ensure availability of the contractor's team to meet OPG's outage schedule. 2. OPG to schedule/ coordinate motor transfers to minimize conflicts with station maintenance evolutions or crane inspections, etc. 3. Identify contingency funding for vendor to implement schedule recovery plans or address resourcing conflicts	No	Low	
Quality/ Performance	There is a risk that quality issues during repair and assembly will result in troubleshooting / repairs during site acceptance test. This could result in critical delays and additional cost.	Mitigate: 1. Perform significant qualification testing to ensure performance and safety. 2. Lessons learned from past motor replacements will be incorporated into the factory acceptance test procedure.	No	Low	
Technical	There is a risk of sudden motor failure during operation or start-up, requiring forced outage(s) and replacement of the motor.	Mitigate: Ensure sufficient spare motors are available, and identify project contingency to implement recovery	No	Low	

Project #: 16-84415

Project Title: DNGS - PHT Motor Oil Seal Leak Repair

Document #: D-BCS-33130-00006

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Business Case Summary

Key Risk Assessment				
For Project Level A, B or C				
Risk Class	Description of Risk	Response Type/ Actions/Final TCD	For Additional Review	Residual Ranking
		plans to expedite motor repair and mitigate impacts from forced / unplanned outages.		

Additional Risk Analysis	
For Project Level A or B	
N/A	

Financial Evaluation					
For Project Level A, B (with multiple feasible alternatives) or Value-Enhancing					
\$K	Preferred Alternative	Base Case (No Project)	Delay work	New Motors	Alternative 5
Project Cost	47,429	N/A	N/A	N/A	
NPV	N/A	N/A	N/A	N/A	
Other: (e.g., IRR)					
Analysis of Financial Evaluation – Key Assumptions and Key Results:					
A financial evaluation is not required for sustaining projects.					

Qualitative Factors	
For Project Level A or B	
Completion of this project will positively impact the business drivers of the nuclear safety and financial performance by improving reliability, reducing maintenance burden, and supporting the long-term operation of DNGS.	

Post Implementation Review (PIR) Plan (refer to OPG-PROC-0056)				
Type of PIR Report	Simplified/Standard PIR	PIR Completion Date	July-2026	
☐ Detailed PIR KPIs will be provided in future BCS(s) when Execution Phase BCS release is requested.				
PIR KPIs	Current Baseline	Target Result	How to measure?	Who will measure?
Condition of Motors	There are six PHT motors considered to be at moderate risk of failure in mid-term operation, and at high risk to DNRU3 and DNRU1 RTS due to oil leakages (M01-M06).	Seal leaks are repaired and risk to continuous operation is low. All motor parameters shall be within the ranges provided in the Technical Specification NK38-TS-33130-10003.	Scheduled routine on-line inspections of motors to ensure oil leaks have been mitigated. Motor operating parameters will be monitored to ensure good health and reliable operation.	Components Engineering

Definitions and Acronyms
BCS - Business Case Summary
DE - Drive End
DNGS - Darlington Nuclear Generating Station
DNRU1 - Darlington Nuclear Refurbishment Unit 1
DNRU3 - Darlington Nuclear Refurbishment Unit 3
DNRU4 - Darlington Nuclear Refurbishment Unit 4
FAT - Factory Acceptance Test
HT - Heat Transport
HTS - Heat transport System
ITP - Inspection and Test Plan

Project #: 16-84415

Project Title: DNGS - PHT Motor Oil Seal Leak Repair

Document #: D-BCS-33130-00006

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Business Case Summary

Definitions and Acronyms

NPV - Net Present Value

OAR - Organizational Authority Register

OEM - Original Equipment Manufacturer

OPEX - Operating Experience

OPG - Ontario Power Generation

PC - Procurement and Construction

PD - Partial Discharge

PHT - Primary Heat Transport

PMP - Project Management Plan

Repair – Disassembly of a PHT motor to incorporate OEM recommended modifications to correct the oil seal leak issue

Refurbish – Mid-life overhaul of a PHT motor to inspect and correct worn or damaged parts to ensure low maintenance operation for the remaining life of the plant.

RFP - Request for Proposal

RMO - Risk Management and Oversight

RTS – Return to Service

SAT - Site Acceptance Test

SOW - Scope of Work

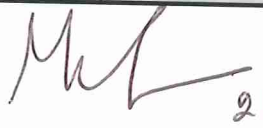
Project #: 16-84415

Project Title: DNCS - PHT Motor Oil Seal Leak Repair

Document #: D-BCS-33130-00006

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OPG-FORM-0076-R006**Business Case Summary****APPENDICES**

Appendix A1: Summary of Estimate - Total Project Cost										
Project Number:	16-84415									
Project Title:	PHT Motor Oil Seal Leak Repair									
\$K	LTD	2019	2020	2021	2022	2023	2024	Future	Total	%
Project Mgmt	-	29	646	914	1,134	864	903	137	4,627	10%
Inspection	-	-	-	-	-	-	-	-	-	0%
Engineering										
Procurement										
Construction										
Commissioning										
Closeout										
Subtotal										
Outside WBS										
Contingency										
Subtotal w/ Contingency										
Interest										
Other										
Total	-	29	3,287	11,246	9,568	15,312	7,516	471	47,429	100%
Removal Costs (incl. above)	-	-	-	-	-	-	-	-	-	0%
Appendix A2: Summary of Estimate - Notes										
Escalation Rate	2.5%				Interest Rate (going-forward)		N/A			

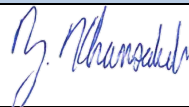
Prepared by:	Reviewed and Endorsed by:
 M. Broekhuysen Project Manager, Projects & Modifications Date: 21-Nov-2019	 M. Campigotto Section Manager, Projects & Modifications Date: 21-Nov-2019

Business Case Summary

Project #	16-84484	Controlled Doc #	D-BCS-50330-00001
Project Title	DN U0 Switchgear Refurbishment		
Facility	DNGS	Investment Classification	Sustaining
Project Level (Scalability)	C	Financial Classification	☒ OM&A ☐ Capital ☐ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others: [if applicable]
Release: Gate and Project Phase	☐ Choose an item. G0: Initiation ☐ G2: Definition ☒ Full G1: Development ☐ G3: Execution		
Estimate Class (overall project)	TBD	Target Project Completion Date	DEC-2028

Recommendation
We recommend a release of \$4,074 K, including [REDACTED] of contingency. The quality of the estimate for this release (Gate 1) is Class 5. The estimated total project cost estimate is to be determined, and will be presented at Gate 2. This project is to perform mid-life maintenance on Unit 0 switchgear to increase equipment and station reliability, and to address commitments made to the CNSC in Darlington's Integrated Implementation Plan (IIP). This partial release will fund the following scope of work: - Preliminary, detail engineering and installation planning of switchgear for transformers T59, T60, and buses BU59, BU60, BU76, BU78 - Procurement and award, phase released Engineering Procurement Construction (EPC) Contract - Preliminary engineering of switchgear for buses BU56, BUA53, BUB53, BUC53 This document was prepared based on assumptions from the Business Plan, Generation Plan and station work programs prior to the commencement of the COVID-19 pandemic. The associated COVID-19 risk mitigation activities may lead to changes to the assumptions which may impact the overall cost and schedule of this project.

Investment Cash Flows									
\$K	LTD	2020	2021	2022	2023	2024	2025	Future	Total
Previous releases	-	-	-	-	-	-	-	-	-
Current request	-	1,197	2,877	-	-	-	-	-	4,074
Total released to date	-	1,197	2,877	-	-	-	-	-	4,074
Future required	-	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Total Project Cost									
Ongoing Costs	-	-	-	-	-	-	-	-	-
					Gate:	G1	OAR Approval:	\$4,074 K	

Approvals	Signatures	Date
The recommendation, including the identified ongoing costs, if any, represents the best option to meet the validated business need.		
Recommended by: Project Sponsor Zar Khansaheb Director, Station Engineering		July, 14 2020
I concur with the business decision as documented in this BCS.		
Finance Approval: Brett Lemmon Finance Controller - Darlington		July 14, 2020
I confirm that this investment/project, including the identified ongoing costs, if any, will address the business need, is of sufficient priority to proceed, and provides value for money.		
Line Approval per OAR 1.1: Val Bevacqua Director, Operations & Maintenance, Darlington		July 14, 2020

Business Case Summary

EXECUTIVE SUMMARY – Project Overview

The business driver for this project is to maintain plant and equipment reliability, and to address a regulatory commitment (IIP CC010: Class IV power system #0013 – Complete the tap changer bypass modification on 0-53240-T60 and bushing replacement on 0-53240-T59).

The switchgear for the Darlington Unit 0 critical electrical buses (4 Class IV, 5 Class III, and 3 Class II) have very high bus availability requirements that imposed constraints for implementing maintenance. While there have not been any failures of these buses to date, industry experience reveals that electrical failures and degradations that lead to failures tend to be random in nature and the consequence of the failure could be significant. The Electric Power Research Institute (EPRI) recommends 12-year frequency for switchgear maintenance. These buses are at risk of experiencing elevated failure rates that could affect power supply to critical nuclear safety loads and the operations support building. Since the equipment cannot be run to failure, the mitigation strategy is to perform preventive maintenance.

This project is to complete the following execution work that includes preliminary and detailed engineering work, install and remove required Temporary Modifications (TMODs):

- The transformer tap changer bypass modification on 0-53240-T60 to satisfy CNSC commitment by December 2022
- The bushing replacement of transformer 0-53240-T59.
- Mid-life maintenance on 12 Unit 0 switchgears buses, relays and circuit breakers by the 2027 VBO. The included buses are BU51-54, BU56, BU59-60, BU76, BU78, BUA53, BUB53, BUC53.
- Design, installation and removal of TMODs required to support the bus maintenance. Design is required for all buses except BU51, BU52, BU53 and BU54.

The project strategy is to complete 0-53240-T60 tap changer bypass modification and BU60 maintenance during the next Tritium Removal Facility (TRF) outage. The remaining buses will be scheduled through station integrated planning and/or for the TRF outage. The sequence of bus maintenance will be coordinated based on the CNSC commitment, criticality, maintenance logistics, station integrated planning and the station outage schedule.

Upon completion of this project, Unit 0 switchgear performance reliability will be improved and current CNSC commitments will be fulfilled.

Project Status

This project has completed the Conceptual stage and requires funding to proceed to the Preliminary and Detailed Engineering for T60, BU60, BU76, BU78 and preliminary engineering for BU56, BU59, BUA53, BUB53, BUC53.

This release request is for the Development Phase (Gate 1), and includes definition (detail design, procurement and execution planning) of B59 and B60. The definition of BU59 and BU60 have been advanced into this release due to emergent maintenance that is time sensitive and requires expedited schedule. The planned strategy for future gates is to split the definition/ execution into three gates: 2/3A, 3B and 3C. Gate 2/3A will include the execution of the transformers T59, T60, buses BU59, BU60, BU76, BU78 and detail engineering of buses BU56, BUA53, BUB53, BUC53. Gate 3B will include procurement and installation planning activities of buses BU56, BUA53, BUB53, BUC53, and execution of buses BU51, BU52, BU53, BU54. Gate 3C will include execution of buses BU56, BUA53, BUB53, BUC53.

Preferred Alternative: Perform Bus Maintenance Proactively

For Project Level A, B or C

Description of Preferred Alternative

The preferred alternative is to perform mid-life maintenance to increase Unit 0 switchgear and overall plant reliability. A design vendor and contractor will be utilized during the preliminary, detailed design, TMOD installations, and bus maintenance phases. OPG will provide oversight and perform the planning work. The scope of work includes taking the buses out of service and performing the maintenance on the related switchgear. This includes switchgear for transformers T59, T60, and for buses BU51-54, BU56, BU59-60, BU76, BU78, BUA53, BUB53, BUC53. Maintenance for the last switchgear 0-53130-BU56 will be completed between in 2027 since it requires the Vacuum Building Outage (VBO) due to the loads it supplies.

This project will be executed as follows:

Business Case Summary

Preferred Alternative:	Perform Bus Maintenance Proactively	For Project Level A, B or C
Description of Preferred Alternative		
- Complete detail design of the TMODs to supply power from difference sources - Layout cable for the TMODs in accordance with the design and connect within available station outage window - Keep the bus isolated until the maintenance is performed - Maintenance activities include servicing and replacing (if required) Circuit Breakers, busbar insulations/connections, control switches, fuses and other required parts within bus - Remove the TMODs after maintenance completion and reactivate the isolated bus to normal operation		
Benefits of this project:		
- Completion of regulatory requirements - Improvement in overall equipment reliability - Meet EPRI and industry best practices		

Deliverables:	Associated Milestones (if any):	Target Date:
<i>Previous releases:</i> NOT APPLICABLE		
<i>Current release:</i>		
Design Contract Awarded/ Issue PO	Contract Award	2020-07-15
Detail Design Complete – T59, T60, BU59, BU60, BU76, BU78	Detail Design Complete	2021-01-31
Preliminary Design Complete – BUA53, BUB53, BUC53	Preliminary Design Complete	2021-06-30
<i>Future release:</i>		
Gate 2/3A BCS Approved	BCS Approval by PMOC	2021-01-31
Start of Installation (SOI) – T59, BU59	SOI – T59, BU59	2021-04-01
Available for Service (AFS) – T59, BU59	AFS – T59, BU59	2021-07-31
Start of Installation (SOI) – T60, BU60, BU76, BU78	SOI – T60, BU60, BU76, BU78	2021-10-15
Available for Service (AFS) – T60, BU60, BU76, BU78	AFS – T60, BU60, BU76, BU78	2021-11-30
Design Complete – BU56, BUA53, BUB53, BUC53	Design Complete – BU56, BUA53, BUB53, BUC53	2022-02-28
Available for Service (AFS) – BU51, BU52, BU53, BU54	AFS – BU51, BU52, BU53, BU54	2023-10-31
Available for Service (AFS) – BUA53, BUB53, BUC53	AFS – BUA53, BUB53, BUC53	2025-10-31
Available for Service (AFS) – BU56	AFS – BU56	2027-12-31
Project Closeout Complete	Project Complete	2028-12-31

Key Risk Assessment					For Project Level A, B or C
Risk Class	Description of Risk	Response Type/ Actions/Final TCD	For Additional Review	Residual Ranking	
Cost	There is a risk that the vendor estimate for the design activities will be more than the estimated because the cost estimate is only an internal estimate.	Mitigate: Project to estimate the vendor cost on the estimate received from projects design which is based on expert judgement.	No	Medium	
Cost	There is a risk that the cost of the procurement for the bus maintenance parts and TMOD will be more than estimated because the estimate	Mitigate: Project will confirm in advance the material availability at the station store. If the material is not available	No	Low	

Business Case Summary

Key Risk Assessment			For Project Level A, B or C	
Risk Class	Description of Risk	Response Type/ Actions/Final TCD	For Additional Review	Residual Ranking
	includes parts assumed to be available at the station and temporary usage of the parts for TMOD. This may result in more than estimated material procurement cost for the project.	at the store, project will ensure the MR is in place prior to the material stage milestone for the execution.		
Schedule	There is a risk that vendor access to the station and walk down to start the design will be restricted due to ongoing COVID-19 pandemic, which may result in delay of the contract award and start-up of preliminary design activities of buses. The issue of COVID-19 may affect the preparation, evaluation of RFP documents, and finally delay the contract award.	Mitigate: Project will coordinate RFP process in parallel with all key stakeholders and evaluate opportunities to minimize the delay.	No	Low
Schedule	There is a risk that Design vendor cannot complete the design of T59 and BU59 in the required timeline due to the aggressive schedule to meet the station priorities, which may require project to change the design and execution strategy for T59 and BU59.	Mitigate: - Project will coordinate station priorities between station Operations/Maintenance and the design vendor - All the important project timelines will be communicated to vendor in the RFP documents ahead of time	No	Low
Schedule	There is a risk that TRF outage scope cannot be met due to aggressive schedule and tight timeline for various milestones for the T2101 outage, which may result in delaying the project scope related to bus maintenances and increase the cost of the project.	Mitigate: - All the important project timelines will be communicated to all key stakeholders of the project to meet the timeline of T2101 TRF outage. - Project will conduct regular meetings with key stakeholders	No	Low

Post Implementation Review (PIR) Plan (refer to OPG-PROC-0056)				
Type of PIR Report	Simplified/Standard PIR		PIR Completion Date	DEC-2028
☒ Detailed PIR KPIs will be provided in future BCS(s) when Execution Phase BCS release is requested.				
PIR KPIs	Current Baseline	Target Result	How to measure?	Who will measure?

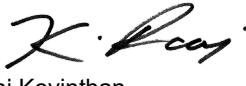
Business Case Summary

APPENDICES

Appendix A1: Summary of Estimate											Choose an item.	
Project Number:		16-84484										
Project Title:		Darlington Unit 0 Switchgear Refurbishment										
\$K	LTD	2020	2021	2022	2023	2024	2025	Future	Total	%		
Project Mgmt		554	691	-	-	-	-		1,245	31%		
Inspection		-	-	-	-	-	-		-	0%		
Engineering												
Procurement												
Construction												
Commissioning												
Closeout												
Subtotal												
Outside WBS												
Contingency												
Subtotal w/ Contingency												
Interest												
Other												
Total	-	1,197	2,877	-	-	-	-	-	4,074	100%		
Removal Costs (incl. above)									-	0%		

Appendix A2: Summary of Estimate – Notes			
Escalation Rate	2.5%	Interest Rate (going-forward)	N/A

Appendix A3: Summary of Estimate – In-Service Estimates				
\$K	Only applicable to capital projects. In-Service amount shall include interest but exclude removal costs.			
Project #	Date (YYYY-MM-DD)	Description	Amount	%
				0%
				0%
Total			-	0%

Prepared by:		Reviewed and Endorsed by:	
 Pankaj Panchal Sr. Technical Engineer, P&M Project Leader		 Raaj Kovinthan Section Manager, P&M	
2020-Jun-15 Date		2020-Jun-15 Date	

Business Case Summary

Project #	16-84589	Controlled Doc #	NK38-BCS-03680-00001
Project Title	Darlington Station Periodic Safety Review (PSR)		
Facility	DNGS	Investment Classification	Regulatory
Project Level (Scalability)	B	Financial Classification	☒ OM&A ☐ Capital ☐ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others: [if applicable]
Release: Gate and Project Phase	☐ Choose an item. G0: Initiation ☐ Choose an item. G2: Definition ☒ Full G1: Development ☐ Choose an item. G3: Execution		
Estimate Class (overall project)	Class 5	Target Project Completion Date	MAY-2024

Recommendation
We recommend a release of \$1,192K, including \$108K of contingency. The quality of estimate for this release is Class 3. The estimated total project cost range will be determined prior to Execution Phase. This project is to conduct a Periodic Safety Review (PSR) and to prepare an Integrated Implementation Plan (IIP) to support the license renewal application (LRA) for Darlington in 2024. This release is to prepare the PSR technical basis document and to complete the scope of work in order to secure vendors for Execution Phase.

Investment Cash Flows									
\$K	LTD	2020	2021	2022	2023	2024	2025	Future	Total
Previous releases									-
Current request	-	1,192							1,192
Total released to date	-	1,192	-	-	-	-	-	-	1,192
Future required	-	TBD	TBD	TBD	TBD	TBD			TBD
Total Project Cost									
Ongoing Costs	-								
					Gate:	G1	OAR Approval:	\$1,192 K	

Approvals	Signatures	Date
The recommendation, including the identified ongoing costs, if any, represents the best option to meet the validated business need.		
Recommended by: Project Sponsor Jeff Wells Manager, Performance Engineering Life Extension		January 23, 2020
I concur with the business decision as documented in this BCS.		
Finance Approval: Brett Lemmon Finance Controller, Darlington		Jan 31, 2020
I confirm that this investment/project, including the identified ongoing costs, if any, will address the business need, is of sufficient priority to proceed, and provides value for money.		
Line Approval per OAR 1.1: Zar Khansaheb Director, Station Engineering Darlington		Feb 3, 2020

Business Case Summary

EXECUTIVE SUMMARY – Project Overview

The current operating license for Darlington is valid until November 30, 2025. As per the Darlington's License Condition Handbook (LCH), the conduct of a Periodic Safety Review is a pre-requisite for license renewal application. A PSR involves an assessment of the current state of the plant and its performance to determine the extent to which it conforms to applicable regulatory requirements, modern codes, standards and practices, and identifies any factors that would limit safe long-term operation. In performing a PSR, the licensee is required to conduct comprehensive reviews, addressing all aspects of safety, in order to conduct a global assessment and develop an implementation plan that describes safety improvements to be carried out by the licensee during the next license period.

The recommended strategy is to conduct a PSR in accordance with REGDOC 2.3.3 – *Periodic Safety Reviews* in preparation for the submission of the Darlington license renewal application in November 2024. The PSR is to be conducted according to the following four phases:

- 1) Prepare PSR basis document (this release);
- 2) Conduct 15 safety factor reviews (SFR);
- 3) Analyze the findings and safety impact in a Global Assessment Report (GAR); and
- 4) Prepare an IIP and document the closure criteria for each safety improvements.

These deliverables will be submitted to the Canadian Nuclear Safety Commission (CNSC) for review and comment, with the CNSC formally accepting the PSR basis document and the final IIP. This strategy will support a successful re-licensing, having regulatory certainty through a CNSC-accepted IIP prior to public hearings and for the duration of the next licensing period.

Preferred Alternative:

PSR for Darlington License Renewal

For Project Level A, B or C

Description of Preferred Alternative

The recommended strategy is to conduct a PSR in accordance with REGDOC 2.3.3 in preparation for the Darlington license renewal application in November 2024. The gating strategy of the PSR project will be as follows:

- Gate 1
 - Document and identify changes to modern codes & standards since previous PSR
 - Define code review types
 - Preparation and internal review of PSR basis document
 - Development of Scope of Work (SOW) to secure vendor
 - Preliminary work in preparation for execution phase
 - Project staffing
- Gate 3A
 - Submission of PSR basis document to CNSC for review and acceptance
 - Preparation and submission of 15 SFRs to CNSC for review
 - 1) Plant Design
 - 2) Actual Condition of Structures, Systems and Components (SSCs)
 - 3) Equipment Qualification
 - 4) Aging
 - 5) Deterministic Safety Analysis
 - 6) Probabilistic Safety Assessment
 - 7) Hazards Analysis
 - 8) Safety Performance
 - 9) Use of Experience for other Nuclear Power Plants (NPPs) and Research Findings
 - 10) Organization, the Management System and Safety Culture
 - 11) Procedures
 - 12) Human Factors
 - 13) Emergency Planning
 - 14) Impact of Radiation on the Environment
 - 15) Radiation Protection

Business Case Summary

Preferred Alternative:	PSR for Darlington License Renewal	For Project Level A, B or C
Description of Preferred Alternative		
- Gate 3B - Preparation and submission of GAR to CNSC for review - Preparation and submission of IIP to CNSC for review and acceptance		

Deliverables:	Associated Milestones (if any):	Target Date:
<i>Current release:</i>		
Scope of Work (SFRs, GAR, IIP)	Approved internally	Apr. 2020
PSR Technical Basis Document	Approved internally	Jul. 2020
<i>Future release:</i>		
PSR Technical Basis Document	Accepted by CNSC	Jan. 2021
15 Safety Factor Reviews	Reviewed by CNSC	Mar. 2022
Global Assessment Report	Reviewed by CNSC	Jun. 2023
Integrated Implementation Plan	Accepted by CNSC	Mar. 2024

Key Risk Assessment				
For Project Level A, B or C				
Risk Class	Description of Risk	Response Type/ Actions/Final TCD	For Additional Review	Residual Ranking
Schedule	As a result of priorities changing within the supporting internal groups, resources may be re-allocated to support other station priorities and become unavailable to prepare and/or review the supporting documents required leading to schedule delays.	Mitigate: Continue interface with Engineering to obtain support	No	Low
Cost	As a result of reviews performed by vendors, or due to future discussions with the regulator, additional scope may be requested by the regulator leading to scope creep and increased cost.	Mitigate: Scope Management Plan to be developed to manage scope and control all changes to scope. Scope will be defined in the PSR Technical Basis document as well as change management process.	No	Low
Schedule	Due to the complexity and interdependency of the various project deliverables, the review and comment disposition of deliverables may require a high level of coordination and effort, SFRs may be delayed resulting in downstream impact on the GAR and IIP submission dates	Mitigate: Project to develop proper work flow tool to manage review and comment disposition for project deliverables. Benchmarking of previous PSRs (OPG and other utilities) have been performed to understand complexity of the project & to identify interdependencies up front.	No	Low
Quality	Due to lack of proficiency in preparation, review and acceptance and disposition of comments without adequate feasibility evaluation, inflated commitment load or unachievable commitment may result in unrealistic or unfeasible future commitments in the IIP.	Mitigate: - Project to develop Quality oversight plan to review & identify potential gaps or issues. - Identify and include stakeholders as reviewers for SFRs, GAR and IIP. - Clearly define commitments, and evaluate/plan when unknowns are evident.	No	Low

Business Case Summary

APPENDICES

Appendix A1: Summary of Estimate - Released to date										
Project Number:	16-84589									
Project Title:	Darlington Station Periodic Safety Review									
\$K	LTD	2020	2021	2022	2023	2024	2025	Future	Total	%
Project Mgmt		131							131	11%
Inspection									-	0%
Engineering		869							869	73%
Procurement		83							83	7%
Construction									-	0%
Commissioning									-	0%
Closeout									-	0%
Subtotal	-	1,084	-	-	-	-	-	-	1,084	91%
Outside WBS									-	0%
Contingency		108							108	9%
Subtotal w/ Contingency	-	1,192	-					-	1,192	100%
Interest									-	0%
Other									-	0%
Total	-	1,192	-	-	-	-	-	-	1,192	100%
Removal Costs (incl. above)									-	0%

Appendix A2: Summary of Estimate – Notes			
Escalation Rate	N/A	Interest Rate (going-forward)	N/A

Prepared by:	Reviewed and Endorsed by:
 Payam Tangestanian Performance Engineering Life Extension Project Manager Date January 13, 2020	 Jeff Wells Performance Engineering Life Extension Manager Date January 13, 2020



Records File Information:
 Records SCI/USI Retention
 - See Guidance Section

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OPG-FORM-0075-R004*

Type 2 Business Case Summary

To be used for investments/projects meeting Type 2 criteria in OPG-STD-0076.

Project Information			
Project #:	16-83280	Document #:	NK38-BCS-31160-00001 R001
Project Title:	Darlington Annulus Spacer Life Management (ASLM)		
Class:	☒ OM&A ☐ Capital ☐ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others:	Investment Type:	Sustaining
Phase:	Execution	Release:	Full
Facility:	Darlington	Target In-Service or Completion Date:	December 2021

Project Overview
We recommend Gate 3B approval and the release of \$20,331k, including [REDACTED] of contingency. The estimated total project cost is \$29,251k, including [REDACTED] The quality of the estimate for this release is Class 3, and for the total project is Class 3. Candu Owners' Group (COG) is the project manager and responsible for the project scope execution through its subcontractors. The project is funded through a joint project (JP) partnership among OPG (47.5%), Bruce Power (BP) (47.5%) and Canadian Nuclear Laboratories (CNL) (5%), respectively. This BCS funds the OPG's portion of the JP total costs. This Darlington Annulus Spacer Life Management (ASLM) project is required to demonstrate spacer fitness-for-service (FFS) as per the long term plan submitted to the Canadian Nuclear Safety Commission (CNSC). Failing to demonstrate FFS could result in imposed idle time and production losses for Units 1 and 4 prior to their planned refurbishment. This release will fund the following scope of work: • Final Report on the testing and examination of four (4) spacers removed from Darlington Unit 1 during the D1711 Outage. • Accelerated aging of X-750 material and ex-service spacers in the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratories (ORNL) and subsequent testing of these irradiated materials at qualified laboratory facilities. • Testing and examination of spacers removed during the Darlington Unit 2 Refurbishment Outage (DNRU2). • Updating predictive models and assessing FFS. • Analysis of fueling machine loading on spacer integrity. • OPG and COG project management activities. Summary of Business Need / Project Description: The Darlington Annulus Spacer Life Management project was raised to address the concerns about spacers as part of the Fuel Channel Life Cycle Management Plan (LCMP). Annulus spacers are designed to maintain a gap between pressure tubes (PTs) and calandria tubes (CTs). If the gap is not maintained, a hot PT comes into contact with the cold CT that leads to blister formation. If the hydrogen equivalent concentration in the PTs becomes sufficiently high, a contacting condition between the PT and CT can lead to the formation of large hydride blisters that can crack under normal operating conditions and subsequently lead to PT rupture during unit operation. The degradation of X-750 spacer material in Darlington Units was confirmed by the Fuel Channel Life Management Project (FCLMP). The current industry knowledge of the degradation mechanisms is based on a limited amount of data obtained from testing and examination of a small number of ex-service spacers. The existing data is insufficient to support high confidence projection on spacer fitness-for-service (FFS) until the end of business plan operating life of the Darlington Units. More experimental data are required to reduce built-in conservatism and uncertainty in the existing predictive models. Spacer material was retrieved from the Darlington Unit 2 refurbishment outage and a single fuel channel replacement (SFCR) outage. Some of the spacer material (D2M09) was placed in the High Flux Isotope Reactor (HFIR) to artificially accelerate material aging to 235k Equivalent Full Power Hours (EFPH) to mimic the end of life spacer material condition. After irradiation period, the aged material will be tested and assessed to inform on material degradation trends. The entire HFIR program consists of four irradiation phases. • Phase I covers unirradiated Darlington type (Darlington's design) spacers and tensile specimens; • Phase II covers unirradiated Bruce Power spacer design fatigue specimens;

*Associated with OPG-STD-0076, Developing and Documenting Business Cases

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Type 2 Business Case Summary

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Project #: 16-83280

Project Title: Darlington Annulus Spacer Life Management (ASLM), Full Execution Release

Project Overview

- Phase III includes aging of ex-service OPG spacer specimens removed from Unit 2 channel M09 during D1321 (after approximately 165k EFPH) to 245k EFPH;
- Phase IV work covers Bruce Power ex-service spacer specimens.

Summary of Preferred Alternative:

The Darlington Annulus Spacer Life Management project is to be executed in two releases.

The scope of the previous partial release included HFIR irradiation program continuation until the following approximate dosing limits:

- 165 kEFPH for Phase I capsules;
- 125 kEFPH for Phase II capsules (spacer coils and tensile specimens irradiated at 200°C);
- 245 kEFPH for Phase III capsules.

The scope of this full release includes the HFIR irradiation program continuation until the following approximate dosing limits:

- 210 kEFPH for Phase I capsules;
- 125 kEFPH for Phase II capsules (spacer coils and tensile specimens irradiated at 330°C and fatigue specimens irradiated at 200°C);
- 300 kEFPH for Phase IV capsules¹.

¹Phase IV HFIR continues through 2020 when OPG plans to pull out of the JP partnership. OPG's portion for the HFIR Phase IV work in 2020 is approximately \$171k. This amount has been included in the budgetary estimate. However, OPG may decide to exclude this amount from the COG's invoice schedule in the future. Also, if OPG decides to fund the Phase IV HFIR beyond 2020, a specific contingency has been set aside to provide the required funding.

The testing and examination of the OPG irradiated samples from the HFIR program (Phase I, II and III) will be completed during the full release. The full release also includes the remaining analysis and modelling work associated with the DNRU2 spacers. The Research & Development (R&D) work is scheduled to be completed by the end of 2020. Although the actual project close-out date is in 2021, for contingency purposes another milestone has been added to close the project in 2024 because OPG may decide to fund the HFIR Phase IV from 2021 to 2023, since this work may be needed to fully characterize the spacer fitness for service (FFS) model for post-Refurb use.

The main objective of the Long Term Spacer Plan is to obtain technical confidence in the spacers' FFS until the target operating life. The projected target operating life, with margin, according to the current Darlington Refurbishment schedule, is approximately 235k EFPH for Darlington's last refurbished Unit 4.

Failure to execute the Long Term Spacer Plan would challenge the OPG's ability to ensure the Darlington spacers will remain fit-for-service. Furthermore, OPG would not be able to fulfill the regulatory requirements that were added to the Darlington LCH. Failure to demonstrate FFS may result in production losses due to idle time in both Units 1 and 4. However, there is also no guarantee that executing the plan won't still result in some Unit 1 or Unit 4 idle time.

The preferred alternative includes the work that is required to be done in order to fulfill LCH requirements and avoid potential imposed idle time. OPG is committed to execute the Long Term Spacer Plan to ensure spacers' FFS to the target service life at the Darlington Units. This plan includes submission of spacer FFS assessments to CNSC staff for acceptance at specified intervals, which are accomplished by CNE Review Gates. The project scope of work completes the required work identified in the Long Term Spacer Plan. This work is not included in any other fuel channel project.

The Fuel Channel Life Extension project (#10-80014) has funded the initial funding requirements of the HFIR irradiation program for the accelerated aging of spacer material, including shipment to ORNL, capsule design, encapsulation, insertion into the HFIR, irradiation costs, and some of the post-irradiation testing. The Fuel Channel Life Extension (FCLE) project provided funding for the irradiation costs of the Darlington ex-service spacer specimens up to 215k EFPH.

Part A: Business Need

OPG has submitted the Long Term Darlington Life Management Plan for Inconel X-750 Annulus Spacers [1] (also known as the Long Term Spacer Plan) to Canadian Nuclear Safety Commission (CNSC) staff. The plan outlines the strategy for managing spacer integrity and material condition over the target operating life of the Darlington Units. The regulator has accepted the plan

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Project Title: Darlington Annulus Spacer Life Management (ASLM), Full Execution Release

Part A: Business Need

and added their own provisions into the Darlington License Condition Handbook (LCH). CNSC staff's acceptance was based on their review of the technical cases that support FFS assessment of Inconel X-750 spacers [4]. The results of the Long Term Spacer Plan's execution will be used for FFS assessments at specific intervals through the use of Chief Nuclear Engineer (CNE) Review Gates and CNSC submissions. The LCH specifies that:

- OPG is required to submit the inspection and surveillance test results to CNSC staff for acceptance;
- The submissions shall include the degradation assessment demonstrating fitness-for-service of spacers beyond the next CNE Review Gate;
- OPG shall not operate a Reactor Unit beyond the CNSC accepted X-750 fitness-for-service interval established by the last CNSC accepted Gate [8];
- Any change to the OPG plan requires prior CNSC notification.

HFIR Phase I, II, and III specimens were transported from CNL to ORNL for irradiation and are going to be shipped back from ORNL to CNL for testing and examinations after irradiation cycles are complete. OPG has funded a portion of Phase IV HFIR program through the partial release. This work included capsule design and irradiation costs of the Bruce Power ex-service spacer material from 2018 to 2020. The Phase IV specimens are currently undergoing irradiation cycles at ORNL.

As part of this ASLM project scope, annulus spacers were retrieved from Darlington Unit 2 during its refurbishment outage. The funding for retrieval tool development and shipment was provided by the Spacer Retrieval Project (#16-80112). However, the receipt and disposal costs of the spacer material for Darlington Unit 1 (D1711) and Unit 2 (Refurbishment) as well as visual examinations, crush testing, endurance testing, Helium and Hydrogen measurement, microstructure characterization, micro-hardness tests and metallography, and density measurements were covered by this ASLM project. The partial release provided funding for reporting of D1711 spacer results and project management activities until the end of 2018.

Part B: Preferred Alternative: Execute remaining work of the Long Term Darlington Life Management Plan for Inconel X-750 Annulus Spacers

Description of Preferred Alternative

The preferred alternative includes the actions required to meet the Long Term Spacer Plan objectives. CNSC has already accepted the Long Term Spacer Plan through the Darlington Senior Site Vice-President. This plan describes specific deliverables for managing spacers' degradation mechanisms over the remaining operating life of the Darlington Units until the respective refurbishment outage commence.

The scope of work of the preferred alternative is as follows:

- Testing and examination of four (4) spacers removed during the D1711 SFCR;
- Accelerated aging of X-750 material and ex-service spacer specimens in the HFIR at ORNL and subsequent crush testing of irradiated materials at qualified laboratory facilities;
- Testing and examination of spacers removed during the first Darlington Unit refurbishment;
- Updating predictive models and assessing FFS;
- Determination of FM loads and analysis of fueling machine loading on spacer integrity;
- OPG and COG project management activities.

The above scope is required to meet the regulatory requirements. It covers the work as identified in the Long Term Spacer Plan.

Through the HFIR program, spacer material is artificially aged to an equivalent dose of 245k EFPH, which is intended to inform on material degradation trends beyond the last Unit refurbishment outage date (i.e. Unit 4). The HFIR irradiation program for Phases I, II, and III will end in Q1 2020. Post-HFIR testing will end by Q4 2020. The HFIR Phase IV is planned to continue until 2023. Currently there is insufficient data to determine whether HFIR is representative of the degradation process of the spacers in the reactor, providing useful data to inform on material degradation trends. Subsequent HFIR samples will be tested and results obtained to help Bruce Power and OPG make the decision whether or not to continue HFIR Phase IV beyond 2020. If the decision is positive, OPG may be obliged to support it by sharing the cost as Bruce Power has been co-funding other work benefiting OPG. Although the current project close-out date is in 2021, for contingency purposes another milestone has been added to close the project in 2024.

The cost of the preferred alternative is [REDACTED] representing the OPG's contribution to the total funding requirement. This funding estimate does not include the costs of the experimental work beyond 2020 (i.e. HFIR Phase IV irradiation and post-irradiation testing). However, if OPG decides to support HFIR Phase IV in future, a specific contingency was set aside to cover the costs.

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Part B: Preferred Alternative: Execute remaining work of the Long Term Darlington Life Management Plan for Inconel X-750 Annulus Spacers

Description of Preferred Alternative

Key Assumptions and Risks:

The key risks and assumptions of this release are as follow:

- It has been assumed that the ASLM project execution will provide OPG with the required basis to assess Darlington's spacer FFS up to 235k EFPH;
- It has been assumed that the HFIR program results will be obtained by the end of 2020. Continuation of the HFIR program beyond 2020 does not serve OPG's short-term objectives but a specific contingency has been included to fund the work if OPG decides to support this work for the future;
- It has been assumed the project will be co-funded by other JP partners and that OPG's portion does not increase during the life of the project;
- There is a risk that co-funding JP partners may pull out causing funding shortfalls in 2019 and 2020. If this risk is realized in future, OPG funding requirements will increase for approximately \$6002k in 2019 and 2020. This release assumed the probability of this risk is low and hence, no funding was allocated to cover for this risk.
- There is a risk that maximum spacer loading during fueling machine interaction may influence spacers' FFS assessment for the target service life. The assessment results may require additional work at the costs greater than the available contingency. This release assumed the funding for such work will be provided by other means outside the budget of this project.

A general contingency is included to cover for potential known and unknown risks. The total funding requirement for general contingency was estimated to be [REDACTED] by the PMO risk management team. This contingency was determined using the approved contingency model. The list of known risks is as follows:

- RMO#: 16684 - There is a risk of the FFS confidence statement requiring to be extended beyond the 235KEFPH operating target due to a refurbishment schedule change causing the last operating Unit to run longer. The work may include analysis to reassess spacer loading. The estimate (~\$280k) was based on the costs of the spacers testing analysis and modeling assessments in JP4584 (WP 51713).
- RMO#: 16683 - There is a risk of adding three SFCRs to the scope of this project due to possible material unavailability for testing. These costs for SFCRs are covered by OMA budget. However, the costs of shipping, handling, disposing and testing of ex-service spacer material must be covered by this project. The costs of each SFCR is approximately \$1.7M. There is a potential for one SFCR due to new technical findings in regard to the spacer FFS confidence statement. The experimental data backing up the spacer FFS confidence statement are required in order to remove the CNE Gate 3 hold points. There is also a potential for another SFCR if the predictions on D1U09 and/or DNRU2 results are not as expected requiring more material for testing. One additional SFCR was added as contingency.
- RMO#: 16682 - There is a risk that maximum spacer loading during fueling machine interaction (i.e. COG-JP-4491-V144 findings per WPR 71916) may influence the spacer's FFS assessment for the target service life. The scope of current assessment may increase based on assessment results (~\$685k).
- RMO#: N/A - Risk of COG JPA cost estimate change (~\$316).

A specific contingency is included to cover for one specific known risk. The total funding requirement for the specific contingency was estimated to be [REDACTED] by the PMO risk management team. This contingency was determined using the approved contingency model. The description of this risk is as follows:

- RMO#: 16033 - There is a risk that OPG may decide to support this project beyond 2020. Currently, OPG plans to continue partnership with BP and CNL until 2020 with close-out activities in 2021. In the future, OPG may change its current position and determine the need to further support this project (i.e. HFIR Phase IV work 2021-2023) in order to have a valid spacer FFS model post-refurbishment.

FFS assessments are done at specific intervals to confirm certain operability limits. The CNE Review Gates are used as hold points to confirm the adequacy of the Long Term Spacer Plan to evaluate spacer FFS. As each CNE gate is achieved, the results

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Part B: Preferred Alternative: Execute remaining work of the Long Term Darlington Life Management Plan for Inconel X-750 Annulus Spacers

Description of Preferred Alternative

are submitted to CNSC. The analytical data on spacer material removed from D1711 will be applied to CNE Review Gate #3. Test results from the removed spacers from Unit 2 will be applied to achieve CNE Review Gate #4. CNE Review Gates #3 and #4 are scheduled on October 2, 2018 and October 7, 2019, respectively. The FFS of spacers up to 235k EFPH and the confidence in projecting the spacer material degradation rate will be established based on analytical results obtained to satisfy the above Gate reviews.

If refurbishment schedule dates are deferred, the remaining running Unit(s) may have to operate beyond 235k EFPH. Under this scenario, the data required to assess FFS to an extended end of life target may not be available. Mitigating action may be additional SFCR(s) to obtain material for testing and surveillance/inspection results. A contingency has been set aside to cover specific aspects of the costs of additional SFCR(s).

This project is in support of OPG reaching its business plan objectives.

Deliverables:	Associated Milestones (If any):	Target Date:
Project Start (BCS approved)		March 31, 2017 (Complete)
PO for COG Joint Project is Issued		June 26, 2017 (Complete)
Full Release BCS Approved		December 15, 2018
CNE Review Gate #3 Cleared	CNE Review Gate #3 (Oct 2, 2018)	January 1, 2019
Updated Spacer Degradation Model Projection (Version 3)		September 13, 2019
CNE Review Gate #4 Cleared	CNE Review Gate #4 (Oct 7, 2019)	January 6, 2020
HFIR Phase II Fatigue Specimens Tested		June 30, 2020
Project Close-Out		December 15, 2021
Project Close-Out if project is extended (see specific risk above and Alternative 4 below)		December 15, 2024

Part C: Other Alternatives

Summarize all viable alternatives considered, including pros and cons, and associated risks. Other alternatives may include different means to meet the same business need, and a reduced or increased scope of work, etc.

Alternative 2: Base Case – Complete all the project planned work with a reduced schedule for the HFIR program

Not Recommended:

Under alternative 2, the scope of work of the preferred alternative will be executed but with a reduction to the scope of the HFIR program. The scope will be limited to a condition when the OPG's ex-service spacers receive an equivalent irradiation dose of 245k EFPH. This alternative does not include further irradiation of fatigue specimens beyond August 2018. The target completion date of the HFIR program is Q3 2019. This alternative completes testing on all removed capsules with an exception of fatigue testing on capsule 19.

Comparison Between Alternative 2 and the Preferred Alternative

Impact on Costs:

- 1) Cost saving associated with reduced irradiation costs (capsules 9, 10, 13, 14, 19) that is scheduled from August 2018 to 2020.
- 2) Cost saving associated with removal of capsule 19 testing.
- 3) Cost saving associated with removal of HFIR phase 4 in 2019 and 2020.

Impact on Schedule:

- 1) Phase I, II, and III of the HFIR irradiation program will end in Q3 2018.
- 2) Post-irradiation tests will end in Q3 2019.

Comparison Result:

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Alternative 2: Base Case – Complete all the project planned work with a reduced schedule for the HFIR program

This alternative includes all of the preferred alternative activities except for stopping the HFIR irradiation in 2019 instead of 2020. Choosing this alternative would result in a cost saving of approximately \$1.4M. Alternative 2 would still fund the testing for removed spacers from Darlington Unit 2.

Risks:

- 1) There is a risk that reduced HFIR program will result in insufficient data to inform on material degradation trends;
- 2) There is a risk that CNSC does not accept scope reduction as this was agreed per "Long Term Spacer Plan". Under this scenario there is a risk of regulator asking for more data through imposing additional SFCR(s).

Conclusion

Under this scenario, the high flux aging to 235k EFPH will not be achieved. Lack of evidence for FFS up to 235k EFPH may be a cause for imposing idle time or additional SFCR(s). This alternative is not recommended because the impacts of the risks outweigh the cost saving benefits.

Alternative 3: Delay Work – Do Nothing

Not Recommended:

Under alternative 3, the preferred alternative would not be continued and stops by the end of 2018. No further funding request will be required. Under alternative 3, all HFIR capsules will be removed and no follow-up testing will be done on the removed capsules. The remaining funds from the partial release would pay for the close-out activities.

Comparison Between Alternative 3 and the Preferred Alternative

Impact on Costs:

- 1) Cost saving on the removal of HFIR Phase I, II, and III irradiation costs from 2018 to 2020.
- 2) Cost saving on the testing that was planned to take place on the removed capsules from 2018 to 2020.

Impact on Schedule:

The project could be closed-out in 2019.

Comparison Result

This alternative would have a financial savings of at least \$13M and would allow for the project to be closed-out in 2019 instead of 2021 under the preferred alternative.

Risks:

- 1) OPG will be unable to demonstrate spacers' FFS to the target service life and would have to instigate idle time once its Darlington reactors reach 213,890 EFPH;
- 2) According to the sensitivity studies performed on the Fuel Channels Life Extension Project, the costs of potential idle time in Darlington Units and operating all of the Pickering Units to the end of 2020 is from \$0.3B to \$1.1B in 2016 present value dollars [10].
- 3) There is a high probability that CNSC will not accept the OPG's deviation from the agreed "Long Term Spacer Plan" as was committed before;

Conclusion:

This alternative was not recommended because the "do nothing" alternative will have a significantly higher financial impact on the organization and discredits OPG's agreement with the regulator. The overall costs of the above consequences outweighs the savings under this alternative.

Alternative 4: Complete all the project planned work including HFIR program Phase IV

Recommended as a contingency (final decision in 2019):

Under alternative 4, the entire scope of work of the preferred alternative will be executed plus Phase IV of the HFIR program. Phase IV HFIR is an extension to the original scope and returns immediate benefit to Bruce Power. HFIR Phase IV continues through 2021 and ends in 2023. This work includes irradiation of B8J18 spacer material to Bruce Power's target EFPH limit in addition to post-irradiation testing and examinations.

The recommendation whether this contingency work will be executed can be made in 2019. Currently there is insufficient data to determine whether HFIR is representative of the degradation process of the spacers in the reactor, providing useful data to the spacer predictive models. Additional HFIR samples will be tested and results obtained to help Bruce Power make the decision

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Alternative 4: Complete all the project planned work including HFIR program Phase IV

whether or not to continue HFIR Phase IV beyond 2020. If the decision is positive, OPG may benefit long term by supporting it by sharing the cost with BP.

Comparison Between Alternative 4 and the Preferred Alternative

Impact on Costs:

- 1) Incurring additional Phase IV HFIR irradiation costs for Bruce Power ex-service spacers;
- 2) Incurring additional examination and testing costs post Phase IV HFIR irradiation;
- 3) Incurring additional project management costs in the years 2021, 2022, and 2023.

Impact on Schedule:

Under this alternative the project close-out date would be in 2024 once the Bruce Power ex-service material testing is complete and the results obtained.

Comparison Result:

Choosing this alternative would require an additional \$4,034k in OPG's contribution to the total funding requirement. This alternative would not cause schedule delays because a contingency close-out date in 2024 has been added to the schedule. The closure date in 2024 is aligned with the original JP close-out date.

Risks:

No additional risks compared to the preferred alternative.

Conclusion

The decision on whether to take this alternative will be determined in 2019. Completing HFIR program under the preferred alternative will be sufficient to achieve the OPG's immediate objectives. Although this alternative has not been selected as the preferred alternative a specific contingency funding was set aside to cover the costs if OPG decides to support this work in future.

Part D: Project Cash Flows, NPV, and OAR Approval Amount

k\$	LTD	2018	2019	2020	2021	2022	2023	Future	Total
Currently Released	2,117	6,803							8,920
Requested Now	-	986	10,281	4,222	2,985	1,257	600		20,331
Future Required	-								
Total Project Cost	2,117	7,789	10,281	4,222	2,985	1,257	600		29,251
Ongoing Costs	-								
Grand Total	2,117	7,789	10,281	4,222	2,985	1,257	600		29,251
Estimate Class:	Class 3			Estimate at Completion:					
NPV:	N/A			OAR Approval Amount:			29,251		

Additional Information on Project Cash Flows (optional):

The estimate at completion of [REDACTED] excludes the total contingency of [REDACTED]. No ongoing costs were considered since irradiation of spacer material in the High Flux Isotope Reactor (HFIR) and subsequent testing are part of the project scope.

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Type 2 Business Case Summary

Project #: 16-83280

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Project Title: Darlington Annulus Spacer Life Management (ASLM), Full Execution Release

Part E: Financial Evaluation

k\$	Preferred Alternative	Alt. 2: Reduced Scope	Alt. 3: Do Nothing	Alt. 4: Expand Scope to Include Phase IV HFIR	
Project Cost		N/A	N/A	25,411	
NPV	N/A	N/A	N/A	N/A	
Other (e.g., IRR)					

Summary of Financial Model Key Assumptions or Key Findings:

The above Project Costs exclude contingency.

Part F: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
Cost	Event: There is a risk that maximum spacer loads during fueling machine interaction (i.e. COG-JP-4491-V144 findings per WPR 71916) may influence spacers' fitness for service assessments for the target service life. Cause: The latest assessment included more details into the loading conditions that may exceed previously assessed values for spacer integrity. Impact: The impact of this risk is increasing the current ASLM project scope.	Action Description: Use the contingency to cover the cost. Closure Criteria: Assessment results confirm no need for additional work (Ref. RMO# 16662).	Low	Low
Cost/Schedule	There is a schedule and cost associated risk that the HFIR program won't achieve its full scope due to the fretting damage on capsules containing the testing specimen. If the specimen that is lost is deemed essential, re-encapsulation and re-insertion in the HFIR will be necessary which will affect greatly cost and schedule.	- As part of the long-term spacer plan, re-evaluate the HFIR program - Determine if capsule redesign is required and confirm the cost of capsule redesign will be covered by COG (Ref. RMO# 15189).	Low	High
Cost	Event: There is a risk of adding potential SFCRs to the scope of this project. The costs of actual SFCRs are covered by OMA budgets. However, the costs of shipping, handling, disposing and testing of spacer material would be covered by this project. The costs of two additional SFCRs need to be added as contingency for this project. Cause: The need for additional SFCR may come from a CNSC request for additional testing or from new findings that require more spacer material for testing. The material may not be available during spacer modeling and FFS assessment window and hence, require additional SFCRs. Impact: The impacts of spacer testing from the additional SFCRs will be on the project cost and schedule.	Action Description: The costs of testing retrieved spacer material is added as contingency work for the final release. Action Closure Criteria: Spacer modeling and FFS assessment are issued. Contingency allocated (Ref. RMO# 16663)	Low	High
Cost/Schedule	Event: There is a risk that the FFS assessments and associated confidence statement need to be extended beyond the 235KEFPH operating target. Cause: The Darlington Refurbishment schedule may be pushed back in future due to resource issues. This would require the	Action Description: The decision on whether or not the refurb schedule is going to be pushed back will be determined in February 2019. This action was assigned to FCLCP Senior Manager to monitor and update as required.	Medium	Medium

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Project Title: Darlington Annulus Spacer Life Management (ASLM), Full Execution Release

Part F: Risk Assessment				
Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
	scheduled units to operate longer and beyond 235kEFPH target. Impact: The Impact of FFS beyond 235 kEFPH will be on the project cost and schedule. If technically feasible this would invoke the need for identified contingency. This would push back the current project close-out phase from 2021 to a later date.	Closure Criteria: If a refurbishment schedule date is accepted and FFS assurance beyond 235 kEFPH is feasible, a contingency would be requested. The closure criteria is either retiring this risk, applying the contingency or identifying this as technically not feasible. (Ref. RMO# 16684).		
Cost/Schedule Technical	Event: There is a risk that scope and timeline of the project may expand to support continued HFIR Phase IV work from 2021 until 2023. Cause: The HFIR Phase IV work may be necessary to confirm the FFS spacer model for post-Refurb. Impact: Supporting continue HFIR work from 2021 until 2023 will impact on the ASLM project costs and schedule. The increased costs may lead to a release of specific contingency and an extended project duration.	Seek FCLCP Line Management Decision on Supporting HFIR Phase IV Work from 2021 until 2023. FCLCP Line Management needs to make a decision on whether or not to recommend support of HFIR Phase IV work for the above period (Ref. RMO# 16033). Closure Criteria: The FCLCP line management decision on supporting HFIR Phase IV work from 2021 until 2023 is obtained and included.	Low	High

Additional Risk Analysis:

The degradation of Inconel X-750 tight-fitting spacer material was confirmed by the work done under Fuel Channel Life Management Project (FCLMP). The current model on degradation rate was based on limited data obtained from ex-service spacers. More data is required to support high confidence projections on spacer FFS late in operating life. OPG needs to demonstrate to the regulator that X-750 spacers are able to carry out their design functions to ensure safe operation of fuel channels and their spacers throughout their service lives. CNSC has accepted the OPG's submission of the "Long Term Spacer Darlington Life Management Plan for Inconel X-750 Annulus Spacers". The execution of this project, which was based on the spacer life management plan provides OPG with technical data to assess spacers' integrity and confidence in FFS until end of life operation. Failure to demonstrate FFS of X-750 spacers may result in idle time for both Units 1 and 4 beyond 213,890 EFPH until their respective Refurbishment outage dates.

Part G: Post Implementation Review (PIR) Plan

☐ It is determined appropriate that only a Project Closure Report (PCR) is needed as the PIR for this project, due to its straight forward deliverables, which do not require any measures other than confirmation of completion or delivery.

Type of PIR Report	Target In-Service or Completion Date	Target PIR Completion Date
Simplified PIR	December 2021	December 2022

Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)
Engineering model to project Darlington Spacer life to 235k EFPH	Preliminary model is available now. This model projects FFS to approximately 213k EFPH	Updated model provides a high confidence prediction of spacer FFS to 235k EFPH	Completion of CNE Review Gate #4 as outlined in NK38-PLAN-31160-10000	MCED
Determination of FFS to 235k EFPH	CNSC acceptance of the Long Term Darlington Life Management Plan for Inconel X-750 Spacers	CNSC acceptance of the spacer FFS assessments to 235k EFPH	Positive CNSC response to OPG's submission after CNE Review Gate #4	MCED

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Document #: NK38-BCS-31160-00001 R001

Project #: 16-83280

Project Title: Darlington Annulus Spacer Life Management (ASLM), Full Execution Release

Part I: Definitions and Acronyms

ASLM - Annulus Spacers Life Management
 CNL - Canada Nuclear Laboratories
 CNSC - Canadian Nuclear Safety Commission
 COG - CANDU Owners Group
 CSA - Canadian Standard Association
 CT - Calandria Tube
 D2M9 - Outage D1321 channel M09
 FCLM(P) - Fuel Channel Life Management (Project)
 FCLCP - Fuel Channel Life Confirmation Projects (OPG work group)
 FFS - Fitness For Service
 FIB - Focused Ion Beam
 HFIR - High Flux Isotope Reactor
 KEFPH - thousand Effective Full Power Hours
 LCH - License Condition Handbook
 MCED - Major Components Engineering Department
 ORNL - Oak Ridge National Laboratories - Purchase Order
 PP&C - Project Planning and Control
 PT - Pressure Tube
 RMO - Risk Management Oversight
 R&D - Research & Development
 SFCR - Single Fuel Channel Replacement
 TEM - Transmission Electron Microscopy

Approvals			
	Signature	Comments	Date
The recommended alternative, including the identified ongoing costs, if any, represents the best option to meet the validated business need.			
Recommended by (Project Sponsor): Steve Gregoris SVP Darlington			02 Oct 18
I concur with the business decision as documented in this BCS.			
Finance Approval: Cynthia Domjancic VP Controllershship per OPG-STD-0076			05 Oct 18
I confirm that this project, including the identified ongoing costs, if any, will address the business need, is of sufficient priority to proceed, and provides value for money.			
Approved by: Sean Granville Chief Nuclear Officer (CNO) per OAR 1.1			2018/10/11

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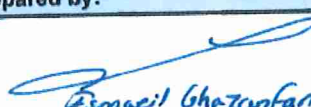
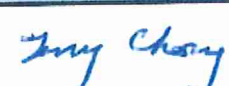
Type 2 Business Case Summary

Project #: 16-83280
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Appendix A: Summary of Estimate										
Project Number:	16-83280									
Project Title:	Darlington Annulus Spacer Life Management									
k\$	LTD	2018	2019	2020	2021	2022	2023	Future	Total	%
OPG Project Management	8	460	460	460	230				1,618	6
OPG Engineering (including Design)	12	588	588	588	294				2,070	7
OPG Other										
Consultants										
Other Contracts/Costs										
Interest										
Subtotal										
General Contingency										
Specific Contingency										
Total	2,117	7,789	10,281	4,222	2,985	1,267	600		29,251	100

Notes			
Project Start Date	APR-2017	Total Definition cost (excludes unspent contingency for Nuclear)	30k
Target In-Service (or AFS) Date	N/A	Contingency included in this BCS (Nuclear only)	
Target Completion Date	DEC-2021	Total contingency released plus contingency in this BCS (Nuclear only)	
Escalation Rate	2.0%	Total released plus this BCS without contingency (Nuclear only)	
Interest Rate	N/A	Total released plus this BCS with contingency (Nuclear only)	29,251k
Removal Costs	N/A	Estimate at Completion (includes only spent contingency for Nuclear)	

Prepared by:	Approved by:
 Esmail Ghazanfari Senior Tech. Engineer/Officer, FCLCP Date: 28 SEP 2018	 Terry Chong, Section Manager Projects, FCLCP Date: 28 Sept 2018
Reviewed by:	
 John Xiao, Project Manager, FCLCP Date: 28 SEP 2018	

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Project #: 16-83280

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Project Title: Darlington Annulus Spacer Life Management (ASLM), Full Execution Release

Appendix B: Comparison of Total Project Estimates and Project Variance Analysis										
Comparison of Total Project Estimates										
Phase	Release	Approval Date	Total Project Estimate in k\$ (by year including contingency)						Future	Total Project Estimate
			2017	2018	2019	2020	2021	2022		
Execution	Partial	June 2017	2,261	6,659	8,850	3,041	360			21,171
Execution	Full	Q3 2018	2,117	7,789	10,281	4,222	2,985	1,257	600	29,251

Project Variance Analysis					
Choose an item.	LTD	Total Project		Variance	Comments
		Last BCS	This BCS		
OPG Project Management		1,110	1,618	508	Labour costs are based on PP&C labour costs charts, which are higher than actual charges for this project. The PP&C charts are recommended to make all project labour charges uniform across the fleet.
OPG Engineering (including Design)		800	2,070	1,270	Labour costs are based on PP&C labour costs charts, which are higher than actual charges for this project. The PP&C charts are recommended to make all project labour charges uniform across the fleet.
OPG Procured Materials					
OPG Other					
Design Contract(s)					
Construction Contract(s)					
EPC Contract(s)					
Consultants					
Other Contracts/Costs					
Interest					
Subtotal					
General Contingency					
Specific Contingency					
Total		21,171	29,251	8,080	

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Project #: 16-83280

Document #: NK38-BCS-31160-00001 R001

Project Title: Darlington Annulus Spacer Life Management (ASLM), Full Execution Release

Appendix C: Financial Evaluation Assumptions

Key assumptions used in the financial model of the Project are (complete relevant assumptions only):

Project Cost:

i

Appendix D: References

1. NK38-PLAN-31160-10000, Long Term Darlington Life Management Plan for Inconel X-750 Annulus Spacers.
2. NK38-PCH-31160-10002, Darlington Annulus Spacer Life Management
3. N-PLAN-01060-10002, Fuel Channel Life Cycle Management Plan
4. NK38-CORR-00531-16240, Darlington NGS A- Long Term Darlington Life Management Plan for Inconel X-750 Spacers – Action Item 2013-13-3962
5. LCH-DNGS-PROL 13.00/2025, Darlington License Condition Handbook
6. N-CORR-31100-80014-0489834 T10, Fuel Channel Research and Development (R&D) and Material Surveillance Funding Requirements, 2017-2021
7. AACE International Recommended Practice No. 18R-97, Cost estimate classification system-as applied in engineering, procurement, and construction for the process industries.
8. NK38-CORR-00531-17500, Updated Long Term Darlington Spacer Life Management Plan for Inconel X-750 Spacers Revision 001.
9. NK38-CORR-31100-80014-0630893 P, CNE Review Gate #2: Evaluation of Long Term Darlington Life Management Plan for Inconel X-750 Annulus Spacers
10. N-BCS-31100-10009 R01, Fuel Channel Life Extension Project, Project# 16-80014

Numbers may not add due to rounding.

Filed: 2020-12-31
EB-2020-0290
Exhibit F2
Tab 3
Schedule 3
Table 1

Table 1
OM&A Project Listing - Nuclear
Projects ≥ \$20M Total Project Cost¹

Line No.	Facility	Project Name	Project No.	Category	Start Date	Final Completion Date	Total Project Cost ² (\$M)	Partial/Devmt Release (\$M)	Initial Full Release (\$M)	Superceding Full Release (\$M)	2016 Actual (\$M)	2017 Actual (\$M)	2018 Actual (\$M)	2019 Actual (\$M)	2020 Budget (\$M)	2021 Budget (\$M)	2022 Plan (\$M)	2023 Plan (\$M)	2024 Plan (\$M)	2025 Plan (\$M)	2026 Plan (\$M)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(n)	(o)	(p)	(q)	(r)	(s)	(s)	(s)	(s)	(s)	(s)
		ONGOING PROJECTS FROM EB-2016-0152																			
1	DN	DN Boiler Blowdown Piping Refurbishment	31506	Sustaining	Dec-12	Aug-20	20.7		20.7		4.4	7.2	3.3	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0
2	DN	DN IFB Stacking Frame Replacement (Long Bundle)	80067	Sustaining	Dec-14	Dec-22	29.7		29.7		2.5	1.3	4.0	4.4	2.3	3.1	0.0	0.0	0.0	0.0	0.0
3	ENG	Fuel Channel Life Extension	80014	Value Enhancing	Nov-13	Dec-21	69.3		69.3		14.9	11.0	8.1	3.9	5.1	4.4	0.4	0.0	0.0	0.0	0.0
		Subtotal					119.7				21.8	19.5	15.5	8.5	7.6	7.5	0.4	0.0	0.0	0.0	0.0
		COMPLETED PROJECTS FROM EB-2016-0152																			
4	ENG	Fuel Channel Life Management	62444	Sustaining	Aug-09	Jun-16	49.5		54.1		0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Subtotal					49.5														
		PROJECTS NOT IN EB-2016-0152																			
5	DN	DN PHT Pump Motor Oil Leak Vendor Support	84415	Sustaining	Jan-20	Jul-25	47.4				0.0	0.0	0.0	0.0	3.2	2.3	2.4	3.9	1.4	0.2	0.1
6	DN	DN UO Switchgear Refurbishment	84484	Sustaining	Jul-20	Dec-27	21.3	4.1			0.0	0.0	0.0	0.0	0.0	5.3	2.1	1.4	1.8	2.2	0.3
7	DN	DN Periodic Safety Review	84589	Regulatory	Feb-20	Mar-24	27.0	15.7			0.0	0.0	0.0	0.0	3.1	5.6	5.5	5.0	1.2	0.0	0.0
8	DN	DN Annulus Spacer Life Management	83280	Sustaining	Jun-17	Dec-21	29.3		29.3		0.0	2.1	6.9	3.7	2.7	3.1	0.0	0.0	0.0	0.0	0.0
		Subtotal					124.9														

Notes:

- 1 Projects with expenditures during IR Term AND Completed/Deferred Projects (from EB-2016-0152 or subsequent).
- 2 Total Project Cost reflects BCS amounts at the time of preparing the Amended 2020-2026 Business Plan, with the exception of Completed/Deferred/Cancelled Projects (for which actual costs are shown). BCS amounts reflect point estimates or, if range estimate or no estimate is provided in lieu of a point estimate, the current estimate of total project cost

Table 2a
OM&A Project Listing - Nuclear
Projects \$5M - \$20M Total Project Cost¹

Line No.	Facility	Project Name	Project No.	Category	Project Description	Start Date	Final Completion Date	Total Project Cost ² (\$M)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
		ONGOING PROJECTS FROM EB-2016-0152						
1	DN	DN GFP Sample Delay and Alternative PHT Sampling Point	31514	Sustaining	Modify the sample lines of the Gaseous Fission Product (GFP) Monitoring system to ensure adequate Heat Transport System (HTS) sample delay in order to correct a legacy design deficiency discovered during commissioning of the new system and allow the GFP Monitoring system to function within its design requirements; and provide an alternate HTS sampling point.	Dec-12	Dec-20	8.5
2	DN	DN OH180 Aging Management/Support Program	34011	Sustaining	Design and qualify replacement circuit boards, power supplies and other components to replenish inventory and eventually replace obsolete components in the OH180 programmable logic controllers.	Dec-08	Mar-20	5.1
3	DN	DN PHT LRV Modifications (Waterhammer)	38933	Regulatory	Developmental activities to investigate waterhammer and Primary Heat Transport Liquid Relief Valve designs that would address issues with original valves and configuration.	Dec-08	Dec-16	9.8
4	DN	DN Reduced HTS Pressure-Temperature Envelope Modifications	80016	Regulatory	Implement modifications necessary to meet the revised pressure-temperature envelope during cooldown arising from results of the Fuel Channel Life Management project.	Jan-14	Dec-26	15.2
5	DN	DN New Heat Transport Pump Seals (OM&A)	80071	Sustaining	Install new design Heat Transport Pump seals that address the operating deficiencies and poor reliability of the existing seals.	Dec-14	Jul-19	16.6
6	DN	DN Aging Management	80079	Sustaining	Fund a dedicated team initially for 2 years at station to strategize and manage the aging management scope in collaboration with Station and Refurbishment stakeholders and eventually manage these issues into Darlington station business plan.	Nov-14	Dec-19	9.5
7	DN	DN Aging Management Scope Defining Inspections	80110	Sustaining	Support execution of inspection activities to better define the aging management scope is support of the updated Integrated Implementation Plan.	Feb-15	Dec-23	9.9
8	DN	Darlington DCC/CP/SEM Computers Software Shipments	82825	Sustaining	Software shipments are a new version of the DCC/CP/SEM computer software, created to maintain configuration control over the real time process control and monitoring software changes to incorporate the existing software.	May-16	Aug-26	6.5
9	DN	DN Annunciation Modifications and Post-Accident Monitoring Configuration Management	83545	Regulatory	Improve control schemes for silencing, acknowledging and resetting annunciations in the Control room to reduce the potential for errors.	Jan-17	Apr-21	9.2
10	PN	PN Instrumentation & Control Obsolescence	41024	Sustaining	Specify and qualify replacement instrumentation and control devices to replace obsolete components in a number of different systems.	Dec-12	Dec-19	13.4
11	PN	PN Equipment Reliability Initiatives	80060	Sustaining	Address selected equipment and/or system degradation to ensure improvement in forced loss rate.	Feb-14	Dec-20	13.4
12	PN	Pickering 58 Digital Control Computer Hardware Modernization (OM&A)	80135	Sustaining	Test and qualify Digital Control Computer hardware components acquired from other CANDU units to increase reliability of Pickering 58 DCCs.	Oct-16	Dec-22	8.7
Table continues on Ex. F2-3-3 Table 2b								

Notes:

- Projects with expenditures during IR Term AND Completed/Deferred Projects (from EB-2016-0152 or subsequent).
- "Total Project Cost" reflects BCS amounts, with the exception of Completed/Deferred Projects (for which actual costs are shown).

Table 2b
OM&A Project Listing - Nuclear
Projects \$5M - \$20M Total Project Cost¹

Line No.	Facility	Project Name	Project No.	Category	Project Description	Start Date	Final Completion Date	Total Project Cost ² (\$M)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
		ONGOING PROJECTS FROM EB-2016-0152						
13	PN	PN Unit 4 SG11 and SG12 Nozzle Installation	83269	Sustaining	Install access nozzles on Steam Generators SG11 and SG12 for water lancing above top pre-heater baffle plate to mitigate outside diameter degradation.	Sep-16	Jun-18	5.3
14	PN	DCC Aging Management	62553	Sustaining	Participate in CANDU Owners' Group joint project to manage the aging of digital control computers vital to the operation of the units.	Mar-04	Dec-20	16.3
15	IRI	Inspection Qualification	66105	Regulatory	Demonstrate compliance with the Canadian Standards Association Standard N285.4 Periodic Inspection of CANDU Nuclear Power Plant Components by proving a systematic and well-documented approach to non-destructive examination qualification.	Nov-06	Mar-22	15.3
		Subtotal						162.5
		DEFERRED/COMPLETED PROJECTS FROM EB-2016-0152						
16	DN	DN RD-310 Implementation - Safety Analysis Improvement	80028	Regulatory	Upgrade the Darlington Safety Report to meet the requirements of CNSC Regulatory Document REGDOC-2.4.1 Deterministic Safety Analysis (formerly RD-310 Safety Analysis for Nuclear Power Plants).	Jul-14	Dec-22	9.0
17	PN	PB DCC Obsolescence	40505	Sustaining	Upgrade display hardware, replace necessary components, and procure critical spares.	Aug-03	Jul-17	5.9
18	PN	PB Boiler Blowdown Pipe Support Improvements	40683	Sustaining	Install new and/or modified piping supports at selected locations in the Reactor Auxiliary Bay and Screenhouse to make the Boiler Blowdown system more robust.	Oct-10	May-17	11.1
19	PN	PB Irradiated Fuel Bay Leakage Mitigation	40703	Regulatory	Reduce leakage rate from PB Irradiated Fuel Bay and collection sumps to minimize potential for leaks to the environment.	Nov-12	Nov-18	12.9
20	PN	PA Fuel Handling SPV Equipment Reliability Improvement Project - OM&A	46635	Sustaining	Refurbish fuel handling equipment that present single points of vulnerability for reliable operation.	Feb-11	Aug-17	7.0
21	PN	Locking Tabs - Boiler Divider Plate (U1 & U4)	49248	Sustaining	Replacing the current locking tabs installed in Units 1 and 4 with a new design will allow for the following which are aligned with the project objectives: SGs to run until EOL without possibility of locking tab failure; ability for maintenance to be conducted with minimal interference from the new design which will replace the current locking tabs; ability to remove and/or replace components of the new design with relative ease if required and installation to be less complex, optimizing cost, schedule and dose.	Jun-07	Nov-12	13.5
22	ENG	Power Operated Valve Program, N-PROC-MA-0092, Recovery	62447	Sustaining	Update power operated valve program to address deficiencies and complete outstanding work.	Jul-11	Apr-16	6.9
23	ENG	Fukushima Oversight Project	62448	Regulatory	Fund a dedicated project oversight team to interface with regulatory and nuclear industry agencies, manage regulatory actions, identify and initiate projects, and provide high level monitoring for successful completion of the Fukushima Response regulatory commitments and project portfolio.	Dec-11	Aug-16	7.4
24	ENG	Severe Accident Management Guidelines (SAMG) Implementation Improvements	62449	Regulatory	Improve the OPG Severe Accident Management program and ensure related CNSC Fukushima Action Items are completed.	Mar-12	Aug-16	19.5
25	ENG	Nuclear Fleet Safety Systems Functional Assessment	80072	Regulatory	Perform functional assessments of the Backup Safety Systems to assure they are capable of performing their functions required by design and licensing basis and that testing is adequate to demonstrate reliable safety functions.	Aug-14	Sep-18	7.3
26	DN	DN X-750 Spacer Retrieval	80112	Regulatory	Retrieve 24 spacers, intact, from all four axial locations of six selected channels, for material surveillance as mandated by OPG's established plan for maintaining Inconel X-750 annulus spacer fitness-for-service and, thereby, allow the Darlington units to operate to their planned service lives in advance of their respective refurbishments.	Mar-15	Nov-18	10.4
		Subtotal						110.9
Table continues on Ex. F2-3-3 Table 2c								

Notes:

¹ Projects with expenditures during IR Term AND Completed/Deferred Projects (from EB-2016-0152 or subsequent).

² "Total Project Cost" reflects BCS amounts, with the exception of Completed/Deferred Projects (for which actual costs are shown).

Numbers may not add due to rounding.

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Exhibit F2
Tab 3
Schedule 3
Table 2c

Table 2c
OM&A Project Listing - Nuclear
Projects \$5M - \$20M Total Project Cost¹

Line No.	Facility	Project Name	Project No.	Category	Project Description	Start Date	Final Completion Date	Total Project Cost ² (\$M)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
		PROJECTS NOT IN EB-2016-0152						
27	DN	DN Civil Building Structure Repairs	83479	Regulatory	Repair degraded civil structures based on inspection findings and assessments performed from 2013 to 2016, to ensure structures can withstand the service conditions safely and reliability throughout their predicted lifetime. The scope is specifically for civil structures specified by the Integrated Improvement Plan (IIP) items. There currently are no other significant civil structures requiring attention.	Mar-20	Nov-22	11.5
28	DN	DN Resin Transfer Modification	84380	Sustaining	Improve access to the Moderator spent resin transfer station by repositioning existing steam and condensate piping.	May-19	Sep-20	8.0
29	DN	DN PHT Pump Motor R01 Refurbishment	84766	Sustaining	Replace partially refurbished pump motor Unit 3, PM1 with a refurbished spare, refurbish PM1 and return to spares inventory.	Dec-19	Sep-23	8.7
30	IRI	DN PRECISE-D Scrape Tooling	84872	Sustaining	Co-develop and lease/rent a new tooling system and test rig, to reliability perform BOT and RJ scrape at DNGS and testing of tools prior to reactor deployment.	Apr-20	Oct-20	5.3
31	PN	Pickering Fuelling Machine Ram Seal Improvement	83302	Sustaining	Participate in CANDU Owners' Group joint project to develop and qualify improved ram seals to improve performance.	Sep-16	Dec-19	14.6
32	SEC	Security Project D	83412	Sustaining	Security Protected	Nov-19	Feb-21	5.4
33	ENG	Asset Management Implementation	83824	Sustaining	Implement a formal asset investment management program in Nuclear that would optimize allocation of resources within budget constraints and risk tolerances.	Dec-17	Dec-19	9.4
34	IRI	DNR3 Reactor Component Harvesting to Displace SFCR	83926	Sustaining	Conduct a Single Fuel Channel Replacement in 2020 on Unit 1 for a destructive testing of at least one pressure tube and four annulus spacers as per Fuel Channels Lifecycle Management Plan.	Nov-17	May-21	7.3
		Subtotal						70.1

Notes:

- 1 Projects with expenditures during IR Term AND Completed/Deferred Projects (from EB-2016-0152 or subsequent).
- 2 "Total Project Cost" reflects BCS amounts, with the exception of Completed/Deferred Projects (for which actual costs are shown).

Numbers may not add due to rounding.

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Exhibit F2

Tab 3

Schedule 3

Table 3

Table 3
OM&A Project Listing - Nuclear
Projects < \$5M Total Project Cost¹

Line No.	Sponsoring Division	Number of Projects	Total Project Cost (\$M)	Average Cost Of All Projects (\$M)
		(a)	(b)	(c)
	Facility Projects:			
1	Darlington NGS	16	37.7	2.4
2	Pickering NGS	16	34.2	2.1
3	Operations and Project Support	6	16.3	2.7
4	Total	38	88.3	2.3

Notes:

1 Projects with expenditures during IR Term.

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Exhibit F2

Tab 3

Schedule 3

Table 4

Table 4
OM&A Project Listing - Nuclear
Portfolio Projects (Unallocated)¹

Line No.	Project Name	Category	Potential Start Date
	(a)	(b)	(c)
	Darlington NGS		
1	Environmentally Qualified Cables Replacement	Regulatory	2022
	Pickering NGS		
2	Polychlorinated Biphenyl Lighting Ballasts Replacement	Regulatory	2022
3	North Yard Fire Header Repair	Sustaining	2022
4	D2O Upgrading Plant A Towers Removal	Sustaining	2022
	Inspection and Reactor Innovation		
5	Fuel Channel Auto-Analysis Software	Sustaining	2021
6	Wet Circumferential Scrape Tool	Sustaining	2022
7	PRECISE (<u>P</u> ressure Tube <u>C</u> ircumferential <u>S</u> ampling <u>E</u> quipment) Wet Tool	Sustaining	2023
8	Fuel Channel Blister Detection Capability	Sustaining	2021
9	Laser-Induced Breakdown Spectroscopy for Hydrogen Characterization	Sustaining	2022

Notes:

1 Projects with potential expenditures during IR Term. Each project is forecast to have a project expenditure of less than \$20M.

Table 5
OM&A Projects - Nuclear Operations
Listing of Business Case Summaries Filed

Line No.	Project Number	Business Case Summary (BCS) Title	BCS Approval Date	Project Stage	BCS Status	BCS Status in EB-2016-0051
	(a)	(b)	(c)	(d)	(e)	(f)
		ONGOING PROJECTS FROM EB-2016-0152				
1	80014	Fuel Channel Life Extension	Aug-16	Execution	Full	Partial
		PROJECTS NOT IN EB-2016-0152				
5	84415	DN PHT Pump Motor Oil Leak Vendor Support	Oct-18	Execution	Full	N/A
6	84484	DN U0 Switchgear Refurbishment	Jul-20	Development	Full	N/A
7	84589	DN Periodic Safety Review	Feb-20	Development	Full	N/A
8	83280	DN Annulus Spacer Life Management	Oct-20	Execution	Full	N/A