

Business Case Summary

Project #	16-84009	Controlled Doc #	D-BCS-04940-00001 R000
Project Title	DN Air Operated Valve (AOV) Replacements		
Facility	Darlington	Investment Classification	Sustaining
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	Dec-2028

Recommendation
We recommend a release of \$1,430K, including [REDACTED] of contingency. The estimate for the current release is Class 3. The estimated total project cost will be determined prior to project Execution Phase. This project is for the replacement of 294 Air Operated Valves (AOVs) in many applications across the Darlington station. This release is for the support the group of AOVs (41 valves) scoped for the DNRU1 outage. The current scope of work will include preparing valve technical specifications, performing Cat ID evaluations, identifying replacement models through a market search, completing engineering assessments to determine the required engineering process (IEE, NICR, MODs) for AOVs, and preparing for the next gate release.

Investment Cash Flows									
\$K	LTD	2020	2021	2022	2023	2024	2025	Future	Total
Previous releases									-
Current request	-	1,430							1,430
Total released to date	-	1,430	-	-	-	-	-	-	1,430
Future required	-		TBD	TBD	TBD	TBD	TBD	TBD	TBD
Total Project Cost									
Ongoing Costs	-								
						Gate:	G1	OAR Approval:	\$1,430 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 Rick Hohendorf Director, Components Engineering, Darlington		Feb. 14, 2020
I concur with the business decision as documented in this BCS.		
Finance Approval: Brett Lemmon Finance Controller, Darlington		Feb 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: Zar Khansabek Val Bevacqua Director, Operations & Maintenance, Darlington		Mar 08, 2020

Project #: 16-84009

Project Title: DN Air Operated Valve (AOV) Replacements

Document #: D-BCS-04940-00001 R000

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Business Case Summary

EXECUTIVE SUMMARY – Project Overview

As part of asset management and life cycle planning, Darlington Nuclear has initiated 5 projects to assess 776 valves (Power operated and Manual valves) across the site, including the replacement or upgrade of 294 Air Operated Valves (AOVs).

Majority of Darlington Nuclear AOVs are approaching end of life, many of these valves are obsolete and overall equipment reliability is not adequate. Many of the AOV's are program valves which carry safety functions. The POV program ensures the associated AOVs are capable of performing their intended functions under design basis accident conditions. It was also discovered during the POV recovery project (10-62447) that some program AOVs have low margins to perform intended safety functions. Valve/actuator upgrades will increase safety margin for these valves.

This project is intended to eliminate obsolescence, regain capability margins (for program valves) and sustain long term operation to station end of life. Wherever applicable, digital controls will be used to allow for condition based maintenance.

This release of funding is for the first group of 41 valves (scoped in DNRU1) and will be used to: conduct Cat ID evaluations, prepare valve technical specifications, perform market search, complete design assessment report for design binning (IEE, NICR, MODs), prepare walk downs, configuration management and OPEX reports for all DNRU1 valves, and prepare a Definition Phase (Gate 2A) release package. Most of the design activities will also cover the sister valves (same Cat ID) in the other 3 units.

Current Project Status:

The following items have been completed:

- Project charter
- Conceptual design report
- Design scope of work
- Initial gating strategy
- Level 2 schedule for Gate 1 deliverables and Level 1 schedule for the remainder of the project.
- Class 3 estimate for Gate 1 package and project Class 5 estimate.

Business Need

For Project Level A or B

This project will address the following issues:

Obsolescence and Reliability: Many AOVs are obsolete and AOV equipment reliability was rated Yellow or Red in past health assessments due to known deficiencies.

Low Safety Margins: The past POV program recovery project (10-62447) completed in April 2016 revises about 200 margin calculations. Some program AOVs were found to have low margins, the valve/actuator upgrade will increase safety margin.

The business objective of this project is to have reliable AOVs particularly in special safety systems (SSS) and Safe Operating Envelop (SOE) systems so the risks can be minimized to: public safety, station personnel safety, environment, and nuclear safety. Replacing AOVs will improve reliability, reduce maintenance expenses and the potential for forced outages including the related risks of production losses.

Safe and reliable operation and performance of these valves play a key role in maintaining the three C's (Control, Cool and Contain) of Reactor Safety, as well, these valves are critical in maintaining proper pressure boundary.

Preferred Alternative:

Replace existing AOVs with new valve assemblies/actuators

For Project Level A, B or C

Description of Preferred Alternative

The existing 294 air operated valves will be replaced with improved design and materials following a full review of internal and external OPEX and maintenance history. The new valve assemblies will be field-proven with enhanced trim technology/materials and reliable actuators. Valve accessories will include positioners, solenoid valves, regulators, limit switches and boosters as required. All accessories will be mounted on the valve body with dedicated installation plate or supporting brackets. The new valves should meet and/or exceed existing functional and performance requirements and meet reliability requirement.

Detailed technical assessment of the new valves will be performed during detailed engineering phase and the type of new valves will be determined and selected. Considering the historical problems, criticality, maintenance/margin issues, full assembly/actuator replacements and use of smart positioners where applicable is recommended. The smart positioners

Business Case Summary

Preferred Alternative:	Replace existing AOVs with new valve assemblies/actuators	For Project Level A, B or C
Description of Preferred Alternative		
will improve reliability, reduce maintenance, enhance diagnostic capability, eliminate potential future obsolescence and enable condition base maintenance.		
The desired outcome for this project is that AOVs will function as expected and achieve a high level of reliability with adequate safety margins.		

Deliverables:	Associated Milestones (if any):	Target Date:
<i>Current release:</i>		
Valve Technical Specs/Data Sheets (Group 1 Valves)		Sep 2020
Engineering Assessment Report (Group 1 Valves)		Nov 2020
Complete Project and Design SOW Documents		Nov 2020
Prepare Project Management Plan		Dec 2020
BCS Package for Gate 2A		Dec 2020
<i>Future release:</i>		
Preliminary Engineering of all valves		Sep 2021
Detailed Engineering of all valves		Oct 2022
Start of Installations (SOI)		Feb 2022
AFS - all valves (294)		Nov 2027
Project Close out		Dec 2028

Alternative 2:	Base Case – No Project
NOT RECOMMENDED	
The existing AOVs covered under the current project scope are obsolete, operating with low margin and are approaching end of life. Any management or operational improvements will not provide a long term solution. Obsolescence will remain a production and safety risk due to non-availability of spare parts in the near future. The maintenance costs associated with failures of these valves will increase over the period as further degradation occurs. Therefore, No Project is not a feasible alternative.	

Alternative 3:	Delay Work
NOT RECOMMENDED	
Most of the AOVs will require outages for the field work. The replacements are planned from 2022 and will be completed by 2027 to ensure safe and reliable continued operation of valves. Any project delay will negatively impact the replacement timetable and the project would miss the opportunity to replace the valves before the next planned outage maintenance window.	
The ongoing risk of the valves failing can cause multiple system impairments, disrupt the work management schedule with unplanned replacements/repairs, and potentially cause production losses due to forced outages. Therefore, delaying the project is not recommended.	

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
Cost	There is a risk that the costs for the new valves and project effort could be under estimated due to the following technical reasons: - Some valves in the project will require margin calculations and others may require seismic qualifications. The valves will have digital positioners which can impose mock up testing and cyber security requirements. New valves could be heavier leading to piping stress analysis and support modifications. - Technical assessments for individual valves could be required to evaluate vibration and hunting issues. Also, the legacy and discovery issues and currency fluctuations can increase the project costs.	Mitigate: - Review OPEX - Perform multiple constructability reviews - Determine maximum requirements during detailed design and installation planning - Price locking before material PO award or buy all valves castings at the time of first order - Complete detailed engineering well before execution	No	Medium
Schedule	There is a risk that the Refurbishment organization may reject inclusion of this project scope in refurb outages due to other high priority core work and non-availability of resources. As most valves require outages for replacement, the project has planned to utilize DNRU1 and DNRU4 refurb outages. Further, if detailed design and/or LLM procurement are delayed, valve replacements could be deferred to future outages delaying the in-service schedule for a number of years.	Mitigate: - Conduct meetings with Refurbishment organization to insert scope in outage. - Change existing planned maintenance WOs to complete replacements - Monitor progress on design and LLM procurement during weekly routine meetings.	No	Medium
Schedule	There is a risk that expert design resources may not be available. Design resources could be assigned to other high priority jobs during outages. Refurbishment design milestones could be missed causing a delay in the Installation of the valves.	Mitigate: - Have firm commitments from design agency and monitor progress weekly - Arrange meetings without any delay to escalate any potential delays	No	Medium

Qualitative Factors
- Improvement in plant safety, production and equipment reliability - Reduction in maintenance burden - Improve work control schedule stability

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Filed: 2020-12-31
EB-2020-0290
Exhibit D2-1-3
Attachment 1, Tab 63, 84009
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Business Case Summary

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?

Definitions and Acronyms
Cat ID – Catalogue ID POV – Power Operated Valve AOV – Air Operated Valve IEE – Item Equivalency Evaluation NICR – Non-Identical Component Replacement MODs – Modifications LLM- Long Lead Materials TCD – Target Completion Date DNRU1- Darlington Nuclear Refurbishment – U1 OPEX – Operating Experience PO – Purchase Order WO – Work Order

Project #: 16-84009

Project Title: DN Air Operated Valve (AOV) Replacements

Document #: D-BCS-04940-00001 R000

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Business Case Summary**APPENDICES**

Appendix A1: Summary of Estimate - Released to date										
Project Number:	16-83298									
Project Title:	DN Secondary System High Priority Control Valve Replacements									
\$K	LTD	2020	2021	2022	2023	2024	2025	Future	Total	%
Project Mgmt		331							331	23%
Inspection										
Engineering										
Procurement										
Construction										
Commissioning										
Closeout										
Subtotal	-									
Outside WBS										
Contingency										
Subtotal w/ Contingency	-									
Interest										
Other										
Total	-	1,430	-	-	-	-	-	-	1,430	100%
Removal Costs (incl. above)									-	0%

Appendix A2: Summary of Estimate – Notes			
Escalation Rate	2.5%	Interest Rate (going-forward)	4.25%

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	%
		To Be Determined prior to Execution Phase		0%
				0%
Total			-	0%

Prepared by:		Reviewed and Endorsed by:	
 Amjad Muhammad Project Manager Projects & Modifications		 Ralph Stube Section Manager Projects & Modifications	
Date: Feb 13, 2020		Date: Feb 13, 2020	

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 #:	84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)	Document #:	D-BCS-63310-10008
Project Title:	Darlington Primary Heat Transport Liquid Relief Valves Modification		
Class:	☒ OM&A ☒ Capital ☒ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others:	Investment Type:	Regulatory
Phase:	Execution	Release:	Partial
Facility:	Darlington	Target In-Service or Completion Date:	2025-10-30

Project Overview
We recommend Gate 3B approval and partial execution release of \$15,820 K, including [REDACTED] of contingency. This brings the total-to-date project release to \$70,064K, including [REDACTED] of contingency. The estimated total project cost is \$97,297 K including [REDACTED] of contingency. The quality of the estimate for this release is Class 3 (+30%, -20%), and for the total project is also Class 3. <u>Scope of Release</u> This release will fund the following scope of work: - Unit 3 – Installation planning, installation and commissioning - Unit 3 – Procurement of piping and all other non long lead materials and tooling - Unit 3 – OPG Oversight activities for Gate 3B (Project Management, Engineering, Planning, Procurement) - Unit 3 – Engineering support for installation planning and execution - Unit 3 – Fracture Mechanics (Appendix L) Inspections including building access platforms, performing UT / RT inspections and engineering analysis of results - Unit 3 – AFS, Close out and OPEX lessons learned - Unit 1 and 4 Execution BCS preparation The future (final) release will fund the following scope of work: - Unit 1 & 4 – Installation planning, installation and commissioning - Unit 1 & 4 – Procurement of piping and all other non long lead materials and tooling - Unit 1 & 4 – OPG Oversight activities (Project Management, Engineering, Planning, Procurement) - Units 1 & 4 – Engineering support for installation planning and execution - Unit 1 & 4 - Fracture Mechanics (Appendix L) Inspections including building access platforms, performing UT / RT inspections and engineering analysis of results - Unit 1 & 4 – AFS, Close out and OPEX lessons learned - Project Closeout Problem Statement / Business Need During the original commissioning of Darlington Nuclear Generating Station (DNBS), the performance of the Primary Heat Transport Liquid Relief Valves (PHT LRVs) was identified as inadequate. Modifications were completed immediately to address these deficiencies. Following the modifications, the LRVs opened and closed faster than the original design basis. This causes water hammer loads on the Heat Transport System piping that are higher than code limits, leading to risk of fatigue failure of piping and supports. Replacement of the LRVs has been committed to the Canadian Nuclear Safety Commission (CNSC) as part of the Darlington Integrated Implementation Plan. Replacement of the existing PHT LRVs with new valves and relocated warming will address the water hammer risk and close the regulatory commitment. The new valve and warming line design will incorporate operating experience from other CANDU stations. History of BCS releases and project cost estimates: The estimate remains essentially unchanged, within the Class 3 uncertainty range at \$97,297 k.

Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)

Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial Execution Release

Project Overview

This BCS includes project numbers: 84235 (Capital), 83232 (Capital Spare), and 38933 (OM&A). Project 84235 includes design, fabrication, installation and commissioning of new LRVs in all four DNGS units for an estimate at completion of \$86,754 k including contingency. Project 83232 includes purchase of a spare LRV for \$755 k, which was delivered and in-serviced in Dec 2017. Project 38933 includes \$9,788 k of LTD costs for developmental activities for waterhammer investigations and LRV design which were completed prior to a 2016 decision to capitalize the project.

Current Project Status

- Unit 2 Installation was completed on Mar 2018. Fracture mechanics (Appendix L) inspections will be conducted in May – Aug 2019. Unit 2 Commissioning will be completed during Return to Service of DNRU2 in November 2019.
- Detailed mechanical, instrumentation & control and civil designs for Unit 3 will be completed by June 2019 with previously released funding.
- LRVs for all remaining units (3, 1 and 4) have been purchased.

Key Assumptions and Risks:

The following are key assumptions used for this project release:

1) The LRV Modification project includes replacement of the LRVs and associated PHT piping. This scope is expected to be similar for all remaining DNGS units where new LRVs have not yet been installed. It is assumed that field conditions for the remaining units are similar to the recently completed Unit 2.

2) It is expected that the Unit 2 commissioning under pressurized conditions will proceed as expected and no major changes / overhaul will be required to the valve operation to satisfy commissioning requirements

The following are key risks for this project:

- Higher than expected weld failures for LRV Tie in welds
 - Changes to execution timeline based on progress of predecessor and successor projects and refurbishment critical path
 - Additional field interferences discovered during Unit 3 execution
- 3) Total project contingency breakdown of [REDACTED] for each unit is as follows:
- U2 – [REDACTED] previously released contingency to account for any design changes arising from Unit 2 commissioning or engineering disposition of any flaws discovered during fracture mechanics inspections).
 - U3 – [REDACTED] (current release)
 - U1 – [REDACTED] (future release)
 - U3 – [REDACTED] (future release)

Project Cash Flows, NPV, and OAR Approval Amount

k\$	LTD	2019	2020	2021	2022	2023	2024	Future	Total
Currently Released	\$34,008	\$16,120	\$2,351	\$656	\$-	\$1,110	\$-	\$-	\$54,244
Requested Now		\$984	\$7,707	\$5,387	\$1,742	\$-	\$-	\$-	\$15,820
Future Required		\$-	\$1,126	\$4,130	\$7,503	\$7,885	\$4,845	\$1,744	\$27,233
Total Project Cost	\$34,008	\$17,104	\$11,184	\$10,172	\$9,246	\$8,995	\$4,845	\$1,744	\$97,297
On Going Cost									
Grand Total	\$34,008	\$17,104	\$11,184	\$10,172	\$9,246	\$8,995	\$4,845	\$1,744	\$97,297
Estimate Class:	Class 3				Estimate at Completion:		[REDACTED]		
NPV:	N/A				OAR Approval Amount:		\$ 97,297		

Additional Information on Project Cash Flows (optional):

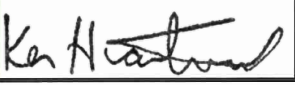
- The cost estimate is classified Class 3 (+30%, -20%) for the requested release and the future release
- The above cash flows include project numbers: 84235 (Capital), 83232 (Capital Spare), and 38933 (OM&A).

Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)

Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial Execution Release

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): Dominique Miniere President, Nuclear			8th of May 2019
I concur with the business decision as documented in this BCS.			
Finance Approval: John Mauti CFO & SVP – Finance (Acting) per OPG-STD-0076			May 9, 2019
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: Ken Hartwick President & CEO per OAR 1.1			June 25, 2019

Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)

Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial Execution Release

Business Case Summary

Part A: Business Need

This project addresses long term valve and piping degradation in the Heat Transport System (HTS) at Darlington Nuclear Generating Station (DNGS), due to valve induced waterhammer. The regulatory driven project will ensure valve, piping and pipe support stresses remain within allowable limits for design basis transients. Replacement of the LRVs will mitigate rapid opening and closing times and eliminate waterhammer, while maintaining overpressure protection requirements.

To ensure overpressure protection of the HTS, each Unit contains four 100% power actuated LRVs, two per HTS loop. Each loop has been designed and instrumented for both valves to open simultaneously on high pressure.

During commissioning of Darlington, it was discovered that the opening force of the LRVs was only designed for zero power hot conditions and not adequate for other operating conditions (e.g. HTS at full power). The original configuration was also not suitable for the high flow rates due to the large differential pressure across the valve. In the rare event (in which LRVs operate simultaneously, OPG is unable to definitively demonstrate that the pipe and support stresses are within American Society of Mechanical Engineers (ASME) code allowable limits, as is required by the Operating License, and is therefore unable to prepare and certify an Analysis of Record.

The Discovery Issues Resolution Process (or DIRP, per N-PROC-RA-0094) was invoked to review this condition and risk assessment was completed to define the nuclear safety risk associated with HTS pipe failure as a result of LRV induced waterhammer. Routine LRV piping and support inspections during planned outages have been implemented, as a result of the DIRP, to confirm structural integrity remains intact for continued operation of the HTS until the replacement valves are installed.

The new LRVs have already been replaced in the first Refurbishment unit during DNRU2 outage. The next outage (DNRU3) is expected to begin in Q4 2019 the last unit Refurbishment outage (DNRU4) is currently scheduled to finish by Q4 2025, with each Refurbishment outage spanning 3 years.

Part B: Preferred Alternative: DNGS PHT LRV Replacement

Description of Preferred Alternative

The proposed solution is to replace the existing LRVs with a new LRVs design which will address the valve opening and closing times to mitigate undesirable waterhammer effects while maintaining overpressure protection requirements. Based on operating experience (OPEX), demonstrated through modifications at Cernavoda B, Wolsung, and Qinshan, this will resolve the existing potential waterhammer problem associated with LRV operation. Additionally, as part of this modification the LRV warming line will be relocated as the present location of the warming line for the current LRVs are too far away to maintain the fluid temperature upstream of the valve. Several supports and supplementary steel in the HTS piping will also be modified to withstand stresses as determined by piping and stress analysis. ASME Section XI Appendix L piping analysis and inspections will be conducted as well to meet code and regulatory commitment.

A total of seventeen (17) Nuclear Class 1 valves / actuator sets, including one capital spare has been purchased under the previous release for delivery with a staggered schedule in accordance with installation windows. Four (4) valves for Unit 2 have already been fabricated and installed awaiting final commissioning during Return to Service of Unit 2.

In February 2009, OPG submitted the proposed two-part strategy to resolve the LRV waterhammer issue to the CNSC, thus closing out the regulatory related Action Request. Part 1 includes removal of the existing LRVs and local piping to the LRVs and replacement with new "flow to open" LRVs. Part 2 involves implementing an inspection process appropriately suited for on-going validation of the pressure boundary integrity of the existing HTS piping and supports. CNSC responded in June 2010 that the CNSC agrees, in principle, to the proposed strategy. A new Action Item was opened to track the completion of OPG undertakings.

This BCS Partial Execution release will allow completion of installation, commissioning and in-service declaration of Unit 3. Future Partial Execution Release BCSs will be released for each of the remaining Darlington units.

Deliverables:	Associated Milestones (if any):	Target Date:
<i>Previous Release:</i>		
U2 Detailed Design (Provisional) Complete	Complete	30-Mar-2017
U2 Detailed Design (Final) Complete	Complete	29-Dec-2017

Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)

Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial Execution Release

Deliverables:	Associated Milestones (if any):	Target Date:
U2 Work Planning Complete	Complete	01-Jun-2017
U3 Detailed Design Complete	U3 Detailed Design Complete	28- Jun-2019
U1 Detailed Design Complete	U1 Detailed Design Complete	15-Sep-2019
U4 Detailed Design Complete	U4 Detailed Design Complete	15-Dec-2019
U2 Installation and Commissioning Complete	AFS Unit 2	30-Nov-2019
Execution Partial BCS Approved (Unit 3)	EXEP	May 2019
<u><i>This Release:</i></u> Execution Partial BCS Approved (Unit 1 and 4) U3 Installation and Commissioning Complete	<u><i>This Release:</i></u> EXEF AFS Unit 3	<u><i>This Release:</i></u> July 2020 Oct 2022
<u><i>Future Releases:</i></u> U1 Installation and Commissioning Complete U4 Installation and Commissioning Complete Project Closure	<u><i>Future Releases:</i></u> AFS Unit 1 AFS Unit 4 PCR Approved	<u><i>Future Releases:</i></u> Sep 2023 Apr 2025 Oct 2025

Part C: Other Alternatives

Alternative 2: Base Case – No Project

This alternative is not recommended as OPG has a Regulatory commitment to CNSC to replace the LRVs.

OPG is also unable to definitively demonstrate that pipe and support stresses are within ASME code allowable limits, as is required by the Operating License, and is therefore unable to prepare and certify an Analysis of Record. This does not satisfy the requirement for a long term solution to address operating outside of ASME code, as required by DIRP N-PROC-RA-0094 (Table 3), per the assessed conclusions of DIRP.

Alternative 3: Minor Modifications to the LRV/Actuator

This alternative is not recommended considering the minor modification will not eliminate the waterhammer problem. This is due to the fact that the present set up of the LRVs makes it difficult to control or to predict the valve behavior. This option is not considered technically feasible.

Alternative 4: Reversal of Existing Valve Body and Replacement of Trim, Valve, Internals, and Actuator

This alternative is not recommended. Similar to the Recommended Option, OPEX indicates that reversal of the valve could correct the waterhammer problem. However, the existing valve internals, trim, and actuators would require replacement if the valves were reversed. Valve testing prior to installation is not possible. As a result, there are numerous uncertainties, reliability issues and a lack of confidence surrounding this option. Additionally, the remaining life of the valve bodies is difficult to quantify as they may have been subjected to past waterhammer loads.

Alternative 5: Perform Analysis to Demonstrate Piping Integrity

After more than two years of analysis using both standard and non-standard methods of analysis, the piping designers concluded that the magnitude of waterhammer load in the event of an extremely rare set of circumstances occurring (under worst case scenario) would be unacceptably high and that stresses cannot be brought within ASME code allowable limits. Further analysis alone would not be beneficial. Therefore, this is also not a viable option.

Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)

Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial Execution Release

Alternative 6: Replace all Potentially Over-Stressed Piping in Conjunction with the Preferred Alternative, or Alternative 3 or 4

Replacement of all affected HTS piping has not been demonstrated to be necessary at this time. This option is not recommended since the cost of undertaking such a large replacement of the HTS piping would be extremely high and require extensive time to install.

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

k\$Choose an item.	LTD	2019	2020	2021	2022	2023	2024	Future	Total
Currently Released	\$34,008	\$16,120	\$2,351	\$656	\$ -	\$1,110	\$ -	\$ -	\$54,244
Requested Now		\$984	\$7,707	\$5,387	\$1,742	\$ -	\$ -	\$ -	\$15,820
Future Required		\$-	\$1,126	\$4,130	\$7,503	\$7,885	\$4,845	\$1,744	\$27,233
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On Going Cost									
Grand Total	\$34,008	\$17,104	\$11,184	\$10,172	\$9,246	\$8,995	\$4,845	\$1,744	\$97,297
Estimate Class:	Class 3				Estimate at Completion:				
NPV:	N/A				OAR Approval Amount:		\$ 97,297		

Additional Information on Project Cash Flows (optional):

- The cost estimate is classified Class 3 (+30%, -20%) for the requested release and the future release
- The above cash flows include project numbers: 84235 (Capital), 83232 (Capital Spare), and 38933 (OM&A).

Part E: Financial Evaluation

k\$	Preferred Alternative	Alt.2 – No Project	Alt.3 – Minor Modifications	Alternative 4	Alternative 5
Project Cost	97,297	N/A	N/A	N/A	N/A
NPV					
Other (e.g., IRR)					

Summary of Financial Model Key Assumptions or Key Findings:

As per OPG-STD-0076, an economic justification is not required for Regulatory Projects.

Part F: Qualitative Factors

The successful completion of this project will address the following:

- 1) Establish acceptable limits for LRV opening and closing operation.
- 2) Confirm that valve operation effectively reduces waterhammer and stresses to acceptable levels.
- 3) Maintain Station Operating License.
- 4) Satisfy Regulatory issues.
- 5) Decrease risk of piping failure.
- 6) Decrease the rate of equipment aging due to fatigue which could potentially impact on plant life extension.

Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)

Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial Execution Release

Part G: Risk Assessment				
Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
Cost	Inadequate vendor performance for certain tasks (e.g. welding) during Unit 2 construction resulted in increases to cost. Similar performances for Unit 3 could result in cost increases that are not accounted in the base estimate	Incorporate lessons learned from Unit 2 execution and investigate alternate technologies (e.g. orbital welding techniques) to reduce risk of weld failures. OPG to conduct strategic oversight through additional hold points for pipe fitup and welding exercise to prevent rework. Pursue contracting terms that transfer certain risks (e.g. high weld failure rates and finding interferences late during execution) to contractor. Specific contingency has been allowed for up to 15% weld failures.	Medium	Low
Scope	Unit 3 stress analysis and design is based on preliminary walkdowns and OPEX from Unit 2. There is a risk that differences in field conditions will result in scope changes with impact to cost and schedule.	Mitigate – Constructivity reviews will be performed when vault access is available after Unit 3 breaker open, ahead of the execution window. Design and construction team will perform detailed walkdowns during Unit 3 planned outage after breaker open prior to execution window to minimize late field changes. Investigate opportunity to use 3D laser scanning to check for interferences prior to execution.	High	Low
Schedule	Any change (delay or acceleration) in schedule and available windows for fieldwork execution during Refurbishment can adversely affect project schedule and cost, especially once the construction workforce is mobilized.	Mitigate - Project team will work closely with NR Work Control and monitor execution windows start/end dates. Project will meet all refurbishment milestones and participate in PCC meetings minimum T-4 weeks prior to execution. Awarding the contract to Canatom also mitigates this risk as Refurbishment critical path is controlled by Canatom. Residual risk of Refurbishment window moves are beyond the control of the project, and sufficient contingency will be allocated to deal with cost issues due to changes in execution schedule.	High	Low
Resources	There is a risk that OPG resources (RP, Ops, Control Maintenance) may not be available during installation and commissioning activities, leading to fieldwork delays.	The project will work closely with Refurb stakeholders to schedule work according to the planned schedule and will escalate conflicts to Darlington senior management as they arise. In particular, project will engage	Medium	Low

Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)

Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial Execution Release

Part G: Risk Assessment				
Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
		maintenance for Station Control maintenance resources in advance to ensure their availability to support commissioning tasks.		
Quality/ Performance	Due to the First Of A Kind (FOAK) nature of this project (until Unit 2 commissioning is completed), there is a risk that valve commissioning will not meet design intent of the modification to eliminate waterhammer.	Project team, valve vendor, Design Agency, and other OPG stakeholders have worked collaboratively to address this risk by performing analysis, prototype valve testing, engineering calculations, etc. to reduce risk. This risk will be significantly mitigated once Unit 2 commissioning is completed. Some contingency is included in the project to address minor design changes that arise from Unit 2 commissioning to Unit 3.	Low	Low
Technical	High weld failure rates were occurred during execution of Unit 2. Similar weld failure rates will cause cost increases beyond the current estimate	Mitigate – Pursue strategy of incorporating machine (orbital) welding to minimize weld failure rates. This strategy will be evaluated by OPG SME's to evaluate effectiveness. Perform detailed mock-up with quantifiable acceptance criteria to prove weld failures will not be a factor. OPG to perform strategic oversight by addition of inspection and testing hold points during execution to monitor fit up and welding activities. There is significant opportunity to reduce future unit costs if optimal performance is obtained during welding and associated installation activities for Unit 3.	Medium	Low
Technical /Schedule	There is a risk that the inspections to detect flaws from fracture mechanics analysis will lead to discovery of flaws that do not meet the acceptance criteria.	Mitigate – Appendix L (fracture mechanics) inspections are part of Unit 2 scope. Lessons learned from Unit 2 will be incorporated. Contingency has been allocated to repair certain discovery failures but extensive number of defects and / or difficult repair activities have not been included in the current project. A detailed extent of condition analysis needs to be performed at that stage. However, based on previous sections, this risk is expected to be very low.	Low	Low

Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)

Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial Execution Release

Part G: Risk Assessment				
Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
Regulatory	Current CNSC memo stipulates that "LRV replacement for the last unit 4 shall begin during the last unit refurbishment outage or 2021, whichever comes first". Given the timing of Refurbishment outages, exemption from this timeline needs to be obtained, and there is a risk that CNSC may reject this request	Mitigate - OPG to re-negotiate with CNSC for U4 LRV replacement dates to delay replacement.	Low	Low

Additional Risk Analysis:

Other risks are identified in online Risk Management and Oversight (RMO) tool.

Part H: Post Implementation Review (PIR) Plan

Type of PIR Report	Target In-Service or Completion Date	Target PIR Completion Date
Simplified PIR	2025-10-30	2026-07-08

Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)
Acceptable LRV opening and closing limits established.	Current opening / closing time is < 0.05 seconds.	Opening / closing times between 1.0-3.0 seconds.	Through valve/actuator testing and commissioning following each unit's installation.	Vendor / Contractor / Maintenance
Relocation of LRV warming line to mitigate large temperature gradient (as high as 80 deg. C) condition upstream of LRVs, due to stagnant fluid.	Current LRV warming line is located on the vertical run of pipe upstream of the LRVs. Due to this configuration, a portion of fluid immediately upstream of the LRVs remains stagnant and cools due to natural convection.	By relocating LRV warming line closer to LRVs with the connection to the horizontal run, fluid will circulate this dead leg region and ensure temperature gradient does not develop.	Temperature will be measured immediately upstream of the LRV inlet and compared with temperature measured at a location further upstream. Temperature measurements are expected to be within 20 deg. C.	Vendor / Contractor / Maintenance
Confirm by analysis that valve operation effectively reduces waterhammer to acceptable levels under all design basis events for which the LRVs are called to operate, with consideration to the full range of design and operating conditions.	Cannot be demonstrated that piping meets ASME Section III stress and fatigue limits under all design basis events for which the LRVs are called to operate, with consideration to the full range of design and operating conditions.	ASME Section XI flaw tolerance evaluation are being performed by OPG to demonstrate piping condition is acceptable under all design basis events for which the LRVs are called to operate, with consideration to the full range of design and operating conditions.	Hydraulic and Stress Analysis modeling to be used as input into the Section XI analysis, which has been completed during Detailed Design Phase.	OPG Design Agency

Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)

Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial Execution Release

Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)
Modified LRVs in service testing program to demonstrate LRV availability	Low Power Hot testing required	Stroking of LRVs under Low Power Hot PHT conditions	Testing program for LRVs modified and communicated to CNSC	OPG Components Engineering

Part I: Definitions and Acronyms

ASME	American Society of Mechanical Engineers
BCS	Business Case Summary
CED	Code Effective Date
CNSC	Canadian Nuclear Safety Commission
Cv	Coefficient of Flow
DIRP	Discovery Issue Resolution Process
DNGS	Darlington Nuclear Generating Station
DSM	Design Section Manager
DTL	Design Team Leader
EDM	Engineering Decision Meeting
DBOM	Design Bill of Materials
EC	Engineering Change
EQ	Environmental Qualification
FRS	Floor Response Spectrum
HT	Heat Transport
HTS	Heat transport System
I&C	Instrumentation and Control
LRV	Liquid Relief Valve
OPEX	Operating Experience
OPG	Ontario Power Generation
PC	Procurement and Construction
PHT	Primary Heat Transport
PMP	Project Management Plan
PRV	Pressure Relief Valve
REGM	Regulatory Management
RFP	Request for Proposal
SMB	Site Management Board
SOW	Scope of Work
SRE	System Release Engineer
SV1	Solenoid Valve 1
SV2	Solenoid Valve 2
TBD	To Be Determined
TSSA	Technical Standards and Safety Authority
US	United States

Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933
(OM&A)

Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial Execution Release

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Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)

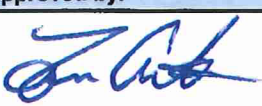
Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial Execution Release

For Internal Project Cost Control

Appendix A: Summary of Estimate										
Project Number:	16-84235 (Capital), 16-83232 (Cap Spare), and 16-38933 (OM&A)									
Project Title:	DN PHT LRV Modifications (Waterhammer)									
k\$	LTD 2018	2019	2020	2021	2022	2023	2024	Future	Total	%
OPG Project Management	\$2,814	\$383	\$176	\$272	\$365	\$253	\$148	\$50	\$4,461	5
OPG Engineering	\$1,631	\$1,377	\$552	\$1,235	\$1,254	\$856	\$499	\$170	\$7,574	8
Permanent Materials	\$4,049	\$3,271	\$1,766	\$656	\$-	\$1,110	\$-	\$-	\$10,850	11
OPG - Prototype LRVs	\$1,864	\$-	\$-	\$-	\$-	\$-	\$-	\$-	\$1,864	2
Detailed Design Contract										
Construction Contract(s)										
Stress Analysis										
Interest										
Subtotal										
Contingency										
Total	\$34,008	\$17,104	\$11,184	\$10,172	\$9,246	\$8,995	\$4,845	\$1,744	\$97,297	100

Notes			
Project Start Date	2008-12-17	Total Definition cost (excludes unspent contingency for Nuclear)	\$27,321 K
Target In-Service (or AFS) Date	2025-04-15	Contingency included in this BCS (Nuclear only)	
Target Completion Date	2025-12-31	Total contingency released plus contingency in this BCS (Nuclear only)	
Escalation Rate	2%	Total released plus this BCS without contingency (Nuclear only)	
Interest Rate	4.5%	Total released plus this BCS with contingency (Nuclear only)	\$70,064 K
Removal Costs	\$144 K	Estimate at Completion (includes only spent contingency for Nuclear)	

Prepared by:	Approved by:
 Mirza Haque Section Manager (Acting) Darlington Design Projects	 Tom Cvitkovic Director Darlington Design Projects
MAR 22, 2019 Date	22 Mar 2019 Date

Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)

Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial Execution Release

Appendix A1: Summary of Estimate										
Project Number:	16-84235 (Capital)									
Project Title:	DN PHT LRV Modifications (Waterhammer)									
k\$	LTD 2018	2019	2020	2021	2022	2023	2024	Future	Total	%
OPG Project Management	\$811	\$383	\$176	\$272	\$365	\$253	\$148	\$50	\$2,458	3
OPG Engineering	\$466	\$1,377	\$552	\$1,235	\$1,254	\$856	\$499	\$170	\$6,409	7
Permanent Materials	\$3,294	\$3,271	\$1,766	\$656	\$-	\$1,110	\$-	\$-	\$10,095	12
OPG – Prototype LRVs	\$524	\$-	\$-	\$-	\$-	\$-	\$-	\$-	\$524	1
Detailed Design Contract										
Construction Contract(s)										
Stress Analysis										
Interest										
Subtotal										
Contingency										
Total	\$23,465	\$17,104	\$11,184	\$10,172	\$9,246	\$8,995	\$4,845	\$1,744	\$86,754	100

Notes			
Project Start Date	2008-12-17	Total Definition cost (excludes unspent contingency for Nuclear)	\$27,321 K
Target In-Service (or AFS) Date	2025-04-15	Contingency included in this BCS (Nuclear only)	
Target Completion Date	2025-12-31	Total contingency released plus contingency in this BCS (Nuclear only)	
Escalation Rate	2%	Total released plus this BCS without contingency (Nuclear only)	
Interest Rate	4.5%	Total released plus this BCS with contingency (Nuclear only)	\$ 59,521 K
Removal Costs	\$ 144 K	Estimate at Completion (includes only spent contingency for Nuclear)	

Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)

Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial Execution Release

Appendix A2: Summary of Estimate										
Project Number:	16-83232 (Cap Spare)									
Project Title:	DN PHT LRV Modifications (Waterhammer)									
k\$	LTD 2018	2019	2020	2021	2022	2023	2024	Future	Total	%
OPG Project Management	-	-	-	-	-	-	-	-	-	-
OPG Engineering	-	-	-	-	-	-	-	-	-	-
Spare Valve	755	-	-	-	-	-	-	-	755	100
OPG – Prototype LRVs	-	-	-	-	-	-	-	-	-	-
Detailed Design Contract	-	-	-	-	-	-	-	-	-	-
Construction Contract(s)	-	-	-	-	-	-	-	-	-	-
Oversight Contract	-	-	-	-	-	-	-	-	-	-
Stress Analysis Contracts	-	-	-	-	-	-	-	-	-	-
Interest	-	-	-	-	-	-	-	-	-	-
Subtotal	755	-	-	-	-	-	-	-	755	100
Contingency	-	-	-	-	-	-	-	-	-	-
Total	755	-	-	-	-	-	-	-	755	100

Notes			
Project Start Date	2008-12-17	Total Definition cost (excludes unspent contingency for Nuclear)	N/A
Target In-Service (or AFS) Date	2017-12-15	Contingency included in this BCS (Nuclear only)	\$0 k
Target Completion Date	2017-12-15	Total contingency released plus contingency in this BCS (Nuclear only)	\$0 k
Escalation Rate	N/A	Total released plus this BCS without contingency (Nuclear only)	\$ 755k
Interest Rate	N/A	Total released plus this BCS with contingency (Nuclear only)	\$ 755k
Removal Costs	N/A	Estimate at Completion (includes only spent contingency for Nuclear)	\$ 755k

Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)

Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial Execution Release

Appendix A3: Summary of Estimate										
Project Number:	16-38933 (OM&A) – LTD 2015 Costs as OM&A Project									
Project Title:	DN PHT LRV Modifications (Waterhammer)									
k\$	LTD 2018	2019	2020	2021	2022	2023	2024	Future	Total	%
OPG Project Management	2,003	-	-	-	-	-	-	-	2,003	20
OPG Engineering	1,165	-	-	-	-	-	-	-	1,165	12
Permanent Materials	-	-	-	-	-	-	-	-	-	-
OPG – Prototype LRVs	1,340	-	-	-	-	-	-	-	1,340	14
Detailed Design Contract	1,166	-	-	-	-	-	-	-	1,166	12
Construction Contract(s)	-	-	-	-	-	-	-	-	-	-
Stress Analysis Contracts	4,114	-	-	-	-	-	-	-	4,114	42
Subtotal	9,788	-	-	-	-	-	-	-	9,788	100
Contingency	-	-	-	-	-	-	-	-	-	-
Total	9,788	-	-	-	-	-	-	-	9,788	100

Notes			
Project Start Date	2008-12-17	Total Definition cost (excludes unspent contingency for Nuclear)	\$ 9,788k
Target In-Service (or AFS) Date	N/A	Contingency included in this BCS (Nuclear only)	\$0k
Target Completion Date	2015-12-31	Total contingency released plus contingency in this BCS (Nuclear only)	\$0k
Escalation Rate	N/A	Total released plus this BCS without contingency (Nuclear only)	\$ 9,788k
Interest Rate	N/A	Total released plus this BCS with contingency (Nuclear only)	\$ 9,788k
Removal Costs	N/A	Estimate at Completion (includes only spent contingency for Nuclear)	\$ 9,788k

Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)

Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial 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	
			LTD	2019	2020	2021	2022	2023		
Execution	Partial	Mar 2017	40,690	4,401	13,041	14,445	4,309		20,221	97,107
Execution	Partial	Apr 2019	34,008	17,104	11,184	10,172	9,246	8,995	6,589	97,297

Project Variance Analysis					
k\$	LTD	Total Project		Variance	Comments
		Last BCS	This BCS		
OPG Project Management	2,814	4,653	4,461	(192)	The decreased cost is based on an updated resource profile based on OPEX from U2 execution.
OPG Engineering/Other	1,631	5,980	7,574	1,594	Increased costs for OPG support to perform fracture mechanics inspections for Units 3, 1 and 4
Permanent Materials and Spare Valves	4,049	13,088	10,850	(2,238)	Cost is lowered based on fixed price PO, which has been awarded to LRV vendor for all remaining valves.
Prototype Valves	1,864	2,017	1,864	(153)	LTD costs were marginally lower than forecasted in previous BCS
Detailed Design Contract					
Construction Contract(s)					
Stress Analysis					
Interest					
Subtotal					
Contingency					
Total	34,008	97,106	97,297	191	

Type 3 Business Case Summary

Project #: 84235 (Capital), 83232 (Cap Spare), 38933 (OM&A)

Document #: D-BCS-63310-10008

Project Title: Darlington Primary Heat Transport Liquid Relief Valves Modification
Partial Execution Release

Appendix C: Financial Evaluation Assumptions

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

Project Cost:

1. Design, Installation and Commissioning Costs are based on Contractor pricing proposals. The proposals are based on 90% detailed design ECs and scheduling information provided by Nuclear Refurbishment. Changes to Refurbishment schedule have a strong impact on project costs and cash flows.
2. Installation costs are estimated on 7 month window available for Unit 3 execution.
3. A 10% reduction in cost from Unit 3 to Unit 1 and a 5% reduction in cost from Unit 1 to Unit 4 is assumed to reflect efficiencies gained from incorporating lessons learned from the previous unit partially offset by escalation costs.

Financial:

1. A financial evaluation is not required as per OPG-STD-0076 for Regulatory Projects.

Project Life:

1. Unit 3,1,4 LRVs will be replaced during respective unit Refurbishment outages, same duration to LRV replacement windows post breaker open as Unit 2
2. Refurbishment outages for Unit 3,1,4 overlap per plan but LRV replacement windows between units do not overlap
3. Current release is based on Unit 3 breaker open date of January 15, 2020.

Business Case Summary

Project #	16-84551	Controlled Doc #	D-BCS-04940-00002 R000
Project Title	DN Motor Operated Valve (MOV) Replacements		
Facility	Darlington	Investment Classification	Sustaining
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	Dec-2028

Recommendation We recommend a release of \$1,091K, including [REDACTED] of contingency. The estimate for the current release is Class 3 The estimated total project cost will be determined prior to project Execution Phase. This project is to replace/upgrade 51 Motor Operated Valves (MOVs) in six applications across the Darlington station. This release will include preparation of valve technical specifications, performing Cat ID evaluation, identifying replacement model through market search, completing engineering assessment to determine engineering process (IEE, NICR, MODs) for MOVs and preparing for the next gate BCS.

Investment Cash Flows									
\$K	LTD	2020	2021	2022	2023	2024	2025	Future	Total
Previous releases									-
Current request	-	1,091							1,091
Total released to date	-	1,091	-	-	-	-	-	-	1,091
Future required	-			TBD	TBD	TBD	TBD	TBD	TBD
Total Project Cost									
Ongoing Costs	-								

Gate: G1 OAR Approval: \$1,091 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 Rick Hohendorf Director, Component Engineering, Darlington		Feb. 14, 2020
I concur with the business decision as documented in this BCS.		
Finance Approval: Brett Lemmon Finance Controller, Darlington Operations Controllershship, Finance		Feb 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: Zar Khanouneh Val Bevacqua Director, Operations & Maintenance, Darlington		Mar 08, 2020

Business Case Summary

EXECUTIVE SUMMARY – Project Overview

As part of asset management and life cycle planning, Darlington Nuclear has initiated 5 projects to assess 776 valves (Power operated and Manual valves) across the site, including the replacement or upgrade of 51 Motor Operated Valves (MOVs).

Majority of Darlington Nuclear MOVs are approaching end of life, many of these valves are obsolete and overall equipment reliability is not adequate. Some MOV's in the scope are program valves which carry safety functions. The POV program ensures the associated MOVs are capable of performing their intended functions under design basis accident conditions. It was also discovered during the POV recovery project (10-62447) that some program MOVs have low margins to perform intended safety functions. Valve/actuator upgrade will increase the safety margin for these valves.

This project is intended to eliminate obsolescence, regain capability margins (for program valves) and sustain long term operation to station end of life. Wherever applicable, digital controls will be used to allow for condition based maintenance.

This release of funding will be used to: conduct Cat ID evaluations, prepare valve technical specifications, perform market search, complete design assessment report for design binning (IEE, NICR, MODs), prepare walk downs, configuration management and OPEX reports for all DNRU1 valves, and prepare a Definition Phase (Gate 2A) release package.

Current Project Status:

The following items have been completed:

- Project charter
- Conceptual design report
- Design scope of work
- Initial gating strategy
- Level 2 schedule for Gate 1 deliverables and Level 1 schedule for the remainder of the project.
- Class 3 estimate for Gate 1 package and project Class 5 estimate.

Business Need

For Project Level A or B

This project will address the following issues:

Obsolescence and Reliability: Many MOVs are obsolete and MOV equipment reliability was rated Yellow or Red in past health assessments due to known deficiencies.

Low Safety Margins: The past POV program recovery project (10-62447) completed in April 2016 revises about 200 margin calculations. Some program MOVs were found to have low margins, the valve/actuator upgrades will increase safety margin for these valves.

The business objective of this project is to have reliable MOVs particularly in special safety systems (SSS) and Safe Operating Envelop (SOE) systems so the risks can be minimized to: public safety, station personnel safety, environment, and nuclear safety. Replacing MOVs will improve reliability, reduce maintenance expenses and the potential for forced outages including the related risks of production losses.

Safe and reliable operation and performance of these valves play a key role in maintaining the three C's (Control, Cool and Contain) of Reactor Safety, as well, these valves are critical in maintaining proper pressure boundary.

Preferred Alternative:

Replace existing MOVs with new valve assemblies/actuators

For Project Level A, B or C

Description of Preferred Alternative

The existing 51 motor operated valves will be replaced/upgraded with improved design and materials following a full review of internal and external OPEX and maintenance history. The new valve assemblies will be field-proven with enhanced trim technology/materials and reliable actuators. All accessories will be mounted on the valve body with dedicated installation plate or supporting brackets. The new valves should meet and/or exceed existing functional and performance requirements and meet reliability requirement.

Detailed technical assessment of the new valves will be performed during detailed engineering phase and the type of new valves will be determined and selected. Considering the historical problems, criticality, maintenance/margin issues, full assembly/actuator replacements are recommended.

The desired outcome for this project is that MOVs will function as expected and achieve a high level of reliability with adequate safety margins.

Project #: 16-84551

Project Title: DN Motor Operated Valve (MOV) Replacements

Document #: D-BCS-04940-00002 R000

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Business Case Summary

Preferred Alternative:	Replace existing MOVs with new valve assemblies/actuators	For Project Level A, B or C
Description of Preferred Alternative		

Deliverables:	Associated Milestones (if any):	Target Date:
<i>Current release:</i>		
Valve Technical Specs/Data Sheets		Sep 2020
Engineering Assessment Report		Nov 2020
Complete Project and Design SOW Documents		Nov 2020
Preliminary PIR objectives and plan		Dec 2020
BCS Package for Gate-2A PMOC		Dec 2020
<i>Future release:</i>		
Preliminary Engineering of all valves		Sep 2021
Detailed Engineering of all valves		Oct 2022
Start of Installations (DNRU1 Valves)		Feb 2022
AFS - all valves (51)		Nov 2027
Project Close out		Dec 2028

Alternative 2:	Base Case – No Project
NOT RECOMMENDED	
The existing MOVs covered under the current project scope are obsolete, operating with low margin and are approaching end of life. Any management or operational improvements will not provide a long term solution. Obsolescence will remain a production and safety risk due to non-availability of spare parts in the near future. The maintenance costs associated with failures of these valves will increase over the period as further degradation occurs. Therefore, No Project is not a feasible alternative.	

Alternative 3:	Delay Work
NOT RECOMMENDED	
Most of the MOVs will require outages for the field work. The replacements are planned from 2022 and will be completed by 2027 to ensure safe and reliable continued operation of valves. Any project delay will negatively impact the replacement timetable and the project would miss the opportunity to replace the valves before the next planned outage maintenance window. The ongoing risk of the valves failing can cause multiple system impairments, disrupt the work management schedule with unplanned replacements/repairs, and potentially cause production losses due to forced outages. Therefore, delaying the project is not recommended.	

Project #: 16-84551

Project Title: DN Motor Operated Valve (MOV) Replacements

Document #: D-BCS-04940-00002 R000

OPG Confidential

OPG-FORM-0076-R006

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
Cost	There is a risk that the costs for the new valves and project effort could be under estimated due to the following technical reasons. Some valves in the project will require margin calculations and others may require seismic qualifications. The valves will have digital positioners which can impose mock up testing and cyber security requirements. New valves could be heavier leading to piping stress analysis and support modifications. Technical assessments for individual valves could be required to evaluate vibration and hunting issues. Also the legacy and discovery issues and currency fluctuations can increase the project costs.	Mitigate: - Review OPEX - Perform multiple constructability reviews - Determine maximum requirements during detailed design and installation planning - Price locking before material PO award or buy all valves castings at the time of first order - Complete detailed engineering well before execution	No	Medium
Schedule	There is a risk that the Refurb organization may reject inclusion of this project scope to refurb outages due to other high priority core refurb work and non-availability of resources. As most valves require outages for replacement and project has planned to utilize DNRU1 and DNRU4 refurb outages. Moreover, if detailed design and/or LLM procurement are delayed, valve replacements could be deferred to future outages further delaying in-service schedule for a number of years.	Mitigate: - Conduct meetings with refurb organization to insert scope in outage. - Change existing planned maintenance WOs to complete replacements - Monitor progress on design and LLM procurement during weekly routine meetings.	No	Medium
Schedule	There is a risk that expert design resources may not be available. It is because important design resources could be assigned to other high priority jobs during outages. Refurb design milestones could be missed causing delay in the Installation of the valves.	Mitigate: - Have firm commitments from design agency and monitor progress weekly - Arrange meetings without any delay to escalate any potential delays	No	Medium

Qualitative Factors
- Improvement in plant safety, production and equipment reliability - Reduction in maintenance burden - Improve work control schedule stability

Project #: 16-84551

Project Title: DN Motor Operated Valve (MOV) Replacements

Document #: D-BCS-04940-00002 R000

OPG Confidential

OPG-FORM-0076-R006

Business Case Summary

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?

Definitions and Acronyms
Cat ID – Catalogue ID POV – Power Operated Valve MOV- Motor Operated Valve IEE – Item Equivalency Evaluation NICR – Non-Identical Component Replacement MODs – Modifications LLM- Long Lead Materials TCD – Target Completion Date DNRU1- Darlington Nuclear Refurbishment – U1 OPEX – Operating Experience PO – Purchase Order WO – Work Order

Project #: 16-84551

Project Title: DN Motor Operated Valve (MOV) Replacements

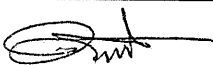
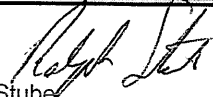
Document #: D-BCS-04940-00002 R000

Business Case Summary**APPENDICES**

Appendix A1: Summary of Estimate - Released to date										
Project Number:	16-84551									
Project Title:	DN Motor Operated Valve (MOV) Replacements									
\$K	LTD	2020	2021	2022	2023	2024	2025	Future	Total	%
Project Mgmt		283							283	26%
Inspection									-	0%
Engineering										
Procurement										
Construction										
Commissioning										
Closeout										
Subtotal	-									
Outside WBS										
Contingency										
Subtotal w/ Contingency	-									
Interest										
Other										
Total	-	1,091	-	-	-	-	-	-	1,091	100%

Appendix A2: Summary of Estimate – Notes			
Escalation Rate	2.5%	Interest Rate (going-forward)	4.25%

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	%
		To Be Determined prior to Execution Phase		0%
				0%
Total			-	0%

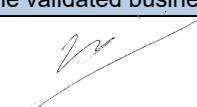
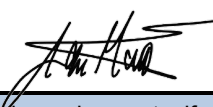
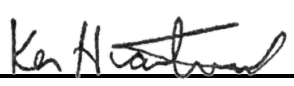
Prepared by:		Reviewed and Endorsed by:	
 Amjad Muhammad Project Manager Projects & Modifications		 Ralph Stube Section Manager Projects & Modifications	
Feb 13, 2020 Date		Feb 13, 2020 Date	

Business Case Summary

Project #	16-84799	Controlled Doc #	D-BCS-33120-0816870
Project Title	DN PHT Pump Rotor Inspect / Replace (RECL)		
Facility	Darlington NGS	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	OCT-2026

Recommendation
We recommend release of \$20,846k [REDACTED] of general contingency). This will bring the total released to date amount to \$31,418 K, including [REDACTED] of contingency. The estimated total project cost is \$89,210 K, including [REDACTED] of contingency ([REDACTED] of specific contingency and [REDACTED] of general contingency). If the specific contingency described below is required, the project team will seek its approval in a future BCS. This project is for the replacement of Primary Heat Transport (PHT) pump rotor components on one of four pumps in each of Units 3, 1, and 4. This release includes: procurement of three sets of PHT pump components (one for each of U3, U1 and U4), one additional set of construction materials for use if the station spare rotor is required, planning, installation and inspections of one PHT pump replacement for Unit 3 and partial planning for Unit 1. The estimate for this known scope is Class 3. However, this estimated total project cost includes both [REDACTED] of general contingency [REDACTED] released in this BCS), and [REDACTED] of specific contingency for the removal / installation of 3 additional pump rotor replacements, procurement of 4 additional sets of PHT pump components and the inventory cost of the station spare rotor. The specific contingency will be requested only if the inspections of the first pump on Unit 3 indicate additional pumps need component replacements. This document was prepared based on assumptions in the Business Plan, Generation Plan, and station work programs, and the current understanding of project schedule impacts 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	10,571								10,571
Current request	-	10,916	6,687	2,747	497	-	-	-	20,846
Total released to date	10,571	10,916	6,687	2,747	497	-	-	-	31,418
Future required	-	-	329	25,741	22,523	6,875	1,967	357	57,792
Total Project Cost	10,571	10,916	7,016	28,488	23,019	6,875	1,967	357	89,210
Ongoing Costs	-								
						Gate:	G3	OAR Approval:	\$89,210 K

Approvals	Signatures	Date
The recommendation represents the best option to meet the validated business need.		
Recommended by: Project Sponsor Dominique Miniere President, Nuclear		May 21, 2020
I concur with the business decision as documented in this BCS.		
Finance Approval: John Mauti CFO & SVP Finance		May 21, 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: Ken Hartwick President & CEO		May 22, 2020

Business Case Summary

EXECUTIVE SUMMARY – Project Overview

There are 4 Primary Heat Transport (PHT) pumps for each Darlington unit for a total of 16 PHT pumps for 4 Units. They were custom designed to suit the size of reactor at Darlington. This project will inspect and assess the condition of the PHT pumps across the station, and replace the PHT pump components as required, in order to maintain nuclear safety, and ensure long term reliability of Darlington.

One PHT pump was inspected on Unit 2 in February 2018. The Unit 2 inspection results assessment identified the need for 1 PHT pump per unit to be inspected and replaced in each of the other units (Unit 3, Unit 4 and Unit 1). These PHT pump replacements for Units 3, 1 and 4 are being executed under the life cycle management of the PHT pumps. The remaining pumps on Units 3/1/4 may also require replacement depending on the results of the planned inspections.

This release is to fund the following scope of work:

1. Long Lead Material (LLP) Procurement of PHT pump rotor components (rotor, cover and hydro bearing) for U3, U1, U4 to make sure 4 PHT pumps are ready for replacement in U3 if required
2. Removal of existing pump internals; on-site and off-site inspections; and installation of new pump internals for one pump in U3
3. Replacement of the degrading PHT alarm switches and neoprene cables with new XLPE cables in U3
4. Partial planning for Unit 1

Future releases for Gate 3B and 3C will request funding for installation costs for U1 and U4 respectively.

The current project status is as follows:

- Long lead materials are purchased, will be shipped starting in May 2020
- Vendor estimate and schedule for U3 have been reviewed and approved
- Vendor is working on detail assessing and construction planning for U3
- Alarm Switch cable replacement scope is to be assigned to the OPG maintenance

The preferred alternative is to schedule this work during the refurbishment outage windows, if lead times for materials, planning and execution of the work allow. Otherwise, the work would need to be completed in a non-standard post-refurbishment outages.

The top risk for this project is that additional PHT pump component replacements may be required as a result of the pump inspections. The worst case situation is that all 4 PHT pumps will require component replacements on all units, including Unit 2, which would require the acquisition of 12 sets of PHT pump components and associated construction cost. The probability of the worst case scenario is considered low. The base scope for this project requires funding for one set of PHT pump component replacements for each of U3, U1 and U4, and an additional set of construction materials for use if the station spare rotor is required to be installed. Since the pump components are long lead items (16 months lead time), the project will have 4 sets of PHT pump components on hand for Unit 3 installation. If scope remains limited to 1 pump per U1, 3 and 4, 3 sets of PHT pump components will be used by this project, and the additional unused construction materials will be added to inventory to support the station spare rotor at the end of the project. However, if inspection results of U3 PHT pump indicate that more pump replacements are required, specific contingency of [REDACTED] for up to 3 additional pump replacements, the inventory cost to use the station spare rotor, and for up to 4 sets of PHT pump components procurement will be included in a future release.

Business Need

For Project Level A or B

Around February 2018, the rotating element of PHT pump 2-33120-P3 was sent off-site, disassembled, and inspected by the Original Equipment Manufacturer (OEM). The inspection identified abnormal wear. This wear, while abnormal, was assessed to not have a significant impact on the pumps' performance and integrity for continued operation. It was also deemed to be bounding for all other PHT pumps based on historical performance data. The engineering assessment recommended a full inspection and replacement of one pump on each Unit. The Unit 3 inspection was included in the Darlington Integrated Implementation Plan (IIP). Additional pump inspections and replacements may be required depending on the results of the pump inspections. This project also includes the replacement of cables associated with PHT pump trip pressure switches, which included in Darlington IIP as well.

Business Case Summary

Preferred Alternative:	Replace and Inspect 1 PHT Pump for U3, U1 and U4	For Project Level A, B or C
Description of Preferred Alternative		
The preferred alternative is to replace the PHT pump rotor components on 1 of 4 pumps in each of Units 3, 1, and 4. The work should be scheduled during the refurbishment outage windows for these units, if lead times for materials, planning and execution of the work allow. Otherwise, the work would need to be completed in non-standard post-refurbishment outages. This release includes core scope materials to address one pump on U3, U1 & U4 and one additional set of construction materials (for use if the station spare rotor is required to be installed), planning for U3 and U1, and execution for one pump replacement in U3. In addition, the project includes replacement of the cables associated with PHT trip pressure switches and to perform any corrective maintenance for switch modules and pressure switches in all units. Inspections may reveal problems that would not be picked up by vibration or other condition monitoring. Obtaining wear rates & NDE (Non-destructive Examination) data of critical components would provide useful data to predict the equipment end of life. Although all units were placed into service over a short time span of approximately 3 years, specific operating conditions have varied from unit to unit, such as chemistry (pH excursions) or unit transients, which can lead to different degradation rates on each unit. Based on a review of the operating history of each pump through SCRs, COG reports, Work Reports, interviews with station personnel, and conditioning monitoring data, the pump that is most suspect of internal degradation from each Darlington unit will be inspected. As inspection information is accumulated, the results may support additional inspections and replacements in other pumps on a particular unit. Specific contingency has been included in the total project cost to replace the other 3 pumps in U3, cover the cost to use one inventory rotor, and procure 4 additional pump components sets for U1 (the long lead materials for the next unit). Additional pumps will only be replaced if the inspection from the first pump indicates that is necessary. Formal decision processes, e.g. EDM/SIM/PMOC (Engineering Decision Making / Senior Information Meeting / Project Management Oversight Committee), will be used to review any additional scope, and to release the specific contingency funding through a future BCS approval. This project is expected to have the following benefits: • Inspection and replacement of the pumps will identify areas of degradation and provide information on the likely state of the other PHT pumps • Repair and replacement activities can return the replaced pumps to a like-new condition, which will ensure their continued safe operation for the Darlington operating life with the applicable maintenance • Repair of the D2O leaks at the pump case gasket will reduce the burden on the D2O collection system and decrease the possibility of forced outages • Resolution of the cover gasket leak will also prevent worsening of the leak which could lead to more costly consequences at a later date (e.g. a forced outage) or more significant damage • If inspections results are favourable, the need to perform further pump inspections will decrease • Reduce the risk of possible pump leakage and the associated radiation hazard • Reduce the risk of severe pump vibrations and degraded seal operation		

Deliverables:	Associated Milestones (if any):	Target Date:
Current release for U3:		
1. Long Lead Material Procurement of PHT pump components for U3, U1, U4 and construction materials	Delivery of Material/Equipment to Site	2020NOV28
2. Removal of existing pump internals, on-site and off-site inspections; and, install of new pump internals for U3 PHT Pump (3-33120-P2)	Start of Execution Window Finish of Execution Window	2021JUL13 2021NOV02
3. Replace the degrading PHT alarm switches and neoprene cables with new XLPE cables for U3	Finish of Execution Window	2022JAN14
4. Engineering review and acceptance of the inspection reports, assess and confirm 2-33120-P3 to be the bounding case		2022JAN06

Business Case Summary

Deliverables:	Associated Milestones (if any):	Target Date:
<i>Future release for U1 and U4:</i>		
1. Removal of existing pump internals, on-site and off-site inspections; and, install of new pump internals for U1 PHT Pump (1-33120-P2)	Start of Execution Window Finish of Execution Window	2023JAN11 2023MAY03
2. Replace the degrading PHT alarm switches and neoprene cables with new XLPE cables for U1	Finish of Execution Window	2023JUN24
3. Engineering review and acceptance of the inspection reports, assess and confirm 2-33120-P3 to be the bounding case		2023MAY19
4. Removal of existing pump internals, on-site and off-site inspections; and, install of new pump internals for U4 PHT Pump	Start of Execution Window Finish of Execution Window	2024AUG13 2024DEC03
5. Replace the degrading PHT alarm switches and neoprene cables with new XLPE cables for U4	Finish of Execution Window	2024DEC10
6. Engineering review and acceptance of the inspection reports, assess and confirm 2-33120-P3 to be the bounding case		2025JAN21

Alternative 2:	Base Case – No Project	For Project Level A, B or Value-Enhancing
This alternative is not recommended. If no inspection and replacement are performed, the actual condition of the pump(s) will not be known. The consequences of a pump failure are high. In addition to significant lost production in the event of a failure, the cost of repair during a forced outage would be high. The condition of PHT pumps is unit specific depending on their operating history. Unexpected deterioration can only be determined by internal inspections. There is also a risk for pumps identified to have cover to case inter-gasket leaks. The two pumps that are currently leaking from the cover to gaskets need to be repaired that is required by IIP. The leaks could worsen and cause a forced outage.		

Alternative 3:	Execute During A Standard Planned Outage	For Project Level A or B or Value-Enhancing
This alternative is not recommended. Delay work will cause additional risks to operation. U3 Refurbishment outage is the earliest opportunity for pump replacement and inspection for U3. Moreover executing this project in the refurbishment outage reduces nuclear safety (NS) risks, simplifies inspection, work planning and construction requirements and needs lower cost. For U4, the work could be executed earlier if there is a need to advance the work earlier than the Refurbishment outage.		

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	Inspection results and engineering analysis on initial U3 PHT pump may show that replacement of the remaining three Unit 3 PHT pumps is required.	Mitigate: U3 PHT Pump inspection report and engineering assessment will be used to re-assess the risk. Specific contingency has been included for 3 additional pump replacements. Final TCD: APR-2022	Yes	Low	
Schedule	Vertical Flux Detector (VFD) Replacement project in the nearby area may run into high radiation contingency that causes the evacuation of the nearby working area. Or significant schedule delay on VFD Replacement project results in both projects need the crane at the same time.	Mitigate: • VFD project to mitigate the risk of high radiation exposure. • Optimize the schedule to avoid conflict on the crane use. Final TCD: NOV-2021	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
Schedule	After the OEM provides the PHT main pump inspection report, delays in decision making could affect the overall execution timing	Mitigate: Project and engineering to develop a decision making memo with all stakeholders to make sure a decision is made in time. Final TCD: DEC-2021	No	Low
Schedule	PHT main pump Foreign Material Exclusion (FME) inspection discovery and recovery work beyond expected time frame (2 weeks).	Accept: Procedures and training are in place to minimize the FME and to manage discovery and recovery work.	No	Low
Cost	The vendor may encounter the challenge to retain qualified skilled trades for this project. If new trades are hired, extra cost will be needed to train and qualify them.	Accept:	No	Low
Schedule	Leakage in the pumps may be found during the post-maintenance leak check, which would require immediate repair.	Accept: Procedures and training are in place to minimize the probability of leakage following maintenance.	No	Low

Financial Evaluation						For Project Level A, B (with multiple feasible alternatives) or Value-Enhancing
\$K	Preferred Alternative	Base Case (No Project)	Delay work			
Project Cost	\$89,210 K	N/A	N/A			
NPV						
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 reduce the future reliability risk since important condition information will be obtained from the PHT pump inspections. Potential failure mechanisms may be identified as part of these inspections. As a result, the condition of the PHT pumps can be assessed to ensure that long-term reliability and health and safety issues are addressed.	

Business Case Summary

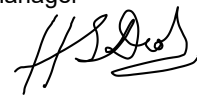
Post Implementation Review (PIR) Plan (refer to OPG-PROC-0056)				
Type of PIR Report	Simplified/Standard PIR		PIR Completion Date	OCT-2026
☐ Detailed PIR KPIs will be provided in future BCS(s) when Choose an item. Phase BCS release is requested.				
PIR KPIs	Current Baseline	Target Result	How to measure?	Who will measure?
Remaining case-to-cover gasket leakage is corrected.	Component Condition Assessment on Primary Heat Transport System Main Pumps (CCA-1148)	No flow identified from gasket leakage to PHT D2O Leakage Collection system during DNRU1 PHT system pressurization and post-DNRU1 operation.	Visual Inspection after the PHT system is pressurized.	Identified by Operations Confirmed by Component and Equipment Engineering
No signs of cracks or micro-cracks on the pump shaft or any other critical pump component for any pump inspections.	Component Condition Assessment on Primary Heat Transport System Main Pumps (CCA-1148)	No cracks are identified during rotating element assembly and pump casing inspection by NDE technique.	The pump rotating element will be inspected by the OEM and IRI to generate inspection reports. The reports will be reviewed and confirmed by engineering team.	Identified by NDE group (e.g. OEM, IRI) Confirmed by Component and Equipment Engineering

APPENDICES

Appendix A1: Summary of Estimate - Total Project Cost										
Project Number:	16-84799									
Project Title:	DN PHT Pump Rotor Inspect / Replace (RECL)									
\$K	LTD	2020	2021	2022	2023	2024	2025	Future	Total	%
Project Mgmt	54	616	1,469	1,927	1,685	1,050	605	195	7,603	9%
Inspection										
Engineering										
Procurement										
Construction										
Commissioning										
Closeout										
Subtotal										
Outside WBS										
General Contingency										
Specific Contingency										
Subtotal w/ Contingency										
Interest										
Other										
Total	10,571	10,916	7,016	28,488	23,019	6,875	1,967	357	89,210	100%
Removal Costs (incl. above)									-	0%

Appendix A2: Summary of Estimate – Notes			
Escalation Rate	2.5%	Interest Rate (going-forward)	4.33%

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	%
84799	4/15/2023	Unit 3 In-Service Date		33%
84799	7/15/2024	Unit 1 In-Service Date		27%
84799	1/15/2026	Unit 4 In-Service Date		40%
84799	10/15/2026	Project Close Out		0%
Total				100%

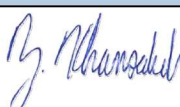
Prepared by:		Reviewed and Endorsed by:	
Jean Wang	May 6, 2020	Harsh Deol	May 6, 2020
Project Engineer	Date	Project Manager	Date
			

Business Case Summary

Project #	16-84939	Controlled Doc #	NK38-BCS-65821-10001
Project Title	DN Revenue Metering Transformer Replacement (Cap)		
Facility	Darlington NGS	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	OCT-2026

Recommendation
We recommend a release of \$978K, including [REDACTED] of contingency. This will bring the total released-to-date to \$978K. The estimated total project cost will be determined prior to the Execution Phase. This project will bring the Revenue Metering System into compliance with the Independent Electricity System Operator (IESO) Market Rules and Measurement Canada (MC) regulations as well as ensure continued reliable operation until station end of life. The scope includes replacing the revenue metering Current Transformers (CTs) and Capacitor Voltage Transformers (CVTs) at both the Main Output Transformer (MOT) and Station Service Transformer (SST). This release is to complete: • Preliminary Engineering • Technical Specifications • Detailed Design Scope of Work • Contracting Strategy for Engineering, Procurement and Construction • Project Definition Phase Gate 2 Package

Investment Cash Flows									
\$K	LTD	2020	2021	2022	2023	2024	2025	Future	Total
Previous releases									-
Current request	-	542	436						978
Total released to date	-	542	436	-	-	-	-	-	978
Future required	-		TBD	TBD	TBD	TBD	TBD	TBD	TBD
Total Project Cost									
Ongoing Costs	-								
					Gate:	G1	OAR Approval:	\$978 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		April 9, 2020
I concur with the business decision as documented in this BCS.		
Finance Approval: Brett Lemmon Finance Controller		April 11, 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		April 14, 2020

Business Case Summary

EXECUTIVE SUMMARY – Project Overview

This project is for the upgrade and replacement of the Darlington Nuclear Generating Station (DNGS) Revenue Metering System. The project goal is to bring the Revenue Metering System into compliance with the Independent Electricity System Operator (IESO) Market Rules and Measurement Canada (MC) regulations as well as to ensure continued reliable operation until station end of life.

The project scope includes replacing the revenue metering Current Transformers (CTs) and Capacitor Voltage Transformers (CVTs) at both the Main Output Transformer (MOT) and Station Service Transformer (SST).

The Project Implementation Strategy is as follows for Development Phase (Gate 1) Scope (this release):

- Complete Preliminary Engineering
- Technical Specifications
- Detailed Design Scope of Work
- Develop Contracting Strategy for Detailed Engineering, Procurement and Construction
- Develop Definition Phase BCS Package for next gate

The project implementation plan for the remaining phases will be determined for the Gate 2 Definition Phase.

The project has completed the Conceptual Design and the Value Engineering.

Business Need

For Project Level A or B

The Aging Management Program Component Condition Assessment of Darlington Switchyard Voltage Transformer recommended that the revenue metering CTs and CVTs should be upgraded at the next available opportunity due to the aging conditions of the components.

The Darlington Nuclear Generating Station (DNGS) Revenue Metering System is currently registered under significant exemptions from the Independent Electricity System Operator (IESO) Market Rules and Measurement Canada (MC) regulations since market opening in 2000. The SST CVTs and CTs are not to the correct accuracy and protection class and have non-compliant neutral connections. The MOT CVTs and CTs are not MC approved, do not meet the required accuracy and protection class and have a non-compliant electrical configuration. Recent revenue metering audits have reinforced the need to address these non-compliances and aging aspects of the equipment. To meet IESO's market rule requirements, DNGS must upgrade its revenue metering system. This will ensure accurate, reliable performance of the revenue metering system and prevent possible sanctions such as fines or loss of Market Participant status.

Preferred Alternative:

New Equip. – New Design (MOT/SST RM Inside SST Meter Shack) For Project Level A, B or C

Description of Preferred Alternative

To ensure overall reliability for life extension of the Revenue Metering System and to meet regulatory requirements the preferred alternative is to replace the metering equipment with IESO compliant revenue meters at the Main Output Transformers (MOT) and Station Service Transformers (SST). This includes the following activities:

- Remove and Install new free-standing CTs (x12) on the MOT line;
- Remove and Install new free-standing CVTs (x12) on the MOT line;
- Remove and Install new CTs (x12) on the SST line;
- Remove and Install new CVTs (x12) on the SST line;
- Procurement of CT (x2) and CVT (x2) project spares, with potential to use existing CTs/CVTs from Nanticoke GS for cost savings to OPG.

This recommended alternative will meet the commitment of OPG to comply with the IESO and MC standards/regulations and extend the life of the metering equipment to support the station to end of extended life.

The CTs and CVTs are identified long lead materials and have an estimated lead-time of about one year.

Deliverables:	Associated Milestones (if any):	Target Date:
<i>Current release:</i>		
Long Lead Material Identified	Long Lead Time Materials Identified (LLT)	15SEP2020
Preliminary Design Complete	Preliminary Design Completed (DES)	16DEC2020

Business Case Summary

Deliverables:	Associated Milestones (if any):	Target Date:
Gate 2 OAR Approval	Gate G2 Approval (GR2)	17MAY2021
<i>Future release:</i>		
Final AFS	Final Available for Service (AFS)	15JUN2025
Project Closeout	Closeout Completed (PCO)	01OCT2026

Alternative 1:	Base Case – No Project	For Project Level A, B or Value-Enhancing
If not replaced, there is an increased risk of sanctions and fines being imposed on OPG by the IESO and a potential for loss of Market Participant status. Further, this option does not address the aging condition of the equipment and components and does not support safe and reliable continued operation.		

Alternative 2:	Like-for-Like Replacement	For Project Level A or B or Value-Enhancing
Like-for-Like Replacement is feasible for reliability extension, however does not address regulatory non-compliance conditions. Like-for-Like Replacement is not considered to be a suitable solution.		

Alternative 3:	New Equip. – Substantially Same Design (HONI Cyber Secure)	For Project Level A or B
New equipment replacement is a feasible option, however maintaining device configuration and placement as per existing design, while resolving identified regulatory non-compliances, does not address required separation of OPG and Hydro One Networks Inc. (HONI) assets as per Transmission Connection Agreement (TCA). This is not considered to be a suitable solution.		

Key Risk Assessment					For Project Level A, B or C
Risk Class	Description of Risk	Response Type/ Actions/Final TCD	For Addition al Review	Residual Ranking	
Cost	Insufficient OPG/Vendor resources to support multiple activities and/or deliverables.	Mitigate: - Engage station & work management to ensure resource availability. - Vendor contractually required to retain adequate skilled resources.	No	Medium	
Cost	Change in outage schedule following workforce mobilization.	Mitigate: - Construction Scope of Work highlighted this risk to avoid idle charges from the vendor. During periods of inactivity on this project, the vendor will attempt to retain key skilled resources by assigning them to different projects that are in execution. - Project will attempt to scope into refurbishment outages where possible to minimize risk to the execution window	No	Medium	
Schedule	Future Risk: Work tasks are currently unscheduled for selected planned outages, potential for project scope to be rejected for future outage windows.	Mitigate: - Front-load procurement & design work packages in the project schedule to facilitate earliest available outage window. - Early scope injection.	No	Medium	
Schedule	Contract Issuance Delay which may impact available execution windows.	Mitigate: Early engagement of Supply Chain. Ensure awareness of OPG project schedule/milestone requirements through RFP process.	No	Medium	

Business Case Summary

Key Risk Assessment				For Project Level A, B or C
Risk Class	Description of Risk	Response Type/ Actions/Final TCD	For Addition al Review	Residual Ranking
Schedule	Long Lead Material Delayed due to manufacturer schedule push resulting in delay or missed outage windows.	Mitigate: Monthly meeting w Vendor and/or Supplier to track Purchase Order progress.	No	Medium
Schedule/Cost	COVID-19 impacts to field work management, skilled resource availability, and vendor supply chain.	Mitigate: 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.	No	Medium

Financial Evaluation						For Project Level A, B (with multiple feasible alternatives) or Value-Enhancing
\$K	Preferred Alternative	Base Case (No Project)	Like-for-Like	New Equipment		
Project Cost	TBD	N/A	N/A	N/A		
NPV						
Other: (e.g., IRR)						
Analysis of Financial Evaluation – Key Assumptions and Key Results:						
A Financial Evaluation is not required for Regulatory Projects.						

Post Implementation Review (PIR) Plan (refer to OPG-PROC-0056)				
Type of PIR Report	Simplified/Standard PIR	PIR Completion Date	OCT-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?

Business Case Summary

APPENDICES

Appendix A1: Summary of Estimate - Released to date										
Project Number:	84939									
Project Title:	DN Revenue Metering Transformer Replacement (Cap)									
\$K	LTD	2020	2021	2022	2023	2024	2025	Future	Total	%
Project Mgmt		127	76						203	21%
Inspection									-	0%
Engineering										
Procurement										
Construction										
Commissioning										
Closeout										
Subtotal										
Outside WBS										
Contingency										
Subtotal w/ Contingency										
Interest										
Other										
Total	-	542	436	-	-	-	-	-	978	100%
Removal Costs (incl. above)									-	0%

Appendix A2: Summary of Estimate – Notes			
Escalation Rate	2%		Interest Rate (going-forward) 4.25%

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	%
		TBD		0%
				0%
Total			-	0%

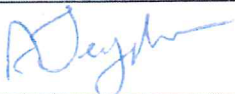
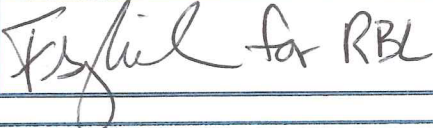
Prepared by:		Reviewed and Endorsed by:	
 Jeffrey Denomme/Teodora Tasic Projects & Modifications Project Manager 01-APR-2020 Date		 Venkat Parthasarathy Projects & Modifications Section Manager 01-APR-2020 Date	

Business Case Summary

Project #	13-83072	Controlled Doc #	P-BCS-36110-0709109 Rev 001
Project Title	Pickering Buried Boiler Blowdown Pipe Replacement		
Facility	Pickering	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 ☐ Choose an item. G2: ☐ Choose an item. G1: Choose an item. ☒ Full G3B: Execution		
Estimate Class (overall project)	Class 3	Target Project Completion Date	NOV-2020

Recommendation
We recommend a release of \$7,728K, including [REDACTED] of contingency. Specific contingency has been allocated to address further discovery issues and repair strategies for the thrust block and existing piping condition. The estimated total project cost is \$20,948 K, including total project contingency of [REDACTED]. The overall estimate has not increased since the previous release. This project will replace Buried Boiler Blowdown piping in Units 1,4,5,6 (Engineer, Procure, and Construct (EPC)). The project will also issue Temporary Modification (TMOD) Packages for Units 7, 8 (Engineering (E) Only).

Investment Cash Flows									
\$K	LTD	2019	2020	2021	2022	2023	2024	Future	Total
Previous releases	4,941	8,279							13,220
Current request	-	6,202	1,366	160					7,728
Total released to date	4,941	14,481	1,366	160	-	-	-	-	20,948
Future required	-	-							-
Total Project Cost	4,941	14,481	1,366	160	-	-	-	-	20,948
Ongoing Costs	-								
					Gate:	G3	OAR Approval:	\$20,948 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 Jey Alalasuntharam Manager, Components & Equipment		July 18, 2019
I concur with the business decision as documented in this BCS.		
Finance Approval: Louisa Kwan Director, Controllership (acting)		July 23, 2019
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: Randy Lockwood SVP, Pickering		July 26, 19

EXECUTIVE SUMMARY – Project Overview
The Buried Boiler Blowdown (BBD) carbon steel piping at Pickering Nuclear Generating Station (PNGS) will require replacement due to known degradation detected during recent inspections. The desired outcome is to maintain unit operation and address potential steam safety hazards. The benefit in replacing buried Boiler Blowdown piping is to reduce the risk of blowdown failures that can take the Units out of service for approximately 40 days for repairs, resulting in a generation loss of \$20 M per system failure. If buried Boiler Blowdown piping line failure occurs in multiple units, this could result in approximately >\$50M loss of generation revenue.

Project #: 13-83072

Project Title: Pickering Buried Boiler Blowdown Pipe Replacement

Document #: P-BCS-36110-0709109 Rev 001

Business Case Summary**EXECUTIVE SUMMARY – Project Overview**

The preferred alternative is to replace one of the two, 6 inch carbon steel buried Boiler Blowdown pipes in U1, U4, U5 and U6 between north and south pit along with concrete transite pipe at excavation location. The tie-in to merge 2 pipes into one will be completed up stream of north pit and splitting of pipe will be completed in south pit or down stream. Removal and replacement of the 6 inch piping will be carried out by having two open pits at the 45 degree pipe anchor, near the middle of the 260 feet pipe run, between the two open manholes at the reactor buildings and the screenhouses.

This release is to fund the following scope of work:

- Complete Construction of the final two units
- Complete the tie ins and AFS for all units

The following risks are currently known with an allocated cost to address them (with technical assumptions) of \$1,863K which has been accounted in total release above.

- 1) Repairs to U5/U6 damaged Thrust Block (\$1,346K).
- 2) Installation of U1 vent line to address possible water hammer issues post commissioning of newly installed pipe (\$346K).
- 3) U4 has a sink hole downstream of the south pit and there is a potential that more sink holes can develop (\$171K).

If the mitigation actions for these known issues are outside of the assumed technical boundaries further funding will be required.

History of scope and schedule changes:

The scope of the project has not changed between this release and the partial execution release from P-BCS-36110-0709109.

The current target in service date is NOV-2020 which has the final tie in must be performed during P2041. If there is opportunity to advance this date, the project will look to perform tie ins during unplanned outages.

Project is on schedule and is on budget:

Unit 1 excavation and pit to pit piping is complete as per schedule.

Unit 5/6 excavation started as per schedule and pit to pit piping installation is on track to be completed in 2019.

Unit 4 excavation and piping installation is on plan to be completed in 2019

Preferred Alternative: Push/Pull Pit-to-pit Pipe Replacement

For Project Level A, B or C

Description of Preferred Alternative

The preferred alternative is to replace one of the two, 6 inch carbon steel buried Boiler Blowdown pipes on units 1 and 4 and replace one of the two lines on units 5 and 6 reusing most of the existing transite pipe which is the outer concrete pipe. Removal and replacement of the 6 inch piping will be carried out by having two open pits at the 45 degree pipe anchor, near the middle of the 260 feet pipe run, between the two open manholes at the reactor buildings and the screenhouses.

The open pits will allow access to pull and cut out sections of the 6 inch pipe in 10-20 feet increments and install the new pipe by pushing and welding the pipe back into the existing transite pipe, without the need to excavate the total pipe run. A transite pipe repair contingency replacement plan may be required, in case of transite pipe damages found during construction. This method is deemed the most cost effective way to meet the stations needs from a safety and reduction of risk of lost revenue perspective.

For Units 7/8, the pipe is considered to be in better condition, it does not require replacement at this time. A TMOD will be designed to tie the two unit 7 or unit 8 lines together into one active line upstream of a leak if there is a pipe burst.

Pros: This method requires minimal excavation efforts, reducing impact on other station services and interfacing System Structure & Components. It is also the most cost effective manner to fix the degraded pipe condition.

Cons: Possibility of damage to existing transite pipe. The transite pipe, which contains asbestos in its existing configuration, would need to be handled with care during installation.

Project #: 13-83072

Project Title: Pickering Buried Boiler Blowdown Pipe Replacement

Document #: P-BCS-36110-0709109 Rev 001

Business Case Summary

Deliverables:	Associated Milestones (if any):	Target Date:
<i>Previous releases:</i>		
Completion of Preliminary Design Completion of Detailed Engineering for all 6 units Preparation of Execution partial Business Case Summary (BCS) and supporting documents for units 6, 1 & 8	Preliminary Design Detailed Engineering Partial Execution Release Business Case	2017-03-31 2017-11-30 2017-06-30
Completion of Detailed Design for all units	Detailed Design for all units	April – 2019
Completion of Planning and Assessing on all units	Planning and Assessing on all units	April – 2019
Completion of Procurement of long lead materials on all units	Procurement of long lead materials on all units	June – 2019
Completion of Construction for two units	Construction for two units	June – 2019
<i>Current release:</i>		
Complete Construction of the final two units excluding tie ins	Complete Construction of the final two units excluding tie ins	Dec – 2019
Complete the tie ins and AFS of Pickering A units	Complete the tie ins and AFS of Pickering A units	P2011 & P2041
Complete the tie ins and AFS of Pickering B units	Complete the tie ins and AFS of Pickering B units	Dec – 2019
Project Completion	Close Out	June – 2021

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 existing transite pipe and thrust block (TB) are damaged and condition of insulation is bad. This will add cost up and above the initial estimate as the plan is to re-use the existing transite pipe and thrust block with insulation in good condition.	Mitigate: Perform an inspection of the transite pipe to ensure that it is in good condition. Have contingency plan in place to replace transite pipe if required. Projects will provide oversight and work with the vendor to assess the condition of TB and insulation material to determine the path forward. Contingency has been allocated for this risk. Risk for TB will be presented to PMOC. Final TCD: [OCT-2019]	No	Medium
Physical/ Personnel Security	There is a risk that work is being carried out close to adjacent operating systems. Worker safety is at risk if there is some sort of pipe rupture or movement of the pipe during blowdowns.	Mitigate: The lines will be isolated when the workers are performing removal/installation of BBD piping. Contractor will do adequate planning to minimize worker exposure. Safe work plan and permit will be in place, work authorization will be obtained. Final TCD: [DEC-2020]	No	Low
Environment	There is a risk that dewatering of the pits could result in a spill to the environment. There is also a risk of tritiated soil which may need to be quarantined and removed from site.	Mitigate Evaluate risk during design phase. Have safe work plans including adding barriers for Worker Safety, Environmental Safety plans prepared and spill kits to be available. Contingency has been allocated for this	No	Medium

Project #: 13-83072

Project Title: Pickering Buried Boiler Blowdown Pipe Replacement

Document #: P-BCS-36110-0709109 Rev 001

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
		risk. Final TCD: [SEP-2019]		
Schedule	There is a risk that the outcome of Go or No Go assessment for the thermal hydraulic calculations results dictates that the current pipe supports cannot withstand the forces of blowing down both lines through a single line which requires reregistration with the TSSA adding additional project scope. Additionally this would require modifications to pipe supports to ensure they can handle blow down stresses.	Mitigate: Thermal Hydraulic (TH) analysis will be performed to confirm single line post installation can withstand the forces of blowdowns. TH analysis has been completed for Unit 1 which supports the single line configuration. This remains relevant to Units 4, 5, 6, 7 and 8. Contingency has been allocated for this risk. Final TCD: [SEP-2019]	No	Medium
Schedule	There is a risk that the heat tracing cables will get damaged while performing the tie-in work for the BBD pipelines. As a result an engineering modification would be required to replace the heat tracing cables.	Mitigate Test cables prior to removal to record as found conditions. Exercise caution while coiling back the heat tracing cables and reinstalling it. Test cables again after reinstallation. Final TCD: [OCT-2019]	No	Medium
Cost	There is a risk that a new vent line may be required in U1 due to known OPEX of water hammer. This would result in additional cost.	Mitigate Thermal Hydraulic (TH) analysis is completed for U1 with no issues found requiring a new vent line. P&M/OPS/Design will validate this during U1 commissioning. Contingency has been allocated for this risk. Risk will be presented to PMOC. Final TCD: [JUL-2019]	No	Medium

Type of PIR Report	Simplified/Standard PIR	PIR Completion Date	May-2021	
☐ Detailed PIR KPIs will be provided in future BCS(s) when Choose an item. Phase BCS release is requested.				
PIR KPIs	Current Baseline	Target Result	How to measure?	Who will measure?
Pipe failures in the newly installed Buried Boiler Blowdown piping.	Failure on U8 2013, and units 2 and 3 in the 1990s. Failure on unit 6 in 2017 resulting in TMOD EC 139038. Failure on Unit 4 in 2019.	Zero Pipe Failures in the newly installed pipe.	Through SCRs and System Health Reports	Performance Engineering/System Health Team

Project #: 13-83072

Project Title: Pickering Buried Boiler Blowdown Pipe Replacement

Document #: P-BCS-36110-0709109 Rev 001

Business Case Summary**APPENDICES**

Appendix A1: Summary of Estimate Choose an item.										
Project Number:	13-83072									
Project Title:	Buried Boiler Blowdown Pipe Replacement									
\$K	LTD	2019	2020	2021	2022	2023	2024	Future	Total	%
Project Mgmt	651	579	230	60					1,521	7%
Inspection									-	0%
Engineering										
Procurement										
Construction										
Commissioning										
Closeout										
Subtotal										
Outside WBS										
Contingency										
Subtotal w/ Contingency										
Interest										
Other										
Total	4,941	14,481	1,366	160	-	-	-	-	20,948	100%
Removal Costs (incl. above)									-	0%

Appendix A2: Summary of Estimate – Notes			
Escalation Rate	N/A	Interest Rate (going-forward)	4.35

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	%
83072	1/31/2020	First 2 units		50%
83072	12/31/2020	Last 2 units		49%
83072	6/30/2021	Project close out		1%
Total				100%

Prepared by:	Reviewed and Endorsed by:
Dany Awad / Kamran Malik PNGS Design Projects Project Engineer / Project Manager	Ahmed Smaili PNGS Design Project Section Manager
Date	Date

Appendix B: Total Project Estimate Variance Analysis (Only required when more than one Execution Phase BCS; delete table if not applicable)									
\$K	LTD	2019	2020	2021	2022	2023	2024	Future	Total
G3A EXEP	7,713	11,001	2,074	160					20,948
G3B EXEF	4,941	14,481	1,366	160					20,948
Total Project Estimate Variance Explanation (delete if not required)									
There is no change in the Total Project Cost.									

Type 2 Business Case Summary

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

Project Information			
Project #:	Project # 13-83088	Document #:	NA44-BCS-43120-00003
Project Title:	PA LP Feedwater Heat Exchangers Replacement		
Class:	☐ OM&A ☒ Capital ☐ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others:	Investment Type:	Sustaining
Phase:	Execution	Release:	Full
Facility:	Pickering	Target In-Service or Completion Date:	SEP-2018

Project Overview
We recommend Gate 3 approval and the release of \$9,351 k, including \$1,145 k of contingency. The estimated total project cost is \$23,529 k, including \$1,145 k of contingency. The quality of the estimate for this release is Class #2, and for the total project is Class #2. This release will fund the following scope of work: - Design documentation and package issued as required, for replacement of Heat Exchangers (HX), 4-43120-HX1A/B and HX2A/B. - Design close-out activities as required. - Procurement of Unit 4 LP Feedwater HXs - Unit 4 pre-requisite work including track installation and materials. <u>Unit 4 during P1841 outage:</u> - Replacement of asbestos insulation with non-asbestos insulation on 4-43120-HX2A/2B. - Removal of old equipment and installation of new equipment during the unit scheduled outage. - Commissioning of 4 new LP Feedwater HXs. History of BCS releases and project cost estimates: The total project cost is now estimated at \$23,529k, including \$1,145k of contingency, compared to \$19,389 k, including \$4,389 k of contingency in the previous release. The change is mainly due to significant design change for track system. Work completed thus far: - Technical Specifications (Rev #1) issued for the procurement of all Units (1 & 4) LP Feedwater HXs. - Preliminary assessment and walk downs completed by Plant Design Engineering, to determine the level of design effort required to support heat exchanger replacement, including piping configuration and floor loading. - Purchase Order has been issued for the procurement of 4 HXs (for Unit 1) based on the revised technical specification issued by Design. - Commitment to vendor to update the purchase order for balance 4 HXs (for Unit 4) after approval of next BCS. - Replacement of asbestos insulation with non-asbestos insulation for 4-41230-HX1A and 1B was completed during the P1641 outage. - Design documentation and package issued, for replacement of 1-43120-HX1A/B and HX2A/B. - Update of purchase order for procurement of balance of 4 HXs (for Unit 4). - Design close-out activities as required. <u>Unit 1 during P1711 Outage:</u> - Replacement of asbestos insulation with non-asbestos insulation on 1-43120-HX1A/1B and HX2A/2B. - Removal of old equipment and installation of new equipment during the unit scheduled outage. - Commissioning of 4 new LP Feedwater HXs.

Type 2 Business Case Summary

Project #: Project # 13-83088

Document #: NA44-BCS-43120-00003

Project Title: PA LP Feedwater Heat Exchangers Replacement, Full Execution Release

Project Overview

- The purchase order has been released for the procurement of HXs, based on the revised technical specification issued by Design. The replacement is with like for like equipment. The new equipment tube bundle material is unchanged as admiralty brass.

History of scope and schedule changes:

The previous approved release of BCS funding was \$ 14,178 k, including \$ 3,218 K of contingency. A PCRAF was submitted in November 2017 AISC to release the contingency funding of \$ 3,218 k to complete the Unit1 installation and advance the Unit 4 pre-requisite work.

The PCRAF addressed changes to the project budget and schedule due to a change in design for the installation of the track system for Unit 1. The pre-requisite work on Unit 4 needed to commence earlier than the original schedule due to the change in design.

The current target in-service date of SEP-2018 has not changed from the previous release.

Part A: Business Need

In December 2013 and January 2014, Pickering Units 1 and 4 Low Pressure Feedwater Heat Exchanger tube bundles were 100% inspected. The inspections confirmed previously suspected tube leaks and identified significant degradation of the tubes in general. The degradation mechanism is suspected to be chemical attack from ammonia as a by-product of hydrazine decomposition. It is recommended that new material is used to mitigate the decomposition mechanism.

As a result of the inspections, tubes were plugged based on allowable wall loss criteria. Additional tubes were plugged to "cage" adjacent breached tubes. The number of tubes plugged for each HX is approaching, or at the plugging limit normally identified for heat exchangers to maintain designed heat transfer capacity. Tube plugging, or isolation, of the affected HXs affects the heat balance of the unit and degrades cycle thermal efficiency, resulting in a decreased Megawatt (MW) output. Furthermore, increased plugging accelerates HX degradation and increases risk of HX unavailability which has the potential to result in extended forced unit outage.

Replacement of LP Feedwater HXs will ensure that MW output is maintained from a LP Feedwater perspective, improve equipment reliability and will minimize the on-going inspection program requirements.

The replacement of the heat exchangers must be weighed against potential Forced Unit Outage as a result of HX unavailability, MW losses incurred due to the plugged tubes, on-going inspection program requirements (inspections must remain on all HXs with known degradation), and on-going degradation associated with the "No Project" option, as per station management decision.

The following scenarios could be expected from the "No Project" option:

- Based on the current degradation levels and rate of degradation, an on-going inspection program of all LP Feedwater HXs would be required on a regular basis. Approximately 400 Hrs of station resources per unit are required for inspection only.
- Based on the results of the latest inspections, there is a significant risk that further leak will develop due to wall thinning, resulting in further plugging to or beyond current limits. This would have a negative impact on thermal efficiency and increase MW losses.
- Any additional plugging of tubes beyond the analyzed design limit may lead to increased vibration of the equipment which has the potential to affect the structural integrity of the component. If this design limit is reached, the HX would be declared unavailable and the bank would be isolated resulting in Unit de-rate. It is not recommended to operate the unit on a single bank for an extended period of time due to significantly increased risk of damage to the available heat exchangers. This would likely result in an extended forced outage for HX replacement.

The table below shows the current conditions of the LP Feedwater HXs for Unit 1 and Unit 4. Based on current design limits (15% plugging allowed), only 128 tubes are allowed to be plugged per HX.

Type 2 Business Case Summary

Project #: Project # 13-83088

Document #: NA44-BCS-43120-00003

Project Title: PA LP Feedwater Heat Exchangers Replacement, Full Execution Release

Part A: Business Need

Equipment	Tubes plugged
1-43120-HX1A	127
1-43120-HX1B	108
1-43120-HX2A	94
1-43120-HX2B	121
4-43120-HX1A	86
4-43120-HX1B	124
4-43120-HX2A	106
4-43120-HX2B	129

The rate of degradation has increased rapidly over the past inspections. In P1511 outage, HX1A and 1B were inspected and due to the observed degradation, the plugging increased by 78% and 29% respectively from the previous P1311 outage.

Part B: Preferred Alternative: Replacement of all LP Feedwater Heat Exchangers

Description of Preferred Alternative

The preferred alternative is to replace the entire heat exchangers with newly procured equipment. The new heat exchangers will be installed on both units during the scheduled outages.

The proposals received from vendors (against RFQ) for the supply of LP Feedwater HX units with stainless steel tubes were over dimensional in size. The over sized equipment could not be accommodated in to existing location. Kepner Tregoe (KT) Decision Analysis was initiated to select the tube material. The analysis indicated that use of brass material for the tube bundle is the optimum solution. The replacement is with like for like equipment. The new equipment tube bundle material is unchanged as admiralty brass.

Replacing the complete LP Feedwater Heat Exchangers in Units 1 & 4 will remove the uncertainty of continued operation and improve equipment reliability. Replacement will reduce the maintenance and inspection burden, with increased MW production and reduced risk of forced unit outages.

Pros:

- Improved equipment reliability.
- No Generation loss.
- Plugging evaluation is not required.
- Shorter vendor lead time compared to tube only replacement, which would require OPG to ship one old HX for reverse engineering, resulting in increased timelines.
- Vendor thermal guarantee is provided for complete heat exchanger replacement.

Cons:

- Expedited schedule for replacement.
- Significant resources required during replacement

Deliverables:	Associated Milestones (if any):	Target Date:
Design Requirements Identified	Issue Technical Specifications	Complete
Vendor assessment to manufacture new exchangers	Issue Purchase Order for Unit 1	Complete
Asbestos insulation removal on 2 LP Feedwater HXs in Unit 4	Complete asbestos insulation removal during P1641 Outage	Complete
Vendor assessment to manufacture new exchangers	Issue Purchase Order for Unit 4	Complete
Delivery of 4 LP Feedwater HXs for Unit 1	Procurement of equipment – U1	Complete

Type 2 Business Case Summary

Project #: Project # 13-83088

Document #: NA44-BCS-43120-00003

Project Title: PA LP Feedwater Heat Exchangers Replacement, Full Execution Release

Deliverables:	Associated Milestones (if any):	Target Date:
Installation and commissioning of 4 LP Feedwater HXs in Unit 1	P1711 Outage	Complete
Delivery of 4 LP Feedwater HXs for Unit 4	Procurement of equipment – U4	09-Feb-2018
Installation and commissioning of 4 LP Feedwater HXs in Unit 4	P1841 Outage	30-Sep -2018

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 – No Project – Do nothing

If the Project is not executed, complete Heat Exchanger inspections will be required every 30 month during planned unit outages and tubes will be plugged as required. If design plugging limits are reached, the HXs will be declared unavailable, which will impact unit operation and has the potential to result in extended unit outage.

Pros:

- None

Cons:

- Continued accelerated degradation, of tube material showing high rate of chemical attack. Tube bundles likely will not meet end of station life with increased plugging limit.
- Generation loss from high tube plugging and/or HX unavailability.
- Increased burden for required inspections. Approximately 400 Hrs of station resources per unit are required for inspection only.

Excess plugging may introduce system vibration, which would result in accelerated degradation and has the potential to compromise component structural integrity, resulting in HX unavailability and potentially extended unit outage.

Alternative 3: Delay Work – Targeted replacement when required

If the project is Delayed, inspections would continue every planned outage and tubes will be plugged as required until the HXs are replaced. Given the current number of tubes plugged and observed degradation rate over the past inspections, there is a significant risk that the upcoming inspections would result in plugging requirements beyond allowable limits, with the HX deemed unavailable.

Pros:

- None

Cons:

- Continued accelerated degradation, and tube material showing high rate of chemical attack.
- Increased maintenance and inspection burden until replacement, approximately 400 Hrs per unit.
- Generation loss from high tube plugging and/or HX unavailability.

Alternative 4: Replace Tube Bundles Only

The alternate option is for the replacement of tube bundles only (internal of heat exchanger) with like for like brass material. Replacing all tube bundles in the U1 & 4 LP Heaters will remove the uncertainty of continued component operation and will improve asset management of subsequent equipment.

Pros:

- Improved reliability.
- Complete replacement of tube bundles only will reduce overall project costs.

Cons:

- There is no design documentation for existing HXs and reverse engineering would be required.
- No confirmation that internal design of U2 HXs bundles is identical to U4 HXs.
- Additional resources to remove two HXs from Unit 2 for shipment to vendor to conduct reverse engineering.
- Transportation of old bundles to vendor facility required.
- Vendor does not provide thermal guarantee on the new bundles.

Type 2 Business Case Summary

Project #: Project # 13-83088

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Project Title: PA LP Feedwater Heat Exchangers Replacement, Full Execution Release

Alternative 4: Replace Tube Bundles Only

This option has uncertainties due to lack of design documentation, vendors not able to confirm / provide performance guarantee and lastly no significant saving in field construction work.

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

k\$	LTD	2017	2018	2019	2020	2021	2022	Future	Total
Currently Released	481	11,733	1,964						14,178
Requested Now	-		9,351						9,351
Future Required	-								
Total Project Cost	481	11,733	11,315						23,529
Ongoing Costs	-								
Grand Total	481	11,733	11,315						23,529
Estimate Class:	Class 2			Estimate at Completion:		\$22,384 k			
NPV:	N/A			OAR Approval Amount:		\$23,529 k			

Additional Information on Project Cash Flows (optional):

The contingency amount of \$3,218k included in the previous release was withdrawn by the project in response to the design scope change.

Part E: Financial Evaluation

k\$	Preferred Alternative	Base Case	Delay Work	Alternative 4	
Project Cost	23,529	NA	NA	NA	
NPV	NA	NA	NA	NA	
Other (e.g., IRR)	NA	NA	NA	NA	

Summary of Financial Model Key Assumptions or Key Findings:

Part F: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
Cost	There is a risk for track system design as incompetent and require changes during installation. There is a risk that alignment of nozzle between new equipment and existing piping will be a challenge and require more time.	U1 design OPEX had been incorporated in U4 design change. Secondly, the OPEX has been realized in the pre-requisite work for Unit 4, hence, the risk is reduced to minimum. The laser measurement is performed on the old equipment to mitigate the misalignment of nozzle location. OPEX from Unit 1 installation will be considered during installation.	Low	Low
Scope	There is a risk that additional scope may be required due to potential discovery issues during execution.	Team consisting of all key stakeholders reviewed the scope for replacement of LP Feedwater HXs. The OPEX from Unit 1 installation are incorporated into Design package. Multiple walk downs have been performed by the team and their inputs were incorporated into the current project estimates.	Low	Low
Schedule	The P014 Cranes may be unavailable to project team at critical execution	Coordination meetings will be conducted between all stakeholders	Medium	Medium

Type 2 Business Case Summary

Project #: Project # 13-83088

Document #: NA44-BCS-43120-00003

Project Title: PA LP Feedwater Heat Exchangers Replacement, Full Execution Release

Part F: Risk Assessment				
Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
	milestones due to insufficient planning and coordination before and during P1841 Outage, which may lead to schedule delays and increased cost.	related to P014 Crane usage during P1841 Outage to identify interferences, schedule overlaps, and mitigation plans. Everyday coordination meeting/discussion will be required during the execution period to avoid any delay to either Turbine crew or LP FW crew.		
Resources	There is a risk that insufficient resources are available to complete replacement of HXs in the outage window.	Contract staff is budgeted and issuance of Purchase Order (PO) will be expedited to secure qualified resources.	Low	Low
Quality/ Performance	There is a risk that vendor quality is poor for the equipment supplied.	Approved Supplier List (ASL) process is being followed. Proposed vendor is in approved ASL list and has previously supplied equipment to OPG. Components Engineering and Design will identify required tests, inspections and vendor oversight to mitigate risk.	Low	Low
Technical	There is a risk that heat exchanger will not meet performance requirements.	Technical Specification and performance data were provided to the vendor. Components Engineering and Design will identify required tests to ensure critical attributes are met.	Low	Low

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		SEP-2018	MAR-2019	
Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)
Thermal Performance	0.85 MW/hr Generation loss as a result of HX performance	No MW/hr Generation loss as a result of HX performance	Health Report	Performance Engineering

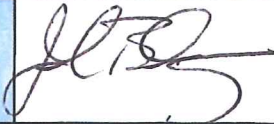
OPG Confidential
OPG-FORM-0075-R004

Type 2 Business Case Summary

Project #: Project # 13-83088

Document #: NA44-BCS-43120-00003

Project Title: PA LP Feedwater Heat Exchangers Replacement, Full Execution Release

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): Randy Lockwood SVP Pickering			Feb 9, 2018
I concur with the business decision as documented in this BCS.			
Finance Approval: John Blazanin VP Nuclear Finance per OPG-STD-0076			March 6 / 2018
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: Glenn Jager President OPG Nuclear & CNO per OAR 1.1			9 MAR 2018

Type 2 Business Case Summary

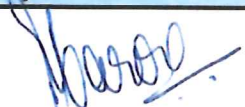
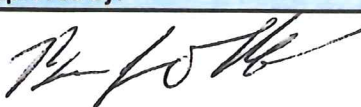
Project #: Project # 13-83088

Document #: NA44-BCS-43120-00003

Project Title: PA LP Feedwater Heat Exchangers Replacement, Full Execution Release

Appendix A: Summary of Estimate										
Project Number:	Project # 13-83088									
Project Title:	PA LP Feedwater Heat Exchangers Replacement									
k\$	LTD	2017	2018	2019	2020	2021	2022	Future	Total	%
OPG Project Management	32	58	100						190	1
OPG Engineering (including Design)	20	37	50						107	0
OPG Procured Materials		3,065	3,050						6,115	26
OPG Other	18	954	840						1,812	8
Design Contract(s)										
Construction Contract(s)	403	7,186	5,730						13,319	57
EPC Contract(s)										
Consultants										
Other Contracts/Costs										
Interest	8	433	400						841	4
Subtotal	481	11,733	10,170						22,384	95
Contingency			1,145						1,145	5
Total	481	11,733	11,315						23,529	100

Notes			
Project Start Date	AUG-2015	Total Definition cost (excludes unspent contingency for Nuclear)	\$1,400 k
Target In-Service (or AFS) Date	SEP-2018	Contingency included in this BCS (Nuclear only)	\$1,145 k
Target Completion Date	DEC-2018	Total contingency released plus contingency in this BCS (Nuclear only)	\$4,363 k
Escalation Rate	n/a	Total released plus this BCS without contingency (Nuclear only)	\$22,384 k
Interest Rate	4.9%	Total released plus this BCS with contingency (Nuclear only)	\$23,529 k
Removal Costs	\$1,000 k	Estimate at Completion (includes only spent contingency for Nuclear)	\$22,384 k

Prepared by:	Approved by:
 Rahul Arora MTL - MMOD Modification Team Leader	 Bruce Ottenbrite Senior Technical Advisor - MMOD Project Manager
FEB 06, 2018 Date	06 FEB 2018 Date

Type 2 Business Case Summary

Project #: Project # 13-83088

Document #: NA44-BCS-43120-00003

Project Title: PA LP Feedwater Heat Exchangers Replacement, 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
			2015	2016	2017	2018	2019	2020		
Definition & Execution	Superseding (from OM&A Project # 82939)	May 2016		1,580	9,717	8,092				19,389
Execution	Partial	Sept 2016		688	10,200	8,501				19,389
Execution	Full	Jan 2018		481	11,733	11,315				23,529

Project Variance Analysis					
k\$	LTD	Total Project		Variance	Comments
		Last BCS	This BCS		
OPG Project Management		249	190	-59	Reflects current requirements
OPG Engineering (including Design)		587	107	-480	Reflects current requirements
OPG Procured Materials		5,800	6,115	315	Additional material was required by the design change
OPG Other		360	1,812	1,452	Increased oversight by Field Engineering (FE) & Contract Management Office(CMO) required for the inspection of New HX equipment at vendor site and during field installation of new HX equipment
Design Contract(s)					
Construction Contract(s)		6,754	13,319	6,565	After Unit 1 installation OPEX, which reflects change in design for installation of the track system, the discovery issues and schedule delay due to field and unit conditions (such as human performance error, unit hydrazine leak and other station safety concerns)
EPC Contract(s)		-			
Consultants		-			
Other Contracts/Costs		400	0	-400	Included in the construction contract.
Interest		850	841	-9	
Subtotal		15,000	22,384	7,384	
Contingency		4,389	1,145	-3244	Total contingency included in the Partial Execution release BCS of \$3,218k was drawn down in 2017.
Total		19,389	23,529	4,140	

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 # 13-83668	Document #:	P-BCS-41110-00001
Project Title:	Pickering High Pressure Turbine Spares		
Class:	☐ OM&A ☐ Capital ☒ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others:	Investment Type:	Sustaining
Phase:	Execution	Release:	Full
Facility:	Pickering	Target In-Service or Completion Date:	2020-06-30

Project Overview
We recommend Gate 3 approval and the release of \$23,375 k, including \$2,125k of contingency. The estimated total project cost is \$23,375k, including \$2,125k of contingency. The quality of the estimate for this release is Class 3. 10% contingency is applied to purchase of components This release will fund the following scope of work: - Detailed Engineering for two new OEM supplied high pressure turbines - Supply and delivery of two high pressure turbines with 8MW improvement per turbine for contingency for P1971 and P1951 outages. <u>Gate Strategy:</u> This is a capital spare purchase directly from the OEM. The OEM will be performing the detailed design with some minor interface modifications, and design documentation acceptance will be performed by Pickering base plant design. Project Management Centre of Excellence has concurred to proceed directly to Gate 3. <u>Problem Statement/Business Need:</u> On November 10th, 2016 during P1671, routine 8-year High Pressure Turbine inspections, the OEM discovered stress corrosion cracks in the Unit 7 high pressure spindle body (P-2016-27993). The cracks were not repairable and it was advised to no longer operate the spindle. Of the six units in operation, two have confirmed cracks and will likely need to be replaced. It is expected that at least four units will eventually require replacement out of six units. Currently, the station has only two viable spares. Therefore, the station requires two additional spares. The lead time on new turbines is 12-16 months. Therefore, initiating a purchase now will minimize future operating risk to the station. The intention of this project is to initiate purchase of two spares with target delivery in time for installation into Unit 7 during the P1971 outage and Unit 5 during the P1951 outage, if required. The station needs to manage production risks while allowing flexibility depending on the findings of upcoming high pressure turbine inspections.

Type 3 Business Case Summary

Project #: Project # 13-83668

Document #: P-BCS-41110-00001

Project Title: Pickering High Pressure Turbine Spares, Full Execution Release

Project Overview

Summary of Preferred Alternative:

The preferred option is to purchase two spare upgraded high pressure turbine modules. The upgrade would result in 8MW per unit of additional production.

The alternatives reviewed are as follows:

1. Purchase two Upgraded High Pressure Turbine Module that offer 8 MW per unit improvement (Preferred Alternative)
2. Base Case – Status Quo
3. Purchase two Identical Spindles (Like for Like) with improved blade design which offer 2 MW per unit improvement
4. Purchase only single Upgraded High Pressure Turbine Module

The primary driver for this project is to sustain the plant operation until 2024. As described above, this capital expenditure is required based on the technical condition of the existing equipment. However, based on the difference in upfront cost and remaining life of operation, the purchase of two upgraded High Pressure turbines is more economic than purchasing two like for like spares. Upgraded turbines will provide potential additional power output and revenue. Purchasing two spares addresses the risk of having cracked turbine spindles resulting in major forced outages on an in-service unit and the associated production losses.

The downside of the upgraded High Pressure Turbine is the potential for incurring cancellation costs if some assumptions prove incorrect (i.e. all remaining spindles are clear of cracks). The cancellation cost is dependent on what stage in the design-manufacturing process the project sits at time of cancellation. Based on the inspection schedule of the units; the assumptions made should be proven prior to incurring any major cancellation fees.

This project is emergent and therefore is not included in the capital project portfolio.

Key background Information/assumptions used to support BCS:

- The OM&A costs for the refurbishing of the current spares (3911A/3885A) are required to mitigate the possibility of an immediate plant shutdown. These costs are not included in this BCS.
- Unit 1 and Unit 4 are currently clear of any indication of cracks and therefore should not require replacement. However, if future inspections indicate that Unit 1 and Unit 4 turbines require replacement, then additional spares may need to be purchased.
- The MW increase for an upgraded module is assumed to be 8MW.
- The financial evaluation assumes System Economic Values provided by Corporate Finance and the projected capacity factors of Unit 7 and Unit 5.

Conclusions:

Based on the inspections to date, it is highly probable that Pickering will have four out of six HP turbines in operation with cracks. The initial inspections are scheduled to be completed by March 2018. The station currently has two spares. Therefore, it is prudent that the station purchase two additional spares to sustain future operation.

This release will be used to secure OPG a place in the OEM supply chain in order to ensure delivery within the timeframe for installation into Unit 7 during the P1971 outage and Unit 5 during the P1951 outage, if required.

Type 3 Business Case Summary

Project #: Project # 13-83668

Document #: P-BCS-41110-00001

Project Title: Pickering High Pressure Turbine Spares, Full Execution Release

Project Cash Flows, NPV, and OAR Approval Amount						
k\$	LTD	2017	2018	2019	2020	Total
Currently Released	0					
Requested Now		1,650	3,300	8,250	10,175	23,375
Future Required						
Total Project Cost	0	1,650	3,300	8,250	10,175	23,375
Ongoing Costs						
Grand Total	0	1,650	3,300	8,250	10,175	23,375
Estimate Class:	Class 3			Estimate at Completion:	23,375	
NPV:	-2,284			OAR Approval Amount:	23,375	
Additional Information on Project Cash Flows (optional):						
The project cash flows are based on budget quality estimates and project milestones provided by the OEM.						
The negative NPV is the outcome a least cost analysis and includes the cost of the spare turbines and benefits of additional production if they are installed. The preferred alternative has an NPV that is 7,778 k\$ higher than a like for like replacement.						

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 Nuclear President and CNO			3 Nov 2017
I concur with the business decision as documented in this BCS.			
Finance Approval: Ken Hartwick CFO and SVP Finance per OPG-STD-0076			Nov 16/17
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 and CEO per OAR 1.2			

Type 3 Business Case Summary

Project #: Project # 13-83668

Document #: P-BCS-41110-00001

Project Title: Pickering High Pressure Turbine Spares, Full Execution Release

Business Case Summary

Part A: Business Need

On November 10th, 2016 during P1671, routine 8-year High Pressure Turbine inspections, the OEM discovered stress corrosion cracks in the Unit 7 High Pressure spindle body (P-2016-27993). The cracks were not repairable, and OEM recommended that it was no longer advisable to operate the spindle.

Of the six units in operation, two have confirmed cracks and will likely need to be replaced. It is expected that at least four units will eventually require replacement out of six units. Currently, the station has only two viable spares. Therefore, the station requires two additional spares.

The intention of this project is to initiate purchase of two spares with delivery that will allow installation into Unit 7 in 2019 (P1971) and Unit 5 in 2019 (P1951) if required. The lead time on new turbines is 12-16 months. Therefore, initiating a purchase now will mitigate the operating risk to the station.

Part B: Preferred Alternative: Two Upgraded Modules with 8MW gain delivered by 2019

Description of Preferred Alternative

The preferred alternative is to purchase of two spare upgraded high pressure turbine modules that will generate 8MW of additional production per unit. The lead time for new turbines is approximately 14 months. Therefore, initiating a purchase now will minimize future operating risk to the station. The intention of this project is to initiate purchase of two spares with target delivery in time for installation into Unit 7 and Unit 5 during the P1971 and P1951 outages, if required. This alternative allows OPG to minimize station risk while also providing the station with the potential for increased revenue for operations from 2019 to 2024.

This release will fund the following scope of work:

- Detailed Engineering for two new OEM supplied high pressure turbines
- Supply and delivery of two high pressure turbines with 8MW improvement per turbine for contingency for P1971 and P1951 outages.

The purchase contract with the OEM will include options to cancel based on the percentage of work completed to date. These options will allow OPG to stop work on the spares in the case future turbine inspections show favourable results. The cancellation terms will be developed as the formal quotation and terms are developed.

Pros:

- Allows OPG to effectively manage risk to station by 2019.
- Provides OPG with a potential upgrade opportunity potential of the 8MW per unit and additional revenue during 2019-2024 time period.

Cons:

- Exposes OPG to cancellation costs if future Pickering HP turbine inspections are all favourable requiring no additional spares.
- Some design work will be required to accommodate the new upgraded design. It is anticipated that only minor modifications to the existing equipment will be required.

Deliverables:	Associated Milestones (if any):	Target Date:
OEM Design Complete		October 20, 2017
Begin Ordering Material		October 23, 2017
Delivery of 1 st HP Spindle		December 20, 2018

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

Type 3 Business Case Summary

Project #: Project # 13-83668

Document #: P-BCS-41110-00001

Project Title: Pickering High Pressure Turbine Spares, Full Execution Release

Deliverables:	Associated Milestones (if any):	Target Date:
Delivery of 2 nd HP Spindle		August, 15, 2019
Project Close Out		June 30, 2020

Part C: Other Alternatives

Alternative 2: Base Case – Status Quo

Spares 3911A/3885A enter service into Unit 7 and Unit 6. Unit 5 and Unit 8 require 2.5-year inspections @\$132k per inspection to cover additional required resources for disassembly. Unit 1 and Unit 4 are assumed clear of cracking.

The status quo will require OPG to manage the cracks through inspections every 2.5 years. A major turbine disassembly normally occurs every 8-10 years on high pressure turbines. The resource requirement to undertake additional inspections will displace from other major turbine work that will be necessary on those units (e.g. generator rotor swap, and low pressure turbine inspections). Mechanical Maintenance turbine resources will be impacted.

This alternative is not recommended because it does not address the risk of operating with cracked spindles. The base case includes two critical assumptions: (1) that Units 1 and 4 are clear of any cracking, and (2) the growth rate of the cracks on the Pickering B units can be managed within the 2.5 years without exceeding critical thresholds. These are two assumptions cannot be validated until Units 1 and 4 are inspected during P1711 and P1841 outages, and multiple inspections are done on affected units to understand the cracking growth rates. If either of these two assumptions are wrong, then new spares will certainly be required to manage the risk.

Pros:

- No capital expenditures
- No additional engineering modifications

Cons:

- Does not fully address risks of operating turbines with known cracks. The risks are currently unquantified. The units have not been fully inspected and the crack growth rate is undetermined.
- Resource intensive during outages for Mechanical Maintenance and IMS resources
- Waiting for inspection results to determine growth rates, based on the long lead time of materials, may result in the worst case scenario of having no viable spares for units that require replacement.

Alternative 3: Purchase two identical spindles with 2MW efficiency gain

This alternative includes the purchase two identical spindles (like for like) as those currently in use, except with an improved blade design which may offer a 2 MW per unit capacity improvement. This alternative offers an existing and proven design, reduced lead time, and somewhat lower costs relative to the preferred alternative. However, this spindle design has not been produced since the 1980s, and therefore also includes some manufacturing risks, which would result in schedule delays.

This alternative is not recommended since the purchase of two upgraded turbines is more economic than purchasing two like for like spares. The financial evaluation shows that, over the remaining life of the station, the value of potential additional production of an upgrade is significantly more than the difference in upfront costs.

Pros

- Offers a proven like for like replacement.
- Marginal MW gain
- Shorter lead time than other upgrade alternatives
- No additional engineering modifications

Cons

Type 3 Business Case Summary

Project #: Project # 13-83668

Document #: P-BCS-41110-00001

Project Title: Pickering High Pressure Turbine Spares, Full Execution Release

Alternative 3: Purchase two identical spindles with 2MW efficiency gain

- Up front capital cost and marginal MW increase does not provide as significant a financial benefit
- Has not been constructed since the 1980s. Knowledgeable people in the design and assembly process are no longer available. There is OPEX from original assembly documents that describe assembly failures requiring re-work, scrap and schedule delays.

Alternative 4: Purchase only one upgraded spare

This alternative includes purchasing only a single upgraded High Pressure Turbine Module as compared to two spares in the preferred alternative. This alternative was considered for primarily for financial reasons, for example, where two spares could not be funded due to budget constraints. However, this is not recommended since it will not fully address the risks of operating with cracked spindles.

Pros:

- Reduces the capital expenditure when compared to the preferred alternative

Cons:

- If all assumptions (cracks exist in uninspected units) are valid will not eliminate risk to station

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

k\$	LTD	2017	2018	2019	2020	Total
Currently Released	0					0
Requested Now		1,650	3,300	8,250	10,175	23,375
Future Required						0
Total Project Cost	0	1,650	3,300	8,250	10,175	23,375
Ongoing Costs						
Grand Total						23,375
Estimate Class:	Class 3			Estimate at Completion:		23,375
NPV:	-2,284			OAR Approval Amount:		23,375

Additional Information on Project Cash Flows (optional):

The project cash flows are based on budget quality estimates and project milestones provided by the OEM.

Part E: Financial Evaluation

k\$	Preferred Alternative – 2 Upgraded Spares	Base Case – Status Quo	2 Like For Like Spares	Single Upgraded Spare	
Project Cost	23,375	0	17,973	12,650	
NPV	-2,284	N/A	-10,072	N/A	
Other (e.g. IRR)					

Type 3 Business Case Summary

Project #: Project # 13-83668

Document #: P-BCS-41110-00001

Project Title: Pickering High Pressure Turbine Spares, Full Execution Release

Summary of Financial Model Key Assumptions or Key Findings:

The negative NPV is the outcome a least cost analysis and includes the cost of the spare turbines and benefits of additional production if they are installed. The preferred alternative has an NPV that is 7,778 k\$ higher than a like for like replacement.

The key assumptions for the financial analysis are as follows:

- The assumed MW gain for upgraded HP Module is 8 MW (Preferred Alternative). Currently, Preliminary Engineering is taking place under Pickering base OM&A. When the formal proposal is issued it is expected that 8MW or greater will be guaranteed as the OEM has full control over spindle and cylinder design and manufacture.
- The cost per upgraded HP module is based on pricing provided by OEM on August 10, 2017. The financial evaluation assumes price \$11,500k per HP module or \$10,625k if two are purchased. A 10% contingency has been applied to the purchase price.
- The Base Case (Status Quo) assumes Unit 5 and Unit 8 require re-inspection every 2.5 years until end of life with an incremental OM&A cost of \$132k per inspection. However, it does not consider the possibility of forced outages due to failure of the turbine.
- The assumed MW gain for an identical spindle is 2MW (Alternative 3). This will be validated by the OEM if the alternative is considered further. This optimistic estimate is expected to be lower as the OEM cannot control the clearances of the equipment currently in operation. A lower MW gain would reduce the NPV for this alternative.
- The costs to refurbish the existing spares (3911A/3885A) apply equally to all alternatives. Therefore, they have not been included in the financial evaluation.

Part F: Qualitative Factors

Purchasing two upgraded High Pressure Turbine Modules addresses the risk of having turbine spindles fail on an in-service unit resulting in a lengthy unit outage, associated production losses, and potential reputational damage to OPG.

It is prudent for OPG to establish a position in the OEM supply chain and cancel the order if necessary if the future inspections do not validate the expected condition of the turbines.

Part G: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
Cost	There is a risk that that project costs could be higher than assumed for the preferred alternative	The estimate is based on OEM budget quality quotations. Class 3 estimates allow up to 30% deviation. A 10% contingency was applied to purchase price.	Low	Medium
Scope	There is a risk that inspections are favourable on all units and no additional spares are required	The purchase agreement will include cancellation penalties that will minimize OPG's financial risk	Low	Medium
Schedule	There is a risk that delivery does not meet 2019 outage schedule	The purchase agreement will include milestone dates that must met by vendor. Penalty and exit terms will be included in the agreement.	Low	Medium
Resources	There is currently no team in place to manage such a large complex purchase	Engaging base resources (Minor Modifications) to support project	Medium	Medium
Quality/ Performance	There is a risk that the upgraded turbines do not deliver the expected performance.	The terms and conditions have not been finalized at this time. However, it is expected that these deliverables will be included in the purchase contract. Warranty clauses will also be included.	Low	Low

Type 3 Business Case Summary

Project #: Project # 13-83668

Document #: P-BCS-41110-00001

Project Title: Pickering High Pressure Turbine Spares, Full Execution Release

Part G: Risk Assessment				
Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
Technical	There is a risk that the preliminary engineering requires substantial plant interface changes to accommodate new design	This will be determined prior to issuing a PO to the OEM for purchase through preliminary Engineering already underway. If any changes are required, then the costs will be re-evaluated and a BCS re-submitted. However, based on the OPEX from Point Lepreau, it is not expected any changes will be required.	Low	High
Additional Risk Analysis:				
N/A				

Part H: Post Implementation Review (PIR) Plan				
Type of PIR Report		Target In-Service or Completion Date	Target PIR Completion Date	
Simplified PIR		2020-02-25	2020-06-30	
Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)
Gross Megawatt (MW) Output as measured by station gross MW output meter will be monitored over time to assess bulk MW increase	540MW	548MW	Based on Station output meters	Performance Engineering

Part I: Definitions and Acronyms	
PO – Purchase Order OEM – Original Equipment Manufacturer HP – High Pressure MW – Mega Watts IMS – Inspection Maintenance Services	

Type 3 Business Case Summary

Project #: Project # 13-83668

Document #: P-BCS-41110-00001

Project Title: Pickering High Pressure Turbine Spares, Full Execution Release

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Type 3 Business Case Summary

Project #: Project # 13-83668

Document #: P-BCS-41110-00001

Project Title: Pickering High Pressure Turbine Spares, Full Execution Release

For Internal Project Cost Control

Type 3 Business Case Summary

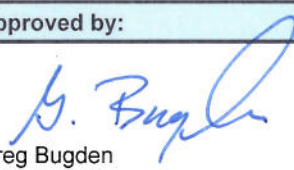
Project #: Project # 13-83668

Document #: P-BCS-41110-00001

Project Title: Pickering High Pressure Turbine Spares, Full Execution Release

Appendix A: Summary of Estimate						
Project Number:	Project # 13-83668					
Project Title:	Pickering High Pressure Turbine Spares					
k\$	2017	2018	2019	2020	Total	%
OPG Project Management						
OPG Engineering (including Design)						
OPG Procured Materials	1,500	3,000	7,500	9,250	21,250	90%
OPG Other						
Design Contract(s)						
Construction Contract(s)						
EPC Contract(s)						
Consultants						
Other Contracts/Costs						
Interest						
Subtotal	1,500	3,000	7,500	9,250	21,250	90%
Contingency	150	300	750	925	2,125	10%
Total	1,650	3,300	8,250	10175	23,375	100%

Notes			
Project Start Date	August 24, 2017	Total Definition cost (excludes unspent contingency for Nuclear)	\$0K
Target In-Service (or AFS) Date	June 2019 (1 st Unit) Feb. 2020 (2 nd Unit)	Contingency included in this BCS (Nuclear only)	\$2,125K
Target Completion Date	June 2020	Total contingency released plus contingency in this BCS (Nuclear only)	\$2,125K
Escalation Rate	2.9%	Total released plus this BCS without contingency (Nuclear only)	\$21,250K
Interest Rate	N/A	Total released plus this BCS with contingency (Nuclear only)	\$23,375K
Removal Costs	N/A	Estimate at Completion (includes only spent contingency for Nuclear)	\$21,250K

Prepared by:	Approved by:
 John Fagan Station Engineering, Pickering Date 2017-10-10	 Greg Bugden Manager, Performance Engineering Project Sponsor/Manager Date 2017-10-10

Type 3 Business Case Summary

Project #: Project # 13-83668

Document #: P-BCS-41110-00001

Project Title: Pickering High Pressure Turbine Spares, 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 Choose an item. (by year including contingency)						Future	Total Project Estimate
			2017	2018	2019	2020	2021	2022		
Execution	Full	Sept. 2017	1,650	3,300	8,250	10,175				23,375

Project Variance Analysis					
k\$	LTD	Total Project		Variance	Comments
		Last BCS	This BCS		
OPG Project Management					
OPG Engineering (including Design)					
OPG Procured Materials			21,250		This BCS represents the first funding request.
OPG Other					
Design Contract(s)					
Construction Contract(s)					
EPC Contract(s)					
Consultants					
Other Contracts/Costs					
Interest					
Subtotal			21,250		
Contingency			2,125		
Total			23,375		

Type 3 Business Case Summary

Project #: Project # 13-83668

Document #: P-BCS-41110-00001

Project Title: Pickering High Pressure Turbine Spares, Full Execution Release

Appendix C: Financial Evaluation Assumptions

Key assumptions used in the financial model of the Project are:

The key assumptions for the financial analysis are as follows:

- The project cash flows are based on budget quality estimates and project milestones provided by the OEM.
- The costs to refurbish the existing spares (3911A/3885A) apply equally to every alternative. Therefore, they have not been included in the financial evaluation.
- It has been assumed that Unit 1 and Unit 4 are currently clear of any indication of cracks and therefore should not require replacement. However, if future inspections indicate that Unit 1 and Unit 4 turbines require replacement, then additional spares may need to be purchased.
- The assumed MW gain for an upgraded high pressure Module is assumed to be 8 MW (Preferred Alternative). Preliminary Engineering is currently taking place. When the formal proposal is issued it is expected that 8MW or greater will be guaranteed as the OEM has full control over spindle and cylinder design and manufacture.
- The cost per upgraded high pressure module is based on pricing provided by OEM on August 10, 2017. The financial evaluation assumes price \$11,500k per HP module or \$10,625k if two are purchased. A 10% contingency has been applied to the purchase price.
- The Base Case (Status Quo) alternative assumes Unit 5 and Unit 8 require re-inspection every 2.5 years until end of life with an incremental OM&A cost of \$132k per inspection. However, the alternative does not consider the possibility of forced outages due to failure of the turbine.
- The assumed MW gain for an identical spindle is 2MW (Alternative 3). This will be validated by the OEM if the alternative is considered further. This optimistic estimate is expected to be lower as the OEM cannot control the clearances of the equipment currently in operation. A lower MW gain would reduce the NPV for this alternative.
- The financial evaluation assumes System Economic Values provided by Corporate Finance and the projected capacity factors of Unit 7 and Unit 5.

Appendix D: References

SF171127497 "PNGS HP Modernization Proposal" rev 1

Type 3 Business Case Summary

Project #: Project # 13-83668

Document #: P-BCS-41110-00001

Project Title: Pickering High Pressure Turbine Spares, Full Execution Release

Business Case Summary

Project #	83039	Controlled Doc #	N-BCS-30540-0764598
Project Title	Rapid Delivery Machine (RDM)		
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 ☒ Superseding G2: Definition ☐ Choose an item. G1: Choose an item. ☐ Choose an item. G3: Execution		
Estimate Class (overall project)	Class 4	Target Project Completion Date	DEC-2025

Recommendation
We recommend an additional release of \$15.7 M. This will bring the total released-to-date to \$108.0 M including [REDACTED] of contingency. The estimated total project cost is \$160.4 M, including [REDACTED] of contingency. The purpose of this Superseding Business Case is to document the removal of the Pickering RDM scope from the project, and to establish a new cost and schedule baseline for the Rapid Delivery Machine project at Darlington only. The removal of the Pickering RDM scope was approved by the Board of Directors on November 13, 2019, along with the delegation of subsequent approvals within the Board approved envelop of \$162.2M. The Pickering RDM was eliminated due to an unachievable development schedule. The Pickering RDM scope was classified as a value enhancing investment. With its removal, the Darlington scope is classified as sustaining, and is targeted to be available for the first required inspections post refurbishment in 2025. This release will continue detailed engineering for the Darlington RDM. The project is continuing within the Board approved envelope of \$162.2M, with subsequent approvals delegated to the President, Nuclear as per the Organizational Authority Register, Element 1.1.

Investment Cash Flows									
\$K	LTD	2019	2020	2021	2022	2023	2024	Future	Total
Previous + Current release	33,895	12,659	30,603	19,327	9,206	1,658	293	360	108,001
Total released to date	33,895	12,659	30,603	19,327	9,206	1,658	293	360	108,001
Future required	-	-	1,522	24,092	13,605	4,630	2,435	6,122	52,407
Total Project Cost	33,895	12,659	32,124	43,420	22,811	6,288	2,728	6,483	160,408
Ongoing Costs	-								
						Gate: G3	OAR Approval:	\$162,200 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 Subo Sinnathamby VP, Inspection & Reactor Innovation		Dec 10, 2019
I concur with the business decision as documented in this BCS.		
Finance Approval: Vice President Controllershship		10 December 2019
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: Dominique Miniere President Nuclear		11 December 2019

EXECUTIVE SUMMARY – Project Overview

The Rapid Delivery Machine project is required to maintain the capability to perform the required fuel channel inspections for the years of operation at Darlington post-refurbishment.

At Darlington, Fuel Channel (FC) inspections are currently performed using aging Channel Inspection and Gauging Apparatus (CIGAR). CIGAR use requires a Fuel Handling (F/H) Trolley for the duration of the inspection. Scrape samples collected from pressure tubes require the use of manual tool sets and installation of ice plugs. The RDM will provide a delivery platform designed with the latest available industry standard automated tooling to allow for safe and reliable fuel channel inspections to meet code and licensing requirements for the next 30 years. Additionally, the delivery machine technology will accommodate new tooling technology for performing machined delivered scrape to yield enhanced radiological protection by removing requirements for ice plugging used in manual scrape campaigns, reducing personnel radiation exposure, and addressing equipment obsolescence.

This project is required to meet DNGS post refurbishments targets for outage durations of >92% Unit Capacity Factor (UCF), which is required in order to achieve top quartile generation cost per MWh.

The preferred alternative is the development of a Rapid Delivery Machine (RDM) for DNGS. The project will deliver a remotely operated fuel channel inspection tool delivery machine that installs on reactor during a planned outage. The project also includes the RDM delivered tooling for fuel channel inspection and scrape to the latest industry standard.

This release will continue detailed engineering for the Darlington RDM and include long lead procurement, including:

- Design of the Darlington Cable Penetration Module.
- Release the funding for the prototype/non-production RDM.
- Design of Darlington RDM Design
- Design of the Darlington Fuel Channel Tooling
- Design of the Site Modifications to interface with Darlington RDM.
- Procurement of long lead manufactured components and tooling.

A future release will include:

- Execution (Fabrication/Testing) of the Darlington RDM
- Execution of MDS and ANDE tool mods for Darlington
- Execution of the Darlington Site Mods
- Commissioning of the Darlington RDM

The primary risks to the project are cost and schedule. Rigorous upfront planning with the prime vendor through a 6 month plan development period sets out the basis for the cost and schedule of the RDM. Comprehensive project controls, oversight, and enhanced contractual liquidated damages are planned to address these risks.

Business Need

For Project Level A or B

The RDM Business Need is based on:

- **Inspection Machine Availability and Reliability** – Inspections of the Fuel channels are regulated by the codes and standards per CSA N285.4. They are required by OPG's operating license and will continue to be needed during the next 30 years of Darlington operations post refurbishment. CIGAR is currently used for volumetric and dimensional inspections. CIGAR was commissioned in the 1970s and is considered dated and has challenging obsolescence issues and is not expected to be able to meet the station's needs post refurbishment due to increasing obsolescence and maintenance demands.

The RDM will be able to deliver current established technology for volumetric and dimensional inspections using the Advanced Non-Destructive Examination (ANDE) tooling to collect pressure tube samples to measure the deuterium content uptake over time using the latest in machine delivered scrape (MDS) technology. Machine Delivered Scrape technology has now been proven at other CANDU facilities. This tooling technology needs to be deployed on reactor under automatic control of a delivery machine, such as RDM, to avoid the use of workers on the reactor face using manual tooling. At Darlington, the RDM will provide a means of delivering this tooling technology for the collection of scrape samples throughout the life post refurbishment.

- **Worker Dose Uptake** – The current manual scrapes performed at DNGS are considered high-hazard work and result in high-dose exposure to nuclear energy workers. With the successful development of Machine Delivered Scrape (MDS) tools at other CANDU sites, it is no longer acceptable to expose workers to dose using the manual tools. The Rapid Delivery Machine will enable the capability of delivering the MDS tool at Darlington and significantly reduce the required

Business Need	For Project Level A or B
open face work and dose received by workers. During the first deployment of MDS at Pickering in 2018, cumulative worker dose was reduced from 11 to 2 REM. Comparable reductions can be expected at Darlington as well. There are additional dose savings associated with operations and the feeder ice plugging by moving to MDS technology. • Nuclear Safety – By bringing MDS capability to Darlington, the need for feeder ice plugging and the associated risks to nuclear safety and work protection are eliminated. With the availability of proven MDS technology, maintaining the Nuclear safety risk associated with the use of ice plugging is no longer acceptable. In addition to nuclear safety concerns, ice plugging can also result in economic losses related to critical path delays when the forming of ice plugs is not successful. • Reduced Outage critical path – In-vault inspections have traditionally defined the outage durations at Darlington. OPG's post refurbishment business objective is to lower generating cost per MWh to be top quartile. In order to achieve this planned outage durations need to be reduced such that a >92% UCF is achieved. The RDM enables the required critical path reductions in the following areas: a. Fuel Channel Scrape: DNGS currently performs its regulatory fuel channel scrape inspections using manual scrape tools. This requires extensive pre-requisite activities that are time consuming and dose intensive. The deployment of the MDS tool using the RDM will result in critical path savings. b. Fuel Channel Volumetric Inspection: DNGS Fuel Channel Inspections cannot be performed using OPG's most advanced tooling due to the absence of a suitable delivery machine for DNGS. Introducing the RDM will allow inspections to be performed using the Advanced Non-Destructive Examination (ANDE) Mk2 tool. For comparison, the average critical path time for volumetric inspection of fuel channels using ANDE Mk2 is 9 hours per channel, while CIGAR (current DNGS inspection tool) requires an average of 19 hours per channel. • Fuel Machine Availability and Reliability - Currently at DNGS, OPG relies on Fuel Handling (F/H) equipment for the execution of fuel channel inspections and scrape campaigns. During CIGAR outages one FM (Fuelling Machine) and trolley is fully dedicated for the duration of the CIGAR campaign. For scrape campaigns, a FM and trolley is also required for the significant pre-requisite and post-requisite work. Overall, Fuel Channel Inspection Campaign reliance on F/H reduces the number of hours available for F/H maintenance. Introducing the RDM at DNGS would significantly reduce reliance on the fuel handling equipment during outages. This would increase F/H system reliability by reducing Fuelling Machine (F/M) wear and tear as well as allow more time for planned maintenance of the F/H systems.	

Preferred Alternative:	Development of a Rapid Delivery Machine (RDM) for DNGS	For Project Level A, B or C
Description of Preferred Alternative		
The preferred alternative is to design a new Rapid Delivery Machine (RDM) system to perform Fuel Channel inspections at DNGS. Pursuing this alternative supports the objectives of replacing ageing equipment with the latest in the industry standard in order to maintain OPG's licence to operate for 30 years post refurbishment. In addition to maintaining the capability to perform the required fuel channel inspections, this technology reduces worker dose by removing workers from performing manual tasks on the reactor face and improves nuclear safety by removing the reliance on feeder freezing during scrape campaigns. The technology chosen also results in significant critical path reductions due to increased automation and the use of modernized tooling. The benefits are summarized in the table further below. The RDM machine would be capable of deploying the following Fuel Channel Inspection and Maintenance (FCIM) services: • Fuel Channel NDE Inspections using ANDE Mk2 & ANDE Replica • Machine Delivered Scrape (MDS) (Axial and Rolled Joint (RJ) Scrape) RDM will also possess the ability to: • Remotely access target fuel channel(s) and deploy FCIM tooling independently of a fuel handling machine and trolley. <u>Machine Concept</u> Modification Design Requirements have been prepared and approved for a machine that provides rapid deployment, similar to the current CIGAR system, and with the capability of the Pickering Universal Delivery Machine (PUDM). The RDM would be capable of locking onto fuel channels and removing closure and shield plugs as well as delivering the entire suite of available inspection tools. The concept for the RDM features a machine Head that includes a Snout and Magazine Assembly mounted on a Suspension system. The Snout provides the ability to sense the position of the end-fitting of the target fuel channel which drives the suspension in X, Y, Z, Pitch and Yaw to facilitate homing and locking onto the target channel. The two-stage		

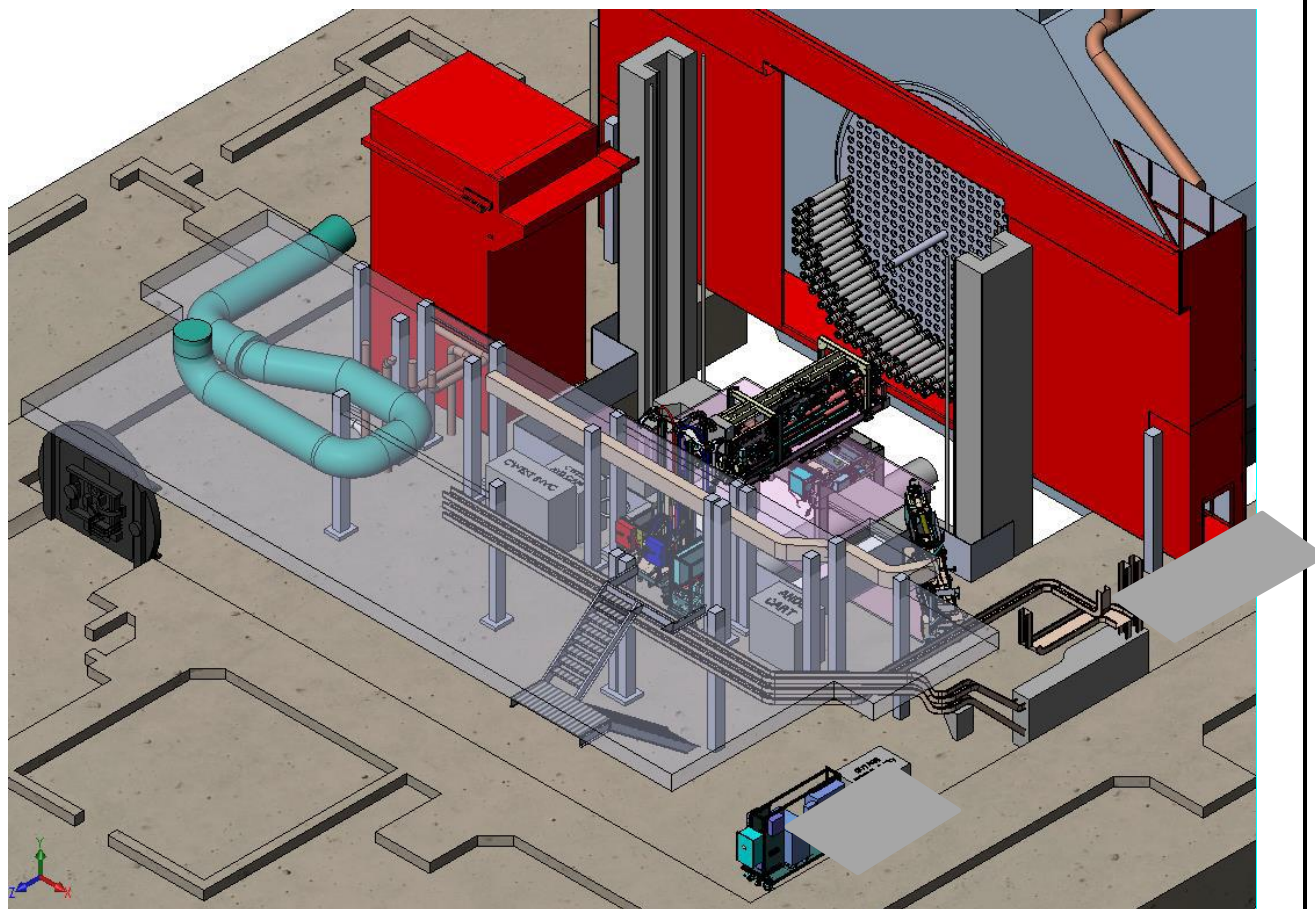
Preferred Alternative: Development of a Rapid Delivery Machine (RDM) for DNGS

For Project Level A, B or C

Description of Preferred Alternative

horizontal magazine supports and aligns (2) Tool Mechanisms, (1) Closure Plug Mechanism and (1) Shield Plug Mechanism to the Snout within a compact footprint.

The Tool Mechanisms are based on UDM designs and provide the capability for delivering ANDE, Replica, and MDS FCIM tools.



As a part of the In-Vault Support Equipment, there are various components which facilitate FCIM tool change, function checks and calibration activities. These are generically referred to as the RDM Calibration Facility and Tooling Stations (CFTS). Machine transporters are to be integrated into the design to transport and position the RDM components in the vault and around the station. The ANDE/MDS CFTS will not need to be re-positioned each time the RDM interfaces with it. This is expected to provide significant time savings and allow the RDM system to yaw and engage with the CFTS remotely.

Vault floor based cable handling equipment is to be used in place of the UDM WINSKY design to improve system installation and removal performance. These units are responsible for management of the FCIM tool umbilical cables and also provide support for the RDM D2O lines and control cables. The in-vault control equipment includes Power Distribution Cart, and D2O pump cart.

The strategy for this alternative is to commission the RDM during the first post-refurb Fuel Channel Inspection outages (D2521). This on channel commissioning at Darlington is targeted during the turbine outage of D2521 when the commissioning activities are expected to be completed off critical path.

Preferred Alternative:	Development of a Rapid Delivery Machine (RDM) for DNGS	For Project Level A, B or C
Description of Preferred Alternative		
Benefits of RDM		
Benefits:	Details	
Inspection Machine Availability and Reliability	□	With the refurbishment of Darlington, asset management of the new fuel channels requires a periodic inspection program for the life of the units. • Eliminate reliance on CIGAR technology that was first commissioned in the 1970s and the associated ageing obsolescence. • Replace manual Scrape tools with more reliable and efficient Machine Delivered Scrape technology.
Dose Savings	□	Dose uptake during Scrape campaigns at DNGS can be reduced from 20 Rem to <6 Rem for standard 6 rolled joint and 10 body of tube scope by replacing current manual Scrape tooling with the automated Machine Delivered Scrape.
Decreased Nuclear Safety Risks		By providing the capability to deploy Machine Delivered Scrape we eliminate the requirement for feeder ice-plugging associated with manual Scrape work.
Reduce Critical Path Duration	□	Enabler for achieving critical path fuel channel inspection duration required to support a 38 day outage critical path leading to a >92% UCF. • Streamlined mobilization and demobilization • Improved equipment reliability during the critical path activities. • Replacement of Manual Scrape with Machine Delivered Scrape • Replacement of CIGAR volumetric inspections with ANDE MK2
Fuel Machine Availability and Reliability		The RDM System acts completely independently of the FM (Fuelling Machine) and trolley. This provides the following benefits: • Eliminates inspection induced wear and tear during outages • Allows more time for scheduled FM Maintenance which is expected to improve performance • Allows the FM to service other units during the outage • Eliminate need for reconfiguring the F/M Trolley to receive the Trolley Mounted Magazine (TMM) required for supporting multiple channel isolation.

To elaborate on the potential fuel handling benefits, the RDM would create fuel handling maintenance hours by not requiring a dedicated Fuel Handling (F/H) Trolley during fuel channel inspection campaigns. Specifically the RDM would eliminate the following uses:

- Currently during CIGAR campaigns at DNGS, one F/H Trolley is required to move the CIGAR package from channel to channel. The RDM will be able to deliver FCIM tooling to channels independently from F/H equipment similar to PUDM which will free up the Trolley during the outage. The only requirement on the F/H Trolley will be to assist with de-fueling the target channels. This is consistent with current operation.
- Currently during CIGAR campaigns, one F/H Trolley is dedicated for the duration of CIGAR campaign due to the required recall time to remove the CIGAR package in the event of an emergency. As stated above, the RDM would be capable of independently removing FCIM tooling, thus freeing the F/H Trolley up for maintenance during fuel channel inspections.
- Currently during scrape campaigns, F/H equipment is utilized to install vented closure plugs (VCP) and channel isolation plugs (CIP). The Machine Delivered Scrape (MDS) tooling operates in a flooded channel thereby eliminating the need for channel isolation and draining.

Deliverables:	Associated Milestones (if any):	Target Date:
<i>Current release:</i>		
SBCS Gate 2 Approval		January 2020
OPG DA WARR1 Authorization (Head & Suspension)		July 2020
RDM Fabrication Start (Head & Suspension)		Sept 2020
ANDE Design Work Complete		April 2021
MDS Design Work Complete		March 2021
Plant Modification Design Complete		July 2021
<i>Future release:</i>		
RDM Fabrication Complete		March 2021
RDM Assembly Complete		November 2021
RDM Power On		December 2021
RDM Delivered to OPG		October 2022
RDM Site Acceptance Testing Complete		December 2022
RDM In-vault commissioning complete		June 2025

Alternative 2:	Base Case – No Project	For Project Level A, B or Value-Enhancing
The “No Project” alternative is not selected as new fuel channel inspection tooling is required to support the continued operation at Darlington going forward post refurbishment. Current tooling is ageing and the technology currently used is no longer industry standard. Additionally, selecting this alternative forgoes the ability to reduce the outage critical path times in the fuel channel inspection activities to meet the required >92% UCF, impacting OPGs generation targets post refurbishment. Additionally, this alternative does not reduce IRI's' reliance on Fuel Handling (F/H) trolleys nor does it provide additional (F/H) maintenance hours. Obsolescence of existing tooling would drive an immediate need to implement alternative projects in order to maintain the capability to perform fuel channel inspections in order to meet code and licensing requirements. Consequently, this alternative is not recommended.		

Alternative 3:	Delay/Pause project expenditures using up schedule float ahead of commissioning to 2025	For Project Level A or B or Value-Enhancing
The alternative to delay/pause work and commissioning until 2025 is not recommended. The current baseline project schedule shows a float from when the Site Acceptance Testing (SAT) is complete and the start of on-channel commissioning. Pros and Cons: The Pros for pausing progress of the RDM project (due to change in commissioning outage schedule) are limited to capital cost flow deferral only. This would make more near term capital available. The Cons for pausing progress of the RDM project (due to change in commissioning outage schedule) are: - Costs would increase for the project due to additional demobilization and re-mobilization costs for OPG and for at least three (3) vendors (RDM vendor, DNGS Site Mods vendor, and MDS Vendor). Based on the contractual terms and conditions, this would be substantial; - The project would be exposed to additional schedule risk as the current plan to be ready for commissioning the RDM in 2023 provides float in case of schedule delays. Also, the new equipment and the associated benefits would not be available to support any emergent or planned demands that may come up during the course of this project. - There would be additional costs and strains on resources as the CIGAR machine, and Manual Scrape equipment would need to be poised and available;		

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	There is a risk that modifications for tooling (MDS, and ANDE) may be delayed thereby impacting the dates of the RDM Delivery Machine FAT, and SAT.	Mitigate through aggressive monitoring of the schedule, regular project and technical meetings, and weekly progress and performance reporting, including earned value management from vendors	No	Medium
Quality	There is a risk that there are interface issues between the existing station equipment and the new RDM and tooling resulting in installation or performance issues. This includes adequate space to fit the RDM inside and through the equipment airlocks.	Mitigate. OPEX reviews will take place along with the development of detailed SAT and commissioning plans. Space frame walk downs will be completed in all units.	No	Medium
Cost & Schedule	There is a risk of discoveries during the detailed design that may have an impact of cost and schedule.	Mitigate: - Schedule and cost contingency have been accounted for to mitigate moderate discovery during the design phase. Risk reduction prototype testing is planned as input to the final design. - Representative Factory Acceptance Testing has been planned as part of the scope to identify and resolve any issues at the prime vendor. - A detailed scope alignment at the preliminary design stage has occurred through a plan development period with the prime RDM vendor.	Yes	Medium
Cost	There is a risk that the RDM on-channel commissioning may not be completed within the prime vendors warranty period. Latest OPG Generation Plan identifies no planned outages before 2025 after the RDM is on-site.	Mitigate: - Identify windows during refurbishment for early in-vault commissioning. - Negotiate an extended warranty period with the prime vendor if required.	No	Medium
Cost & Schedule	There is a risk that OPG Design deliverable acceptance is delayed or prolonged, impacting cost and schedule with the vendor.	Mitigate: - The prime vendor has the accountability to maintain a detailed level 3 schedule with all deliverable submissions updated weekly. - OPG Project has implemented an engineering work management process to plan and monitor progress with internal escalation protocols.	No	Medium

Financial Evaluation For Project Level A, B (with multiple feasible alternatives) or Value-Enhancing					
\$M	Preferred Alternative	Base Case (No Project)	Delay work		
Project Cost	160.4	N/A	N/A		
NPV	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 as per section 3.2 of the BCS Standard.					

Qualitative Factors For Project Level A or B
As described above, the benefits of the RDM include: • Dose Reduction • CIGAR Reliability and Obsolescence • Fuel Machine Availability and Reliability • Nuclear Safety

Post Implementation Review (PIR) Plan (refer to OPG-PROC-0056)				
Type of PIR Report	Comprehensive PIR	PIR Completion Date	Dec-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?
FH Trolley availability during outage campaign	0 hours/outage	200 hours/outage	Campaign Actuals post first deployment	DAMS, SME
Dose Reduction (Scrape Campaign)	20 REM/outage	<6 REM/outage	Campaign Dosimetry At first deployment	DAMS, SME
Average Volumetric Inspection Time per Channel	19 hours/channel	9 hours/channel	Inspection logs from ANDE deployment at DNGS	Fuel Channels, SME
Feeder Ice-Plugging for Fuel Channel Inspections	Feeder Ice Plugging Occurs	No Feeder Ice Plugging	Campaign Report At first deployment	DAMS, SME

Definitions and Acronyms
AFS - Available for Service ANDE - Advanced Non Destructive Examination BCS - Business Case Summary BOT – Body of Tube CIP - Channel Isolation Plug DAMS - Delivery and Reactor Maintenance Systems DNGS – Darlington Nuclear Generation Station FCIM – Fuel Channel Inspection and Maintenance F/H - Fuel Handling F/M - Fuelling Machine IRI - Inspection and Reactor Innovation MDS - Machine Delivered Scrape MWh - Mega Watt-hour NPV - Net Present Value OPEX - Operating Experience OPG - Ontario Power Generation PIR - Project Implementation Report PNGS – Pickering Nuclear Generation Station PUDM – Pickering Universal Delivery Machine

Definitions and Acronyms
RJ – Rolled Joint SME – Subject Matter Expert UCF – Unit Capacity Factor UDM - Universal Delivery Machine VCP - Vented Closure Plug

APPENDICES

Appendix A1: Summary of Estimate - Total Project Cost										
Project Number:	83039									
Project Title:	Rapid Delivery Machine									
\$K	LTD	2019	2020	2021	2022	2023	2024	Future	Total	%
Project Mgmt	1,678	2,023	928	693	723	327	172	110	6,652	4%
Inspection										
Engineering										
Procurement										
Construction										
Commissioning										
Closeout										
Subtotal										
Outside WBS										
Contingency										
Subtotal w/ Contingency										
Interest										
Other										
Total	33,358	12,659	32,124	43,420	22,811	6,288	2,728	6,483	159,871	100%
OM&A (Project# 80077)	537	-	-	-	-	-	-	-	537	0%

Appendix A2: Summary of Estimate – Notes			
Escalation Rate	2.90%	Interest Rate (going-forward)	4.41%

Appendix A3: Summary of Estimate – In-Service Estimates				
\$M	Only applicable to capital projects. In-Service amount shall include interest but exclude removal costs.			
Project #	Date (YYYY-DD-MM)	Description	Amount	%
83039	2020-30-08	Non-Production RDM		
83039	2022-15-12	Partial AFS - Out of vault commissioning		
83039	2025-30-06	Final AFS - In-vault commissioning		
83039	2025-15-12	Close out		
Total				

Prepared by:		Reviewed and Endorsed by:	
 Brent Achtymichuk Project Leader IRI Fuel Channel Innovation		 Bradley Greenland Manager Projects IRI Fuel Channel Innovation	
November 29, 2019 Date		November 29, 2019 Date	

Business Case Summary

Project #	10-83828	Controlled Doc #	N-BCS-09701-0671681
Project Title	Fleet Monitoring Initiative (Monitoring and Diagnostic Centre)		
Facility	PNGS, DNGS	Investment Classification	Sustaining
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 ☒ Partial G2: Definition ☐ Choose an item. G1: Choose an item. ☐ G3: Execution		
Estimate Class (overall project)	Class 4	Target Project Completion Date	DEC-2023

Recommendation
We recommend a release of \$3,740 K, including ████████ of contingency. This will bring the total released-to-date to \$9,146 K including ████████ of contingency. The previously approved contingency was released to the project. The estimated total project cost is within the range of \$25 M to \$40 M. This release is requesting a partial definition of Phase III scope for the Monitoring and Diagnostic Centre including design engineering and procurement. The project will implement a pilot to install and commission 50 sensors (of 3800 sensors) at PNGS and DNGS to establish a Class 3 estimate for future installations. Future releases will request completion of Phase III design engineering, procurement and installations, and the development of an advanced data analysis application.

Investment Cash Flows									
\$K	LTD	2020	2021	2022	2023	2024	2025	Future	Total
Previous releases	4,656	750							5,406
Current request	-	3,740							3,740
Total released to date	4,656	4,490	-	-	-	-	-	-	9,146
Future required	-	TBD	TBD	TBD	TBD				TBD
Total Project Cost									
Ongoing Costs	-								
					Gate:	G2	OAR Approval:	\$9,146 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 Jenny Leung Manager, Equipment Reliability Nuclear Engineering		March 6, 2020
I concur with the business decision as documented in this BCS.		
Finance Approval: Brett Lemmon Finance Controller – Darlington		Mar 19, 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: Dean Townsend VP, Engineering Strategy Nuclear Engineering		March 25, 2020

Business Case Summary

EXECUTIVE SUMMARY – Project Overview

Business Need

This project is to implement the use of low-cost online equipment condition monitoring sensors (wired & wireless) at both Darlington and Pickering nuclear generating stations to allow more important work to be performed. Upon completion of this project, OPG will provide significant improvement to the existing sensors, communications, analytics, interconnectivity, and data visualization.

Currently, equipment condition assessment in the power generation industry is primarily relying on inspection campaigns during scheduled outages and online maintenance schedules. Inspection scope is currently primarily developed based on pre-determined time intervals, past events, and probabilistic models. Real-time monitoring of predictive indicators has been identified as an area of improvement in the stations.

OPG established a Monitoring & Diagnostic Centre (M&DC) within the Nuclear and Renewable Generation organizations to leverage new equipment condition monitoring technologies to develop a strategic approach for implementing advanced monitoring and diagnostic capabilities. These new technologies will be fundamental in ensuring equipment reliability and transitioning to CBM the nuclear stations.

Preferred Alternative

The M&D Center predictive analytics tools allow analysts to visualize actual and expected performance of an asset including detailed information on ambient conditions, unit loading, and operating modes. Using the Advanced Pattern Recognition (APR) software, the M&D Centre is able to improve equipment reliability and performance while avoiding potential failures. Implementing this project is estimated to improve thermal performance efficiencies and transition time based maintenance to condition based maintenance.

In order to ensure that all of the Nuclear fleet's critical equipment's failure modes are captured, the M&D Centre project is requesting a partial release for the design engineering, procurement, installation and commissioning of new sensors at both PNGS and DNGS between 2020-2023.

The project has been divided into the following four (4) phases:

Phase I: Establishing a Monitoring & Diagnostic (M&D) Centre.

Phase II: Initial Planning and Pilot Installs.

Phase III: Design Engineering, Procurement and Installations.

Phase IV: Advanced Data Analytic Application.

This release is requesting a partial release (Gate 2A) of Phase III to execute the design engineering and procurement activities, as well as to complete Phase II pilot installations and commissioning of 50 sensors at PNGS and DNGS to establish a Class 3 estimate for future installations. OPEX within the organization has proven the benefits of implementing pilot projects to obtain lessons learned as well as more accurate cost and schedule estimates.

The scope for this release includes:

PNGS:

- Transformer Dissolved Gas Analyzers (DGA) U1-8.
- SRV Room Temperature Monitoring U5-8
- Class IV switchgear ESA U1, 4, 5-8 (PNGS A and B)
- Class III switchgear ESA U1, 4, 5-8 (PNGS A and B)

DNGS

- Transformer Mixed Gas Analyzers (MGA) U0, 1-4.
- EQ Rooms Temperature Monitoring U0, U1-4.
- Class IV switchgear U1-4
- Class III switchgear U1-4

Business Need

For Project Level A or B

This project is to implement the use of online equipment condition monitoring sensors (wired & wireless) at both Darlington, Pickering nuclear generating stations to transition time based maintenance to condition based maintenance and improve plant performance. Upon completion of this project, OPG will provide significant improvement to the communications, analytics, interconnectivity, and data visualization through existing and new sensors.

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Business Need	For Project Level A or B
The Nuclear and RG organizations are leveraging new equipment condition monitoring technologies to develop a strategic approach for implementing advanced monitoring and diagnostic capabilities. Through Continuous On-line Monitoring (COLM) guides, sensor technologies across OPG will cover failure mode analysis of components to monitor equipment health and allow early detection of equipment degradation/anomalies. By detecting degradations early, catastrophic or consequential failures will be avoided, and work will be planned in advance to reduce costly time-based Preventive Maintenance (PM) with condition-based maintenance tasks to perform the right work at the right time. The M&D Centre predictive analytics tools allow analysts to visualize actual and expected performance of an asset including detailed information on ambient conditions, unit loading, and operating modes. Using the APR software, the M&D Centre is able to provide an opportunity for improving equipment reliability and performance while avoiding potential failures.	

Preferred Alternative:	Advanced Continuous Online Monitoring (COLM) Program
Description of Preferred Alternative	
In the development phase of the Monitoring & Diagnostic Centre project, an evaluation on both nuclear and RG business units was conducted to define the scope of the project. In this process, critical and non-critical station assets were identified requiring additional failure mode coverage such as temperature, vibration, electrical signature analysis to provide full failure mode coverage. The benefit of this coverage is for the M&D Centre analysts to monitor the assets, and in the case of performance deviations, the M&D Centre team will work with various parts of the organization to mitigate the risk of catastrophic failures and accidents and plan and extend outage work. The project is requesting a partial release of Phases II and III to execute the design engineering, procurement, installation and commissioning activities for sensors at PNGS and DNGS. The installation and commissioning activities of 50 sensors will fall under a pilot to obtain lessons learned and better estimates for future installs. Station staff, including maintenance, operations, system and component engineers, and other subject matter experts will be heavily involved in the planning and execution of the project. The project will also work together with various other stakeholders within OPG's organization, such as CIO, RG, Nuclear Waste, Supply Chain, Finance, Design Engineering, Performance Engineering, Operations, Work Control and Maintenance, to plan and execute the project successfully. The project has been divided into the following four phases: (COMPLETED) Phase I: Establish the M&D Centre (2017-2018): - Perform M&D Centre evaluation (OPG Nuclear & RGPM Business units) - Procure and utilize an Advanced Pattern Recognition (APR) software - Hiring of staff (IN PROGRESS) Phase II: Initial Planning & Pilot Installs (2018-2019): - Identify fleet monitoring priority equipment scope - Design OPG OLM information architecture - Develop the preliminary design engineering scope - Sensor installations pilot (PARTIAL RELEASE) Phase III: Design Engineering & Installations (2020-2022): - Develop detailed design engineering packages for selected scope - Procurement of required hardware and software equipment - Installation of required hardware and software equipment - Implement Start-up, commissioning and site turn over of selected scope - Plan outage installations - Route new data into the plant historian (FUTURE) Phase IV: Advanced Data Analytic Application (2021-2023): - Develop advanced diagnostics and prognostics - Design fleet data integration/visualization for decision optimization analytics M&D Centre Functional Model Existing and future plant data that are received from equipment sensors are stored in the Plant Information (PI) data historian. The data will then be used by the Advanced Pattern Recognition (APR) software (e.g. PRISM), and thermal performance software (PEPSE/PMAX).	

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Preferred Alternative:	Advanced Continuous Online Monitoring (COLM) Program
Description of Preferred Alternative	
Existing data stored in PI has been integrated into models developed by the M&D Centre staff. These models will detect early warnings of equipment failures and abnormal operating conditions at both PNGS and DNGS. The M&D Centre project has also been working with various initiatives such as the Right Work, Right Time, Right Value (RWRTRV) and Value Based Maintenance (VBM) initiatives to execute work in alignment with on-going OPG maintenance activities.	

Deliverables:	Associated Milestones (if any):	Target Date:
<i>Previous releases:</i>		
1. Perform M&D Centre evaluation (OPG Nuclear & RGPM Business units)		2018
2. Hiring of staff		2018-2019
3. Identify fleet monitoring priority equipment scope		March 2019
4. Develop the preliminary design engineering scope		November 2019
<i>Current release:</i>		
5. 100% Detail Design Complete for: - EQ / SRV Room Temperature Monitoring - Mixed / Dissolved Gas Analyzers (M/DGAs) - Class III Motor Current Signature Analysis (MCSA) - Class IV Motor Current Signature Analysis (MCSA)	100% Detail Design Complete (OPG Acceptance) - G2A - Class IV Switchgear for Darlington: 30 Jun 2020	June 30, 2020
6. Procurement (PO issued): - EQ / SRV Room Temperature Monitoring - Mixed / Dissolved Gas Analyzers (M/DGAs) - Class III Motor Current Signature Analysis (MCSA) - Class IV Motor Current Signature Analysis (MCSA)	Procurement - ESA - Class IV Switchgear Materials – PO Issued - Darlington: 20 Jul 2020	July 20, 2020
7. Finish of Installation: - EQ / SRV Room Temperature Monitoring - Dissolved Gas Analyzers (DGAs)	FOI - Finish of Installation - G2A - DNGS - EQ Rooms Temperature Monitoring - DNGS - U0, U1-4: 29 Jun 2020	June 29, 2020
8. Available For Service (AFS): - EQ / SRV Room Temperature Monitoring - Mixed / Dissolved Gas Analyzers (M/DGAs)	AFS - Available for Service - G2A - DNGS - EQ Rooms Temperature Monitoring - DNGS - U0, U1-4: 27 Jul 2020	July 27, 2020
<i>Future release (Future phases):</i>		
9. Develop detailed design engineering packages		Phased approach 2020-2022
10. Procurement of required hardware and software equipment		
11. Installation of required hardware and software equipment		
12. Implement Start-up, commissioning and site turn over of selected scope		
13. Plan outage installations		
14. Close out activities		

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Alternative 2:	Base Case – No Project
The benefits described in the Nuclear Fleet Scope Summary (N-REP-01500-00003) would not be realized if this project does not proceed.	

Alternative 3:	Delay Work
Delays on executing this project will result in missing critical timelines required to meet benefits expected from installing more coverage at PNGS. This will also reduce equipment reliability benefits and maintain the current risks of FLRs.	

Key Risk Assessment				For Project Level A, B or C
Risk Class	Description of Risk	Response Type/ Actions	For Additional Review	Residual Ranking
Cost	Cost estimate exceeded.	Mitigate: Continuous monitoring of cost by the Cost and Schedule Analyst (CSA) and Project Leader. Pilot installs will be executed to provide better estimates for future installs to control costs.	No	Low
Schedule	Delays establishing procurement contracts Delays in installations	Mitigate: Work closely with Supply Chain SPOC to evaluate the proposals received for the Data Acquisition and Analysis System (DAAS). Currently working with Supply Chain, Law, and Renewable Generation to ensure meeting the target completion deadlines.	No	Medium
Quality	Lack of expertise to execute work	Mitigate: Use of third party experts with previous experience at Duke Energy and successful implementation of M&D Centres and working closely with station SMEs to ensure alignment on scope and expectations.	No	Low

Financial Evaluation					
\$M	Preferred Alternative	Base Case (No Project)	Delay work	Alternative 4	Alternative 5
Project Cost	\$25-40	N/A	N/A		
NPV	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
Some of the qualitative factors provided by the Preferred Alternative are as following: - Contribute to reducing Forced Loss Rate (FLR) - Contribute to the nuclear fleet reduction target for preventive maintenance on selected critical & non-critical maintenance-hours. This includes reduction of electrical and mechanical maintenance work dedicated to major equipment PM tasks, optimizing instrument calibrations and eliminating a significant amount of manual condition monitoring data collection (vibration, electrical testing, oil analysis, non-destructive testing, etc.) - Improve unit heat rates through on-line thermal performance monitoring	

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Post Implementation Review (PIR) Plan (refer to OPG-PROC-0056)				
Type of PIR Report	Simplified/Standard PIR		PIR Completion Date	12-2023
☒ 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?

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APPENDICES

Appendix A1: Summary of Estimate - Released to date								
Project Number:	10-83828							
Project Title:	Monitoring and Diagnostic Centre							
\$K	LTD	2020	2021	2022	2023	Future	Total	%
Project Mgmt	230	110					340	4%
Engineering								
Procurement								
Construction								
Commissioning								
Closeout								
Subtotal								
Contingency								
Subtotal w/ Contingency								
Interest								
Total	4,656	4,490	-	-	-	-	9,146	100%
Removal Costs (incl. above)							-	0%

Appendix A2: Summary of Estimate – Notes			
Escalation Rate	2.5%	Interest Rate (going-forward)	4.33%

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	%
10-83828	3/15/2020	Advanced Pattern Recognition Model Building Equipment Analytics		51%
10-83828	6/30/2020	Engineering, Procurement and Installation of Pilot		49%
Total				100%

Prepared by:		Reviewed and Endorsed by:	
 Hassan Jaber Monitoring and Diagnostic Centre Project Leader		 Jenny Leung Manager, Equipment Reliability Project Sponsor	
3/6/2020 Date		3/6/2020 Date	