UNIT 2 PERFORMANCE

1.0 OVERVIEW

This exhibit provides an update on the refurbishment of Darlington Unit 2, with a focus on OPG’s cost and schedule performance. It concludes by discussing OPG’s proposed treatment of the IR term rate base as it relates to the variance against the EB-2016-0152 approved in-service additions for the Darlington Refurbishment Program (“Program” or “DRP”) and associated balances in the Capacity Refurbishment Variance Account (“CRVA”).

As noted in Ex. D2-2-1 and further explained in this exhibit, in this application, OPG is not seeking inclusion of variances against the EB-2016-0152 approved DRP-related in-service additions in rate base and is also not seeking recovery of the related CRVA balances accumulated to date.¹

OPG started the refurbishment of Unit 2 as planned on October 15, 2016 and returned Unit 2 to service on June 4, 2020, just over three months later than its committed schedule. Of note, the final two-and-a-half months of the Unit 2 refurbishment outage were completed under the state of emergency declared in Ontario on March 17, 2020 as a result of the COVID-19 pandemic. OPG captured thousands of Lessons Learned² during the course of the Unit 2 refurbishment. These Lessons Learned as well as a number of Strategic Improvements³ have been incorporated into the planning and execution of the refurbishments of Units 3, 1, and 4 (the “Remaining Units”), and are expected to result in unit-over-unit cost and schedule duration improvements.⁴

¹ Other than the D2O Storage Project (Ex. D2-2-10) and the impacts of capital cost allowance deductions arising from changes in income tax legislation since EB-2016-0152 (Ex. F4-2-1), OPG also did not seek recovery of DRP-related CRVA balances in its EB-2018-0243 application for disposition of deferral and variance account balances, meaning that none of DRP-related CRVA balances accumulated since January 1, 2016 have been sought for clearance to date.
² “Lessons Learned” refers to specific and detailed knowledge and experience gained during a process, project or activity which, when applied to the same or similar processes, projects or activities in the future, results in improved performance.
³ “Strategic Improvements” are new approaches and/or innovative methods for planning and executing the Remaining Units’ refurbishments that are being implemented in addition to Lessons Learned.
⁴ Ex. D2-2-3 (Remaining Units Planning), Sections 4 and 5, for a detailed discussion of the Lessons Learned program and Strategic Improvements.
Relative to the OEB approved amounts in EB-2016-0152 of $5,177.4M for the refurbishment of Unit 2 (including the Definition Phase), Early-In-Service projects, Facilities and Infrastructure Projects (“F&IP”) and Safety Improvement Opportunities (“SIO”), there is a forecast variance of $132.7M or 2.5%. See Section 5.0 for further discussion of variances against the amounts approved for Unit 2 and for the Early-In-Service projects, F&IP and SIO.

Compared to the Unit 2 Execution Estimate (“U2EE”), which is discussed below, the refurbishment of Unit 2 itself was completed on budget at $3,417M.\(^6\)

**2.0 UNIT 2 EXECUTION ESTIMATE**

Cost estimating is a process that is repeated and refined at different stages of a program or project, particularly as a project progresses through its project life-cycle. With each iteration a cost estimate is expected to become more accurate. The OEB approved OPG’s revenue requirement in EB-2016-0152 based on the RQE for the Program, which was approved by the OPG Board of Directors in November 2015 and reflected in OPG’s evidence submitted in the application.\(^7\) Two months prior to the start of the refurbishment of Unit 2, as planned, OPG completed the “final check” of the forecast cost and schedule for the refurbishment of Unit 2, which resulted in the U2EE.\(^8\) The U2EE was approved by the OPG Board of Directors in August 2016 and established the Unit 2 project baselines for cost and schedule monitoring. Therefore, OPG tracked its Program performance through the execution of the Unit 2 refurbishment both internally and to the public against the U2EE.

\(^5\) Early-In-Service projects are those that provide benefit to the station prior to the return-to-service date of the nuclear unit under refurbishment. Examples include in-plant modifications which are of immediate benefit to multiple or all units.

\(^6\) Of the $3,417M final cost of Unit 2, $3,340.5M represents the capital in-service amount.

\(^7\) EB-2016-0152, Ex. D2-2-8, Section 1 and Attachment 1.

\(^8\) EB-2016-0152, L-04.3-1 Staff-055.
Compared to the RQE, the U2EE was a more highly developed estimate in the following ways:

1. A larger percentage of the U2EE was at Class II or Class III compared to the RQE.
2. Base cost estimates had been updated to reflect the further development of comprehensive work packages, which led to an enhanced understanding of the effort and cost to execute the work and updates to contingency and residual risks.
3. The overall schedule to execute Unit 2 had been revisited, including the elimination of a planned two-month overlap with Unit 3, which was the plan at the time of the RQE.9
4. Cash flows, interest and escalation had all been updated.
5. Regulatory certainty had been achieved and regulatory hold points during execution agreed to with the Canadian Nuclear Safety Commission (“CNSC”).
6. OPG’s role as General Contractor had been reviewed and adjustments were made to the size of OPG functions (i.e., OPG’s Program Management and Execution Management and Support organizations) based on Lessons Learned from the prerequisite projects.

Excluding the Definition Phase, the U2EE estimate to complete the refurbishment of Unit 2 itself was $3,417M. The High Confidence Schedule duration for Unit 2 remained at 40 months, as it was in the RQE. The U2EE also continued to forecast total Program costs at $12.8B and total Program duration at 112 months, as was the case in the RQE.

OPG’s cost performance relative to the OEB approved amounts, which were based on the RQE, and also relative to the U2EE is further discussed in Section 5.0.

3.0 QUALITY PERFORMANCE

The refurbishment of a nuclear unit requires a constant focus on the quality of the construction to meet or exceed all required specifications. The refurbishment of Unit 2 involved many thousands of removal and installation activities, which required a high degree of precision. Completion of work on Unit 2 required co-ordination, and detailed scheduling of,

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9 Per the Long Term Energy Plan, the Province of Ontario required demonstrated success on the first unit prior to commencing the Remaining Units’ refurbishments.
the activities of multiple trades, e.g., boilermakers, welders, millwrights, pipefitters, carpenters, electricians, painters, field engineers and radiation protection technologists in concert with the activities of OPG operations and maintenance staff.

OPG’s Quality Management program monitored quality issues and OPG worked collaboratively with its contractors to resolve all quality events and to ensure mitigation measures were implemented to prevent recurrence. As a result, the quality of the work completed on Unit 2 was excellent.

4.0 SCHEDULE PERFORMANCE

As discussed in Ex. D2-2-5, and extensively in EB-2016-0152, OPG measures progress against two schedules:

1. A Working Schedule; and
2. A High Confidence Schedule.

The difference between these two schedules is that the High Confidence Schedule includes contingency durations based on detailed analyses of risks. These contingency amounts are expected to be utilized over the course of the Program. Thus, the High Confidence Schedule is the basis of OPG’s public commitments and the approvals sought from the OEB. The Working Schedule is used to calculate performance metrics, e.g., Schedule Performance Index (“SPI”), and manage day-to-day activities, allowing for early escalation of issues. The use of a Working Schedule and a High Confidence Schedule is an industry leading best practice for large and complex projects.10

OPG commenced the Unit 2 refurbishment outage on October 15, 2016. At the time of the RQE, OPG had developed both a Working Schedule and a High Confidence Schedule for the Unit 2 refurbishment outage. Following the RQE, these schedules were refined over the next 10 months as the U2EE was completed. OPG then used the U2EE Working Schedule to

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10 This strategy provides an early indication of potential risks or issues and allows OPG to proactively manage Program performance.
drive the work on Unit 2 to completion. OPG monitored progress against both the U2EE Working and the High Confidence Schedules.

The refurbishment outage of Unit 2 was completed in four major segments. Figure 1 shows a comparison of the actual execution performance versus planned performance (per the U2EE High Confidence Schedule) for each segment.

**Figure 1: Comparison of Actual versus Planned Performance on Critical Path**

In the first segment, the unit is de-fuelled and physically isolated from the three operating units; this segment was completed in 12.8 fewer days than planned in the High Confidence Schedule.

In the second segment, the reactor is disassembled and existing reactor components removed; this segment was completed in 15.5 fewer days than planned in the High Confidence Schedule.

OPG began the third segment ahead of the High Confidence Schedule by approximately 28 days. The third segment involves the installation and reassembly of reactor components, and includes the installation of feeder pipes. This segment was completed in 105.9 more days than the planned duration. Thus, at completion of this segment, the U2 refurbishment outage was 78 days behind the High Confidence Schedule. Challenges experienced with the procurement and installation of feeder pipes affected the refurbishment schedule. Additional discussion of feeder pipe procurement and installation is provided in Section 4.1. In August 2019, the Working Schedule and High Confidence Schedule return-to-service dates for Unit 2 were reforecast to May 20, 2020 and June 25, 2020, respectively.
The fourth major segment of the Unit 2 refurbishment outage, which involved the loading of new fuel, removal of isolation from the other units, completion of the return to service of all systems and the restarting of Unit 2, was completed in 23.3 more days than the planned duration in the High Confidence Schedule. The refurbishment of Unit 2 was completed on June 4, 2020, with the declaration that the unit had returned to commercial service. This date was just over three months behind the U2EE High Confidence Schedule, and three weeks ahead of the date projected in the August 2019 re-forecast the High Confidence Schedule. Overall, the Unit 2 refurbishment outage was completed within 8% of the U2EE High Confidence Schedule.

As discussed in greater detail in Section 4.1 below, feeder pipes are installed in three sequential work programs, upper feeder pipe installation, followed by middle feeder pipe installation, followed by lower feeder pipe installation. The design of a CANDU nuclear unit means that only lower feeder pipe installation must be planned as a critical path activity, although installation of lower feeder pipes can be impacted by delays in installation of upper and middle feeder pipes. Analysis of the Unit 2 schedule performance shows that without the challenges experienced on lower feeder pipe installation, the Unit 2 refurbishment outage would have been completed on schedule.

Given the impact of the lower feeder pipe installation work on the Unit 2 schedule and the importance of improving performance on this work for the Remaining Units, the following sections provide an explanation of the function of feeder pipes, the procurement and installation process for these components, and briefly summarizes key Lessons Learned and Strategic Improvements that will be implemented for the procurement and installation of feeder pipes on the Remaining Units. Attachment 6 of Ex. D2-2-3 provides more details on the specific actions and Lesson Learned, which have been implemented to provide confidence that the procurement and installation of feeders will go according to plan for the Remaining Units.
4.1 Unit 2 Feeders – Function, Procurement and Installation

4.1.1 The Function of Feeder Pipes

Feeder pipes are a part of the heat transport system of a CANDU nuclear reactor. The feeder pipes transport heated heavy water from the fuel channels in the reactor to the steam generators, where steam is produced to turn the turbine-generator set. After passing through the steam generators, the heat transport heavy water is recirculated back to the fuel channels in the reactor to start the cycle all over again. Figure 2 shows a simplified schematic of the heat transport system in a Darlington unit.

Figure 2: Simplified Schematic of the Heat Transport System of a Darlington Unit

Figure 3 below is an illustration of a Darlington nuclear reactor showing the organization of the feeder pipes. Each Darlington nuclear unit has 960 feeder pipes (480 inlet pipes and 480 outlet pipes) connected to the inlet and outlet ends of each of the 480 fuel channels in the reactor and to the inlet and outlet feeder headers.
Figure 3:
Darlington Reactor Showing Feeder Pipes and Feeder Inlet and Outlet Headers

4.1.2 Feeder Pipe Procurement

Feeder pipes are fabricated off-site under strict quality requirements, then delivered to a warehouse facility where the quality documentation is verified and final preparation and quality checks are performed, before being shipped, in the required sequence, to the Darlington site for installation.

As can be seen from Figure 4, each individual run of feeder piping has its unique geometric shape to connect from the feeder headers to the fuel channels. In addition, each feeder pipe is fabricated from a number of components, including: straight pipe runs; angled sections to meet the geometric shape required to permit connection to the feeder headers and the fuel channels; and elements to facilitate the measurement of flow, temperature and pressure.
Figure 4:

Feeder Schematic Showing Feeder Pipes, Flow Elements, Supports and Spacers

1. FE = Flow Element; PBO = Pressure Breakdown Orifice;
2. A swage, also known as a reducer, is used to connect two sections of pipe of different diameters.

4.1.3 Feeder Pipe Installation Approach

As previously mentioned, feeder pipes are installed in three sequential campaigns. First, upper feeder pipes, which are welded to the feeder headers, are installed. Second, middle feeder pipes are welded to the upper feeders for 25% (248 of the 960) of the feeders which
have longer pipe runs, in order to facilitate connection to the lower feeders. Finally, lower feeder pipes are installed mechanically at the fuel channel and then welded to the already installed upper/middle feeders.

The installation of feeder pipes involves the execution of high-precision work, in a prescribed sequence, while working in very cramped conditions. For example, 960 high quality welds must be completed to attach the upper feeder pipes to the feeder headers. In addition, as seen in Figure 4, there are a large and varied number of pipe supports and other hardware to be installed. Proper alignment of upper/middle feeders is critical to achieving a proper connection to the lower feeders. Misalignment could lead to difficulty welding the two sections, unacceptable welds, residual stresses, and a resultant inability to meet the strict quality requirements.

Lessons Learned on the feeder series during the execution of Unit 2 included:

• Delays were experienced in the receipt of the new feeders due to the required qualification of fabrication welding specifications, inspection of fabrication, and welding, fabrication and delivery issues. Quality non-conformances, found upon inspection, needed to be resolved. Thus, planning for the Remaining Units includes longer procurement lead times to ensure that feeders are received at the station at least 12 months prior to the installation window. The qualification of fabrication welding specifications, which impacted Unit 2, is approved for all four units, thereby eliminating this source of delay in subsequent units.

• Higher than expected weld failure rates were experienced in field welds. As a result of Lessons Learned, welding on the Remaining Units will utilize improved welding condition setup, training processes, and the use of specialty welders with deep experience. These changes, among others, are expected to improve productivity and reduce weld-failure rates.

• Congestion was experienced on the reactor face, particularly as regards to scaffolding. Thus, the Remaining Units will employ a streamlined scaffolding approach to reduce

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11 See Ex. D2-2-3, Section 5.1.5 regarding Training Program Improvements and Ex. D2-2-8, Section 2.2.1.1 for a discussion of the implementation of components of the Organizational Evolution Strategic Improvement, which includes the Project Centric Organization and Workstream Specialization.
congestion, and facilitate transitioning from one work site to another on the reactor face. The use of smaller, more highly trained work crews, trained for proficiency in the entire work series, is also expected to contribute to reduced congestion.

- Installation of the upper feeder pipes to the inlet feeder headers will be simplified for the Remaining Units by leaving short pieces of feeder pipe in place on the inlet feeder headers, thereby simplifying the machining process in advance of welding the new pipes into place.

As indicated above, Lessons Learned from Unit 2 are being applied to the planning of the Remaining Units to enable unit-over-unit efficiencies. Many challenges faced on the Unit 2 refurbishment have been resolved and improvements to methods and tooling have been made, all of which are expected to lead to significant execution improvements for the Remaining Units. See Ex. D2-2-3 for a detailed discussion of planning for the Remaining Units including the incorporation of Lessons Learned and Strategic Improvements.

5.0 COST PERFORMANCE

In EB-2016-0152, the OEB approved a total in-service amount of $5,177.4M, consisting of $4,800.2M ($4,799.8M in 2020 and $0.4 in 2021) for the refurbishment of Unit 2 (including the Definition Phase) and $377.2M for Unit 2 Early-in-Service projects, F&IP, and SIO. Relative to the total approved in-service amount of $5,177.4M, there is a forecast variance of $132.7M or 2.5%.

Focusing on performance relative to the $4,800.2M approved in-service amount for Unit 2 (including the Definition Phase), OPG is forecasting an amount of $4,761.8M for 2020 and $0 for 2021, for a variance of $-38.5M. This negative variance is due to placing $70.3M of projects, which had been approved as part of the $4,800.2M, in-service earlier than Unit 2 because they provided immediate benefit to the Darlington station. This reduction of $70.3M to the Unit 2 in-service amount (including Definition Phase) was offset by an increase of $31.8M in the Unit 2 in-service amount (including the Definition Phase) due to higher spend, resulting in the net variance of $-38.5M (see D2-2-9, Section 4).
For the Unit 2 Early-In-Service projects, F&IP and SIO, compared to the OEB approved amount in EB-2016-0152 of $377.2M, there is a forecast total over-variance $171.2M. This variance is the result of increased costs of $100.9M for these projects, and declaring in-service $70.3M for new Unit 2 Early-In-Service projects, as discussed above. Further information on in-service amounts is provided in Ex. D2-2-9.

Compared to the U2EE, OPG completed the refurbishment of Unit 2 itself (i.e. excluding the Definition Phase) on budget at $3,417M. 12

The final two-and-a-half months of the Unit 2 refurbishment outage were completed under the state of emergency declared in Ontario on March 17, 2020 as a result of the COVID-19 pandemic. The COVID-19 pandemic did not materially impact OPG’s safety, quality, cost, or schedule performance for the refurbishment of Unit 2. Further discussion of the COVID-19 impacts on the schedule and costs of the Remaining Units is provided in Ex. D2-2-5 (Remaining Units Schedule) and Attachment 1 to Ex. D2-2-7 (Remaining Units Cost).

The successful completion of the Unit 2 refurbishment on budget and reasonably on schedule represented a significant achievement in mega-project execution for OPG. A picture showing the completed Unit 2 reactor face is provided in Figure 5. A panoramic view of the Unit 2 turbine hall is provided in Figure 6.

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12 See footnote 6.
Figure 5: Close-up of the Finished East Face of the Unit 2 Reactor
6.0 OVERSIGHT

During the execution of the Unit 2 refurbishment, OPG had implemented an assurance plan comprised of several layers of oversight. This oversight structure effectively helped OPG and its contractors meet safety, quality, cost and schedule expectations by identifying issues and aiding in their expeditious resolution. OPG’s oversight structure for the Remaining Units is discussed in Ex. D2-2-8.

For Unit 2, the Refurbishment Construction Review Board (“RCRB”) supported Program-level oversight for OPG’s Chief Project Officer, Chief Nuclear Officer, and Chief Executive Officer, and Burns McDonnell/Modus Strategic Solutions (“BMcD/Modus”) was engaged by the OPG Board of Directors to provide independent oversight of the DRP. These two independent advisors provided regular and effective reviews of Unit 2 execution progress.14

13 See EB-2016-0152, Ex. D2-2-9 Program Execution, Section 8, for discussion of the forms of oversight in place at the beginning of the execution of the Unit 2 refurbishment.
14 See Ex. D2-2-8 Oversight, Section 5, for more detailed descriptions of the RCRB and BMcD/Modus roles.
The RCRB delivered 14 reports over the course of Unit 2 refurbishment. In general, the RCRB provided overall findings on Unit 2 progress as well as more specific observations regarding the current and upcoming scopes of work.

BMcD/Modus reported to the OPG Board of Directors on a quarterly basis over the course of the Unit 2 refurbishment. BMcD/Modus delivered detailed reports regarding OPG’s Unit 2 execution performance as well as on all other major scopes of work being executed.

7.0 REPORTING

In accordance with the OEB’s Decision and Order in EB-2016-0152, OPG produced annual reports on the DRP in each of 2018, 2019 and 2020 which summarized Program performance, including the refurbishment of Unit 2. Copies of the 2018 and 2019 reports are provided in Attachments 1 and 2.

8.0 RATE BASE AND CAPACITY REFURBISHMENT VARIANCE ACCOUNT TREATMENT

The revenue requirement impact of the difference between the OEB approved amounts and actual in-service additions (and associated timing) to rate base for DRP is recorded in the CRVA. Clearance of balances in the CRVA is predicated on the OEB determining the prudence of any in-service amounts over the approved amounts prior to disposition. The CRVA includes capital and non-capital costs and firm financial commitments incurred in respect of the DRP, which is forecasted to be completed in 2026.

As noted above, OPG provided the U2EE in EB-2016-0152 and used the U2EE as the baseline against which to track its Program performance through the execution of the Unit 2 refurbishment. OPG did not update its EB-2016-0152 revenue requirement as a result of the U2EE and instead requested that any variance against the originally proposed (and ultimately approved) in-service amounts be recorded in the CRVA. The OEB agreed with this approach, stating as follows in the EB-2016-0152 Decision and Order:

15 EB-2016-0152 Decision and Order, pp. 44-45.
The OEB is of the view that it is not necessary to use the Unit 2 Execution Estimate as the basis for its approvals. The OEB notes that the CRVA will operate to capture any revenue requirement impacts of changes to in-service dates and in-service amounts between OEB-approved and actual. Therefore, using the in-service amounts and dates as proposed by OPG is reasonable.  

As noted in Section 5.0, there is a forecast variance of $132.7M, or 2.5%, against the total EB-2016-0152 approved in-service addition of $5,177.4M (which was comprised of in-service additions of $4,800.2M for Unit 2, including the Definition Phase, and of $377.2M for the Unit 2 Early In-Service projects, F&IP and SIO); the revenue requirement impact corresponding to this variance is recorded in the CRVA.

In this application, OPG is not seeking inclusion of the variance against the EB-2016-0152 approved in-service additions in rate base for the purposes of setting payment amounts for the IR term. Under OPG’s proposal, the revenue requirement impact of the variance would continue to be recorded in the CRVA. Further details regarding the proposed rate base treatment can be found in Ex. B1-1-1, Section 2.

OPG also is not seeking clearance of DRP-related amounts in the CRVA in this application, except for certain amounts related to the D2O Storage Project. OPG proposes to defer the clearance of DRP-related amounts recorded in the CRVA to a future application, which would assess of the recoverability of any DRP-related variances in the context of the overall performance of the four-unit refurbishment, including the effectiveness of Lessons Learned and Strategic Improvements from the earlier unit refurbishments. OPG’s proposed treatment of the variances is consistent with the DRP being a single mega-program as opposed to a collection of smaller projects. The CRVA is discussed further in Ex. H1-1-1, Section 5.6.

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16 EB-2016-0152 Decision and Order, p 39.
17 Ex. H1-1-1, Section 5.6 and see, footnote 1.
ATTACHMENTS

3  Attachment 1: Darlington Refurbishment Program 2018 Annual Report
4  Attachment 2: Darlington Refurbishment Program 2019 Annual Report
Darlington Refurbishment Program Annual Report

AS PER DECISION AND ORDER IN EB-2016-0152
# TABLE OF CONTENTS

**INTRODUCTION** ........................................................................................................................................... 2
**EXECUTIVE SUMMARY** .......................................................................................................................... 2

**DARLINGTON REFURBISHMENT PROGRAM STATUS** ........................................................................... 3
  **OVERVIEW** ............................................................................................................................................... 3
  **PROGRESS** .............................................................................................................................................. 3
  **SAFETY** .................................................................................................................................................... 5
    Campaigns, Programs and Initiatives ................................................................................................... 6
  **RADIOLOGICAL SAFETY** ........................................................................................................................ 7
    Program Radiological Events ................................................................................................................ 7
  **QUALITY** ................................................................................................................................................... 7

**SCHEDULE** ............................................................................................................................................... 8

**COST** ...................................................................................................................................................... 10
  Performance Metrics Summary ........................................................................................................... 10

**ENGINEERING** ....................................................................................................................................... 10

**PROCUREMENT** .................................................................................................................................... 12
  OPG’s Overall Contracting Strategy ................................................................................................... 12
  Procurement Status for Unit 2 ............................................................................................................. 12

**CONSTRUCTION** ................................................................................................................................... 12
  Construction Progress Summary ........................................................................................................ 12
  Labour Relations Issues Summary ..................................................................................................... 13
  Environmental Issues Summary ......................................................................................................... 13

**TESTING, START-UP AND COMMISSIONING** ..................................................................................... 13
  Return to Service (RTS) Summary ..................................................................................................... 13
  RTS Process ....................................................................................................................................... 14

**PROGRAM RISKS AND RISK MANAGEMENT** ..................................................................................... 14

**STAFFING** ............................................................................................................................................... 15
  OPG Unit 2 Resources ........................................................................................................................ 15
  Efforts to Fill Open Positions ............................................................................................................. 15
INTRODUCTION

This report provides the status of the Darlington Refurbishment Program (DRP), hereafter referred to as the “Program”. The Program comprises Unit 2, early in-service work and pre-requisite projects.

Unless otherwise noted, this report includes a summary and a review of the Program performance through September 30th, 2018.

This is the first in a series of annual reports to be provided by Ontario Power Generation (OPG) to the Ontario Energy Board (OEB) pursuant to the OEB’s decision and order in EB-2016-0152.1

EXECUTIVE SUMMARY

The Darlington Refurbishment Program is a multi-year, multi-phase, mega-project that will enable the Darlington Generating Station (“Darlington”) to continue safe and reliable operation until approximately 2055. The Program includes the replacement of life-limiting critical components, the completion of upgrades to meet applicable regulatory requirements, and the rehabilitation of components at Darlington’s four units.

The Release Quality Estimate (RQE) for the four-unit refurbishment is $12.8 billion. Under RQE, the first unit to be refurbished (Unit 2) is scheduled to be returned to service in the first quarter of 2020 and the last unit is scheduled to be completed by 2026. The RQE formed the basis of OPG’s May 2016 pre-filed evidence in EB-2016-0152. Since the development of the RQE in November 2015, OPG continued detailed planning and preparations for execution of Unit 2 and established a Unit 2 Execution Estimate (U2EE). This estimate was approved by OPG’s Board of Directors in August 2016 and has been used to establish Unit 2 project baselines for cost and schedule monitoring. Details of the U2EE were provided in EB-2016-0152, Exhibit L, Tab 4.3, Schedule 1, Staff-055. Detailed planning associated with U2EE confirmed that the overall program and associated contingencies were within the $12.8 billion RQE, but resulted in a 1% increase specific to program costs for Unit 2 and the early in-service work and pre-requisite projects. The OEB approved the EB-2016-0152 revenue requirements based on the RQE forecasts per Ex. N2, Tab 1, Schedule 1 in that proceeding. The High Confidence Schedule2 discussed in this Report is unchanged between the RQE and the U2EE.

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1 EB-2016-0152, Decisions with Reasons, dated December 28, 2018, p.44, Table 16.
2 OPG’s description of the High Confidence Schedule is found under the “Schedule” section in this report. Note that any reference to ‘as planned’ or ‘on plan’ refers to the High Confidence Schedule.
OPG commenced the refurbishment of Unit 2 in October 2016. The Program has been divided up into segments of work that focus on the various refurbishment stages that Unit 2 must go through prior to returning to service. The first segment, which includes the de-fuelling of the reactor and the physical separation of Unit 2 from the three operating units, was completed in the first half of 2017 in accordance with the High Confidence Schedule. The second major segment, which included the disassembly and removal of the existing reactor components, was completed in May 2018 in accordance with the High Confidence Schedule. Unit 2 is currently in the third major segment, the installation and reassembly of reactor components. To date, the third segment is progressing as planned with the installation of all calandria tubes and a number of systems have been returned to service in accordance with the High Confidence Schedule. Preparation activities for the fourth segment, the restart of Unit 2, have commenced and 22 of 58 systems have been returned to service.

Anticipating that a mega-project such as the Darlington Refurbishment would be subject to varying degrees of risks, OPG built contingency into the High Confidence Schedule to help address risks that materialize as the refurbishment progresses. Since the beginning of the project, OPG has used its risk management and project control processes to address project risks effectively within existing contingencies. With a large portion of the work on Unit 2 now complete, and looking ahead at the work that remains, OPG expects to have sufficient contingency to address the remaining risks and complete the Program at the in-service amounts approved by the OEB.

OPG continues to identify, document, evaluate and incorporate lessons learned from ongoing and completed projects into future work, leading to opportunities to execute work more efficiently.

DARLINGTON REFURBISHMENT PROGRAM STATUS

OVERVIEW

Key Program highlights include:

- **SAFETY**: Over 11 million hours have been worked since Unit 2 breaker open in October 2016 and there have been no lost time injuries. Safety performance continues to be 10 times better than the average construction industry performance in Ontario.

- **QUALITY**: There were no high level quality events or impacts to the High Confidence Schedule; however, as anticipated, there have been low level events resulting in rework.

- **SCHEDULE**: Execution of the Unit 2 Refurbishment is currently 70% complete and forecasting ahead of the 40-month High Confidence Schedule.

- **COST**: Life-to-date Program costs are $4.57 billion. The Current Estimate at Completion consistent with the predicted early in-service date to complete all Program work is $5.62 billion, which is within the amounts approved by the OEB.

PROGRESS

The following is a status summary of the major work groupings since the start of Unit 2 refurbishment. As expected, there have been challenges during execution, however the Program remains on track.

- **De-Fuel & Islanding (Critical Path Work)**
  During the first segment of the Program, all of the fuel bundles for Unit 2 were successfully removed from the reactor core and moved to the used fuel bay for storage. Additionally, bulkheads were installed to separate Unit 2 from the rest of the station and, following the repair of weld defects, the
pressure test hold point was completed to confirm that Unit 2 was completely isolated from the operating units. Segment one was completed in April 2017.

- **Re-tube & Feeder Replacement (RFR) (Critical Path Work)**
  The second major segment of the Program, the removal segment, is complete. During this segment, the remaining reactor components, including end fittings and fuel channel assemblies and feeders, were all removed safely. Following removal of the reactor components, key inspections were done on components such as the calandria and bellows. The reactor face was cleaned in preparation for new components.

  The Program’s third major segment, the installation segment, is underway. In this segment, new fuel channel assemblies and feeder pipes are being installed. The calandria tube installation series is complete and fuel channels are being installed. This work is forecast to be completed in Q1 2019. Feeder installation is also progressing in parallel with the installation of the fuel channel assemblies and is forecast to be completed in Q2 2019.

- **Turbine Generator (TG)**
  Since September 2017, all three low pressure turbine rotors and all major turbine stationary components were removed for inspection and repaired as required. All generator cooling water hoses were replaced, the generator current transformers and high voltage bushings were replaced, minor stress corrosion cracking on the turbine rotors was repaired, and steam valves, vessels and heat exchangers were inspected and repaired. Technical issues experienced during TG execution and work required based on the results of inspections delayed the completion of the TG work. However, the re-assembly phase is progressing and the remaining inspection-based repairs are being closed out. The TG project is forecast to be completed by early 2019 with no impact to Unit 2 return to service or critical path.

- **Balance of Plant (BoP)**
  Work completed in the BoP bundle includes electrical maintenance work, water systems maintenance, and the replacement of a number of large valves throughout the primary heat transport and moderator systems. Primary and secondary side steam generator clean work and substantial work related to the adjuster rods replacement, horizontal and vertical flux detector replacement is complete. Preparations are currently underway to execute activities related to restoring Unit 2 as well as the completion of a shutdown cooling system modification. The majority (85%) of the BoP work is complete with a few work programs continuing into 2019.

- **Return to Service (RTS)**
  Preparation activities for the restart of Unit 2 have commenced and 22 of 58 systems have been returned to service. RTS work will continue through 2019 when the work is forecast to be complete and the unit brought back online.

- **Facilities & Infrastructure Projects (F&IP) and Safety Improvement Opportunities (SIO)**
  Of the 11 F&IP and SIO projects in the Program, 10 have been placed in service. The Shield Tank Overpressure Protection (STOP) installation is complete on Units 1, 3, and 4 and will be complete on Unit 2 in Q1 2019 as planned.

- **Integrated Implementation Plan (IIP)**
  Annual IIP tasks are commitments to the Canadian Nuclear Safety Committee (CNSC). To date, OPG has completed 44 out of 51 tasks and the remaining 7 are on plan for completion by year-end 2018.
SAFETY

Safety is a paramount priority for OPG. Due to this focus on safety, OPG has one of the lowest injury rates in the Canadian electricity sector. The Canadian Electricity Association (CEA) awarded OPG the President’s Award of Excellence for its 2017 safety performance. Additionally, the Canadian Nuclear Safety Commission has awarded the Darlington Nuclear Generating Station the highest possible safety performance rating for the last eight consecutive years in publicly released safety assessments.

In order to maintain this safety performance, OPG continues to set challenging targets for its day-to-day operations. Notwithstanding that the Program work is being executed by contractors and trades in a very complex construction environment, OPG purposefully sets the same challenging targets and expects the same level of performance from the Program. This expectation has resulted in a Program safety performance that is 10 times better than the overall construction industry average as illustrated in Table 1.

OPG employs a variety of leading indicators to ensure that issues are addressed before incidents occur. OPG’s practice of proactively tracking events where no injuries occur, but where there is potential for harm, is one example of a leading indicator. OPG carefully logs and reviews each of these incidents and adopts corrective actions to prevent future incidents.

In 2017, the first full year of execution of the Program, there was an increase in the number of people working on the Program, which resulted in a proportional increase in the number of incidents with higher potential for harm. In 2018, the number of these incidents dropped significantly demonstrating the effectiveness of OPG’s rigorous approach to safety.

Performance Metrics Summary

Table 1 provides a summary of the Program safety performance and includes OPG and contractor employees.

<table>
<thead>
<tr>
<th>Category</th>
<th>Measure</th>
<th>Historical Actuals</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2016</td>
<td>2017</td>
</tr>
<tr>
<td>Safety</td>
<td>All Injury Rate (per 200k hours)¹ / Total Recordable Injury Frequency</td>
<td>0.64</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>Lost Time Due to Injuries</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Notes:
1  In 2018, OPG selected Total Recordable Injury Frequency (TRIF), replacing All Injury Rate (AIR), as a measure for evaluating health and safety performance, which reflects a change instituted by the Canadian Electrical Association. Total Recordable Injury Frequency is the average number of fatalities, lost time injuries, medical treatment injuries and restricted work injuries per 200,000 hours worked.
2  OPG sets very challenging targets for its operations and expects the same level of performance from the Program.
3  This rating is the most current safety rating for the Ontario Construction Industry.

³ Compared to the Industrial Health and Safety Association injury rate.
CAMPAIGNS, PROGRAMS AND INITIATIVES

OPG developed a corporate ‘Why iCare to Work Safely’ campaign that underlies all OPG’s safety initiatives and programs. The purpose of this campaign is to encourage workers to view safety as a personal endeavour and to reinforce OPG’s robust safety culture.

OPG’s strong safety performance is underpinned by the practice of monitoring low level precursor issues and proactively taking action to reduce the risk of serious events from occurring. With the ‘iCare’ message in place, the following are additional safety campaigns, programs and initiatives that OPG and its vendor partners have launched:

- **Seven Life Saving Rules Campaign (March 2017 – Ongoing)**
  This campaign was developed to communicate industrial safety to all trades and to educate contractors about OPG’s higher safety standards, the fact that adherence to these rules is mandatory, and that there is zero tolerance for violations.

- **Working at Heights (July 2017)**
  This initiative, which aligns with the Ministry of Labour’s focus on this area for the construction industry, is aimed at improving worker awareness and the ability to perceive risk and hazard recognition. The initiative emphasized required equipment inspections and improvements in physical barriers and housekeeping to better manage falling objects.

- **Safety Stand-Down (November 2017)**
  Safety stand-downs are a standard industry practice to pause work and reset workers’ attention to focus on safety. In keeping with OPG’s safety practice to monitor low level precursors and proactively reduce the risk of higher-level events, one of OPG’s major vendor partners stood down their workforce, with OPG’s support, due to concerns over a small but increasing number of incidents related to potential conventional workplace safety issues.

- **Continuous Air Monitoring Sampling for Calandria Tube and Calandria Tube Insert Removal (January 2018)**
  OPG installed continuous air monitors in the vault during removal of fuel channel reactor components to provide more accurate, real time indications of changing air quality conditions and ensure worker safety and comfort while working at the reactor face.

- **Material Handling (February 2018)**
  The initiative was aimed at enhancing material movement planning, job site risk recognition and increasing awareness of experience from both the nuclear industry and other industries.

- **Musculoskeletal Disorder (MSD) and Hand Injury Prevention (May 2018)**
  OPG collaborated with its vendor partners to implement actions such as:
  - purchasing improved dexterity gloves for both conventional and radiological work;
  - engaging in strategic dexterity gloves with workers regarding glove use policy;
  - increasing MSD awareness and consideration during work planning; and
  - creating a Two Minute Jobsite Drill to help workers recognize work tasks that could potentially lead to an MSD injury.

- **Heat Stress Campaign (Summer 2017 – Summer 2018)**
  The primary strategy of this campaign was to increase worker awareness and ensure workers in the field could recognize signs and symptoms of heat stress. The campaign included the construction of 5 cooling tents, distribution of water bottles, promotion of hydration and the entire organization taking a proactive approach to heat stress awareness.
RADIOLOGICAL SAFETY

OPG has a robust Radiation Protection (RP) program and overall performance continues to be good with total worker dose better than plan. No worker has received a dose above either regulatory limits or OPG’s own more stringent internal targets. Based on the execution work done to date, the Program is currently on track to finish with the lowest Collective Radiation Exposure (CRE) of any nuclear refurbishment completed to date. This is a result of OPG’s robust nuclear safety culture and its As Low As Reasonably Achievable (ALARA) RP program.

PERFORMANCE METRICS SUMMARY

Table 2 provides a summary of the Program radiological safety performance and includes OPG and contractor employees.

<table>
<thead>
<tr>
<th>Table 2 – Radiological Safety Performance Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016 Year End</td>
</tr>
<tr>
<td>Actual</td>
</tr>
<tr>
<td>CRE (person-rem)</td>
</tr>
<tr>
<td>Unplanned Exposures</td>
</tr>
</tbody>
</table>

One event of interest to OPG’s nuclear regulator, the Canadian Nuclear Safety Commission (CNSC), occurred in February 2018, and corrective actions and improvement initiatives have been implemented or continue to be underway throughout the year. Further details on this event are outlined under ‘Program Radiological Events’.

PROGRAM RADIOLOGICAL EVENTS

In February 2018, two workers in the Re-tube Waste Processing Building (RWPB) received an unplanned internal dose of alpha radiation. Although doses involved were small (less than 1% of the legal limit), the CNSC performed a Reactive Inspection and requested that OPG provide detailed information to show that OPG had adequate controls over RP practices throughout the Program. OPG provided a comprehensive response with corrective measures on oversight of RP practices in the field, training of field RP staff, and documentation of survey results, among others. Other improvement initiatives are also being pursued to better align RP work schedules with Vendor partners’ schedules, improve pre-job briefings, and investigate opportunities in RP innovation for efficiency gains.

QUALITY

There have been no high-level Quality events or impacts to the High Confidence Schedule to date on the Program. OPG’s contractors are required to perform all work safely and diligently, in an organized and timely manner, and in accordance with the agreement, applicable laws and prudent practices. Notwithstanding the exercise of prudent practices by OPG and its contractor, a certain amount of typical rework is to be expected on a project of this nature. As such, OPG included an allowance for rework in its agreements with its contractors and included sufficient contingency in its High Confidence Schedule in recognition of this risk. OPG’s Quality Management program monitors lower level quality issues and OPG works collaboratively with its contractors to ensure mitigation measures are implemented to prevent

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4 This event did not meet the criteria to be classified as an ‘unplanned exposure’ as in Table 2.
recurrence. Lessons learned from lower level incidents are incorporated into the planning of future Unit 2 work as well as future unit refurbishment planning.

PROGRAM QUALITY EVENTS

Complexities related to welding of dissimilar metals required to accommodate components used to measure the flow of water through the feeder pipes were encountered during feeder fabrication. These issues are not unique to OPG as dissimilar metal welds have presented a world-wide industry challenge. OPG, together with the Electric Power Research Institute (EPRI), CanAtom, Candu Energy and US research labs, a specialized mill in France, BWXT in Cambridge and Laker Energy Products, successfully overcame the feeder pipe fabrication challenges.

This is a major industry breakthrough and will result in significant benefits to the nuclear industry as it has solved a life-limiting condition for CANDU reactors.

While the start of feeder pipe installation was delayed due to this challenge, there was no impact to the High Confidence Schedule as rework was considered in the contingency built into the original plan. The feeder work program is progressing in parallel with fuel channels on critical path. OPG continues to monitor execution of the feeder pipe installation closely and is taking actions to mitigate any further delays.

SCHEDULE

OPG measures Program progress against two estimates:

1. A High Confidence Schedule (released by OPG publicly in 2016 and reviewed by the OEB as part of OPG’s 2017-2021 rate application5); and

2. A shorter “Working Schedule” that excludes contingency, which OPG uses to manage day-to-day activities. Schedule Performance Index (SPI)6 is measured against the Working Schedule.

The difference between these two schedules is that the High Confidence Schedule includes contingency amounts that were quantified based on detailed analysis of risks and these contingency amounts are expected to be utilized over the course of the Program. The Working Schedule is used to calculate performance metrics, for example Schedule Performance Index (SPI), and manage day-to-day activities, allowing for early escalation of issues. The use of a Working Schedule is an industry leading best practice for large and complex projects.

PERFORMANCE METRICS SUMMARY

The Program is currently tracking ahead of the High Confidence Schedule and forecasting a late 2019 completion date.

Table 3 provides a summary of the Program schedule performance as of October 29th, 2018.

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5 While the budget for U2 and associated campus plan projects increased between RQE and U2EE, the High Confidence Schedule did not change.

6 This strategy provides an early indication of potential risks or issues and allows OPG to proactively manage Program performance.
# Table 3 – Schedule Performance Metrics

<table>
<thead>
<tr>
<th>Measure</th>
<th>2016 Year End Actual</th>
<th>2017 Year End Actual</th>
<th>2018 Q3 Actual</th>
<th>Working Schedule Target</th>
<th>High Confidence Schedule Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days Ahead of / Behind High Confidence Schedule Life-to-Date ¹</td>
<td>28 Days Ahead</td>
<td>10 Days Ahead</td>
<td>33 Days Ahead</td>
<td>N/A</td>
<td>27-Feb-2020</td>
</tr>
<tr>
<td>Critical Path Days Ahead of / Behind³ Working Schedule Life-to-Date</td>
<td>19 Days Ahead</td>
<td>47 Days Behind</td>
<td>50 Days Behind</td>
<td>19-Sep-2019</td>
<td>N/A</td>
</tr>
<tr>
<td>Schedule Performance Index (SPI)²</td>
<td>0.97</td>
<td>0.94</td>
<td>0.92</td>
<td>1.00</td>
<td>N/A</td>
</tr>
<tr>
<td>Forecast Completion Date ³</td>
<td>31-Aug-2019</td>
<td>5-Nov-2019</td>
<td>8-Nov-2019</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Notes

1. Days Ahead/Behind is calculated as progress for all work currently completed relative to the life-to-date allotment of Contingency Days available in the High Confidence Schedule.
2. Schedule Performance Index is calculated for construction, commissioning and inspection work packages only against the Working Schedule.
3. Critical Path Days Ahead/Behind and Forecast Completion Date are calculated as progress for all work currently completed relative to the Working Schedule and does not consider projected gains or losses for future work.

Table 4 provides a summary of the key Program milestones and the actual and forecast completion against the High Confidence Schedule. Each segment was completed or is currently forecasted to be completed ahead of plan.

# Table 4 – Key Unit 2 Milestone Status

<table>
<thead>
<tr>
<th>Key Milestone</th>
<th>Planned Completion ¹</th>
<th>Actual/Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment 1 [Lead In] Complete</td>
<td>April 27th, 2017</td>
<td>April 9th, 2017</td>
</tr>
<tr>
<td>Segment 2 [Removal] Complete</td>
<td>June 2nd, 2018</td>
<td>May 5th, 2018</td>
</tr>
<tr>
<td>Segment 3 [Install] Complete</td>
<td>August 7th, 2019</td>
<td>May 6th, 2019</td>
</tr>
<tr>
<td>Segment 4 [Lead Out/Return to Service] Complete</td>
<td>February 27th, 2020</td>
<td>November 8th, 2019</td>
</tr>
</tbody>
</table>

Note

¹ Planned completion date refers to the High Confidence Schedule.
COST

PERFORMANCE METRICS SUMMARY

Total Program costs are currently $4.57 billion life to date. Forecast total life cycle cost at completion is expected to be $5.62 billion, which is within the amounts approved by the OEB, recognizing that risks remain, particularly those associated with Return to Service as discussed below.

Similar to SPI, Cost Performance Indicator (CPI) is measured against the working schedule budget that excludes contingency. The CPI for Unit 2 is 0.90.

Table 5 provides a summary of the key Program cost performance.

<table>
<thead>
<tr>
<th>CPI</th>
<th>Life to Date Q3 2018 (LTD) Actual Cost</th>
<th>Current Estimate to Complete (ETC)</th>
<th>Current Estimate at Completion (EAC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9</td>
<td>$4.57 Billion</td>
<td>$1.05 Billion</td>
<td>$5.62 Billion</td>
</tr>
</tbody>
</table>

Note

1 Program expenditures include Capital and Operations, Maintenance and Administration (OM&A) costs consistent with OEB-approved amounts.

In its December 28th, 2017 Decision and Order in EB-2016-0152, the OEB included Actual Versus Forecast Cumulative Capital Costs as part of OPG's annual reporting requirements. This requirement was further defined in JT1.17C in the same proceeding as quarterly cost flows for the Unit 2 in-service amount of $4.8 billion approved by the OEB (excludes early in-service and pre-requisite projects that are included in Table 5 above). Table 6 and Figure 1 provides this information:

<table>
<thead>
<tr>
<th>M$</th>
<th>OEB Undertaking JT 1.17C (Forecast)</th>
<th>Actual Cost Incurred (September 2018)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTD 2016</td>
<td>2,280</td>
<td>2,118</td>
</tr>
<tr>
<td>Q1 2017</td>
<td>2,501</td>
<td>2,350</td>
</tr>
<tr>
<td>Q2 2017</td>
<td>2,721</td>
<td>2,616</td>
</tr>
<tr>
<td>Q3 2017</td>
<td>2,960</td>
<td>2,886</td>
</tr>
<tr>
<td>Q4 2017</td>
<td>3,188</td>
<td>3,175</td>
</tr>
<tr>
<td>Q1 2018</td>
<td>3,433</td>
<td>3,348</td>
</tr>
<tr>
<td>Q2 2018</td>
<td>3,674</td>
<td>3,536</td>
</tr>
<tr>
<td>Q3 2018</td>
<td>3,909</td>
<td>3,742</td>
</tr>
<tr>
<td>Q4 2018</td>
<td>4,147</td>
<td></td>
</tr>
<tr>
<td>Q1 2019</td>
<td>4,292</td>
<td></td>
</tr>
<tr>
<td>Q2 2019</td>
<td>4,435</td>
<td></td>
</tr>
<tr>
<td>Q3 2019</td>
<td>4,563</td>
<td></td>
</tr>
<tr>
<td>Q4 2019</td>
<td>4,689</td>
<td></td>
</tr>
<tr>
<td>Q1 2020</td>
<td>4,800</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4,800</td>
<td></td>
</tr>
</tbody>
</table>
ENGINEERING

Aggregate earned value for engineering is 99% complete for Unit 2. This figure includes both vendor and OPG engineering work that is being performed for the Program.

All planned engineering work is complete for Unit 2 and the majority of engineering requirements through execution are complete. Field engineering activities continue as planned to ensure issues are resolved as they emerge and designs are modified in field as required.

Major engineering accomplishments in the period include:

- A process was designed to ensure successful return to service of Unit 2 components. This “System Available for Service” process was developed, piloted and finalized and has been used to successfully return 22 systems to service. Training for staff involved in restart activities is underway.

- A construction/field engineering group was established to focus on improving processes and enable the timely response to field-initiated changes.

- Lessons learned from previous work is being captured and applied to all future work.

- Engineering review forums were enhanced for strong management and control of scope.

In addition, the following First of a Kind (FOAK) projects are being monitored closely:

- Shutdown Cooling System enhancements involving the addition of two new auxiliary shutdown cooling pumps which are currently in the installation phase.

- Steam Generator Inlet Strainers are being designed, fabricated and tested to enhance the build-clean process and mitigate the impact of any foreign material in the heat transport system. Delivery of the strainers is expected early in 2019.
• Modifications to improve margin in the Emergency Service Water system following a main steam line break and provide an emergency water supply for Beyond Design Basis Accidents (BDBA). The project is currently in-progress to complete early 2019.

PROCUREMENT

OPG’S OVERALL CONTRACTING STRATEGY

To manage the work associated with the Program, OPG uses a “multi-prime contractor” model in which there is more than one prime contractor working on the Program. OPG, as the owner, has a separate contract with each prime contractor. Each prime contractor is responsible for completion of the work that is within the scope of its contract. As the owner, OPG is the integrator among the prime contractors and is responsible for the entire Program.

OPG’s contract management approach allows for early identification and quick resolution of issues, while holding each party to its respective accountabilities in accordance with contract terms and conditions. OPG’s contract provisions tie contractors’ incentives to the long-term success of the Program and align OPG and contractors’ goals. This approach was developed from lessons learned in other refurbishment projects and is considered an industry best practice.

OPG has developed robust processes and tools to ensure all services and materials are brought in on time, on budget, safely and with quality. OPG’s extensive contract management processes track contractors’ costs and performance. These processes also ensure that issues are addressed and parties are held to their respective accountabilities under contract terms and conditions.

PROCUREMENT STATUS FOR UNIT 2

At the end of Q3 2018, over 95% of all the requested materials for Unit 2 refurbishment were on site, with delivery of the remaining material items on track.

CONSTRUCTION

CONSTRUCTION PROGRESS SUMMARY

The execution of Unit 2 is currently 70% complete. The bulk of the construction on Unit 2 is related to the disassembly and removal of the existing reactor components, followed by the installation and reassembly of the new reactor components. The following key construction challenges have been encountered and addressed during Unit 2 refurbishment (see the Safety and Quality sections for other challenges encountered):

• The construction of the Re-tube Waste Processing Building (RWPB) was delayed, which created a risk to the building being available in time to receive waste from the End Fitting Removal series. To mitigate this risk, OPG assembled a dedicated team of subject matter experts to assist the contractor, perform targeted oversight and advise on certain aspects of the remainder of the facility’s construction. This action contributed to the RWPB being made available for use on time to receive the first delivery of end fittings with no impact to critical path.

• During the removal phase there were a few construction series that experienced tooling issues. An integrated Tool Management team was assembled to focus on resolving issues quickly using equipment suppliers and industry experts from previous nuclear refurbishment programs. The work involved enhanced use of the mock-up facility at the Darlington Energy Complex, to prepare for subsequent series, and optimizing equipment operation. As a result, some tooling issues were mitigated.

• Recent industry refurbishment operating experience on foreign material in the Heat Transport (HT) system during unit restart was assessed. The identified risk will be mitigated with the insertion of
strainers during HT system commissioning. Mock-up testing of the approved strainer design has shown favourable results. Once testing has been completed, the temporary strainers will be installed as an additional barrier to remove foreign material from the system.

- Welding upper feeders to the existing reactor inlet/outlet headers involved production challenges associated with tooling performance and weld quality during the Upper Feeder Installation series. OPG established a technical team, which included industry experts, to mitigate these challenges through tool set-up and evaluation of weld requirements.

- The calandria tube installation series experienced challenges with a limited number of rolled joint leak tests due to site conditions. A cross-functional team reviewed the efficacy of the test requirements, developed a cleaning process to establish a better seal and brought in new tools from Pickering to corroborate the previous test results.

- The adjuster rod replacement project was challenged by the discovery of several elongated titanium rods. A team was formed to modify the removal process. This allowed work to proceed and lessons learned will be used in subsequent unit refurbishments.

- The moderator system valve rehabilitation project was challenged with insufficient weld purge and nitric acid build up. The team worked through technical and scheduling issues in order to accomplish the work safely and with quality.

The following were key construction challenges with the Turbine Generator (TG) work program.

- Inspections done on the low-pressure turbine rotors identified required repairs. Under tight timelines, a large lathe was located, leased, transported and assembled to machine the spindles. This significant undertaking was a first-of-a-kind for OPG’s nuclear stations and involved complex logistics and coordination with multiple internal and external groups throughout North America. These repairs have now effectively extended the life of the rotors for at least another 30 years.

- Final inspection of condenser diffuser welds revealed repairs required prior to return to service. Multiple vendors are collaborating to find the required number of qualified welders to expedite the repairs to ensure years of reliable operation.

LABOUR RELATIONS ISSUES SUMMARY

There have been no labour relations impacts on the Program to date and OPG is proactively taking steps to mitigate any future issues.

ENVIRONMENTAL ISSUES SUMMARY

To date, the Program has had no reportable spills or infractions. Emissions are better than target and well below all regulatory limits.

TESTING, START-UP AND COMMISSIONING

RETURN TO SERVICE (RTS) SUMMARY

Preparation activities for the restart of Unit 2 have commenced and 22 of 58 systems have been returned to service.

Over the period, the following RTS focus areas were identified:

- returning systems to service to support the first Restart Control Hold Point (RCHP);
- working with vendor partners on documentation submissions required to support the start up of Unit 2; and
• finalizing station integration plans to ensure resources, plans and procedures are in place to support the successful start of Unit 2.

RTS PROCESS

The RTS process is a highly complex process and involves eight planned RCHPs, addressing regulatory and non-regulatory checks. The first RCHP will confirm that all system requirements have been met prior to refilling the moderator with heavy water. The second RCHP is a regulatory hold point prior to loading the reactor with fuel. As Unit 2 refurbishment moves through the eight RCHP’s, stringent measures are in place to ensure safety and quality are maintained at all times and each system is subjected to rigorous checks and testing prior to being returned to service.

In order to ensure worker safety and to reinforce the significance of this crucial segment, OPG has developed a ‘Road to Restart’ communications campaign that outlines the five important stages leading up to Unit 2 returning to service. The five stages are:

1. Fuel Channels Installed – focus will be on the moderator being filled
2. Feeders Installed – focus will be on fuel load and the heat transport system being filled
3. Primary Heat Transport Strainer Clean – focus will be on Unit 2 warming up
4. Auxiliary Shutdown Cooling Complete – focus will be on containment being restored
5. Plant Restored – focus will be on the approach to criticality and then full power operation

The ‘Road to Restart’ messaging will be at the forefront of the Return to Service organization and will be reinforced with workers throughout the remainder of all Unit 2 work.

RTS RISKS FOR UNIT 2

Actions are in place to mitigate risks associated with returning the Unit 2 to service such as foreign material exclusion, hot conditioning of the unit and integration between the station and the Program.

PROGRAM RISKS AND RISK MANAGEMENT

OPG uses a robust risk management process where risks are identified, classified, quantified and mitigated to the extent possible. In a project of this size and scope, global experience dictates that there will be uncertainties that cannot be entirely mitigated or avoided. As such, OPG maintains a detailed inventory of risks and contingency amounts in accordance with the recommended practices of the Association for the Advancement of Cost Engineering – a leading authority in the area of project cost estimation. These contingency amounts are expected to be used over the course of the Program.

The following two risks associated with trades are actively being managed by OPG:

1. AVAILABILITY OF SKILLED CRAFT RESOURCES / SUPERVISION FOR FUTURE UNITS

   Shortage of skilled trades is a risk for the Program. OPG identified this risk early in the Program and has taken mitigating actions, which are tracked and regularly reported to senior management and OPG’s Board of Directors.

   OPG continues to address gaps in the availability of skilled trades. In particular, OPG is continuing its collaboration with Bruce Power, relevant unions, educational institutions and other stakeholders to minimize potential cost and disruptions to the Program. This collaboration involves three streams to mitigate the risk of skilled trades’ availability as outlined below:

   a. collaboration between OPG, Bruce Power, vendors and trade unions to develop enhanced skilled trades’ supply and demand data;
b. initiatives to build capacity within the current supply of trades by streamlining processes at both OPG and Bruce Power, including coordinated security processing and training, as well as modified shift schedules to attract talent;

c. building new sources of supply by promoting trades programs through recruitment initiatives at local job fairs, community outreach and specific initiatives to increase the level of interest of women and indigenous peoples in the trades; and

d. working with various Provincial entities and other Canadian organizations across the country such as trade unions, colleges and other stakeholders, to increase the supply of skilled trades.

2. TIMELY RENEWAL OF COLLECTIVE AGREEMENTS FOR UNIONIZED CONSTRUCTION TRADES

The collective agreements at risk relate to construction trades. The construction agreements are set to expire on April 30th, 2020 for all construction and Electrical Power Systems Construction Association collective agreements. However, Nuclear Program Agreements (NPA) expire December 31st, 2032, which mitigates construction collective agreement labour disruption risks throughout the life of the Program. The NPA is an appendix to the current collective agreements and will be included in each renewal collective agreement occurring during the term of the NPA.

The PWU and Society agreements typically are effective for two to three years. OPG is in the process of collective bargaining with PWU and Society.

For other risks and challenges, see the ‘Construction’ and ‘Testing, Start-up and Commissioning’ sections.

STAFFING

REFURBISHMENT RESOURCES

Table 7 provides a summary of the OPG Resources on the Refurbishment program.

<table>
<thead>
<tr>
<th>Measure</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQE</td>
<td>501</td>
<td>740</td>
<td>752</td>
<td>758</td>
</tr>
<tr>
<td>Actual Full Time Equivalents (FTEs)¹</td>
<td>535</td>
<td>766</td>
<td>821</td>
<td></td>
</tr>
</tbody>
</table>

Note

¹ Actual FTEs for 2018 are as of September year to date

EFFORTS TO FILL OPEN POSITIONS

OPG has a number of programs in place to attract, retain and develop qualified personnel for the Program. Management continues to use corporate-wide succession planning and talent review processes to identify and prepare future leaders to assume key roles over the life of the Program.

OPG’s Enterprise Projects Organization is focused on implementing a standardized and scalable project delivery model throughout the enterprise. This organization has developed a training program specifically designed to advance project management capability across the organization. In addition, OPG’s succession planning program and mentoring initiatives are designed to ensure that capability is sustained throughout the Program.
Darlington Refurbishment Program Annual Report

2019 REPORT

AS PER DECISION AND ORDER IN EB-2016-0152
TABLE OF CONTENTS

INTRODUCTION .............................................................................................................. 2

EXECUTIVE SUMMARY ................................................................................................. 2

DARLINGTON REFURBISHMENT THRU UNIT 2 STATUS .................................................. 3

OVERVIEW ......................................................................................................................... 3

PROGRESS .......................................................................................................................... 3

SAFETY ............................................................................................................................... 4

  Performance Metrics Summary ....................................................................................... 4

  Campaigns, Programs And Initiatives ............................................................................ 5

RADIOLOGICAL SAFETY ................................................................................................. 5

  Performance Metrics Summary ....................................................................................... 6

QUALITY ............................................................................................................................ 6

SCHEDULE .......................................................................................................................... 6

  Performance Metrics Summary ....................................................................................... 7

COST .................................................................................................................................. 8

  Performance Metrics Summary ....................................................................................... 8

ENGINEERING ................................................................................................................... 10

PROCUREMENT ............................................................................................................... 11

  Procurement Status For Unit 3 ....................................................................................... 11

CONSTRUCTION .............................................................................................................. 11

  Construction Progress Summary .................................................................................... 11

  Labour Relations Issues Summary ................................................................................... 11

  Environmental Issues Summary ..................................................................................... 11

TESTING, START-UP AND COMMISSIONING .................................................................. 11

  Return-To-Service .......................................................................................................... 11

  RTS Risks For Unit 2 ...................................................................................................... 12

PROGRAM RISKS AND RISK MANAGEMENT .................................................................. 12

STAFFING .......................................................................................................................... 13

  Refurbishment Resources ............................................................................................. 13

  Efforts To Fill Open Positions ........................................................................................ 13
INTRODUCTION

This report provides the status of the Darlington Refurbishment Program (DRP), hereafter referred to as the “Program”.

Unless otherwise noted, this report includes a summary and a review of the Program performance through September 30th, 2019.

This is an annual report to be provided by Ontario Power Generation (OPG) to the Ontario Energy Board (OEB) pursuant to the OEB’s decision and order in EB-2016-0152.¹

EXECUTIVE SUMMARY

The Darlington Refurbishment Program is a multi-year, multi-phase, mega-project that will enable the Darlington Generating Station (“Darlington”) to continue safe and reliable operation until approximately 2055. The Program includes the replacement of life-limiting critical components, the completion of upgrades to meet applicable regulatory requirements, and the rehabilitation of components at Darlington’s four units.

The Release Quality Estimate (RQE) for the four-unit refurbishment is $12.8 billion. Under RQE, the refurbishment of the first unit (Unit 2) was to start in the fall of 2016 and be returned-to-service in the first quarter of 2020, with the last unit scheduled to be completed by 2026. The RQE formed the basis of OPG’s May 2016 pre-filed evidence in EB-2016-0152. Since the development of the RQE in November 2015, OPG continued detailed planning and preparations for execution of Unit 2 and established a Unit 2 Execution Estimate (U2EE). This estimate was approved by OPG’s Board of Directors in August 2016 and has been used to establish Unit 2 project baselines for cost and schedule monitoring. Details of the U2EE were provided in EB-2016-0152, Exhibit L, Tab 4.3, Schedule 1, Staff-055. Detailed planning associated with U2EE confirmed that the overall program and associated contingencies were within the $12.8 billion RQE, but resulted in a $89 million increase specific to program costs for Unit 2 and the Early In-service Work and Campus Plan projects. The OEB approved revenue requirement in EB-2016-0152 was based on the earlier RQE forecasts per Exhibit N2, Tab 1, Schedule 1 in that proceeding as opposed to the U2EE.

OPG commenced the refurbishment of Unit 2 in October 2016. The refurbishment of Unit 2 was divided into segments of work that focus on the various stages that Unit 2 must go through prior to returning to service. The first segment, which included the de-fuelling of the reactor and the physical separation of Unit 2 from the three operating units, was completed in the first half of 2017 in accordance with the original High Confidence Schedule. The second major segment, which included the disassembly and removal of the existing reactor components, was completed in May 2018 in accordance with the original High Confidence Schedule. The third major segment involving the installation and reassembly of reactor components was completed in October 2019.

Unit 2 is now scheduled to be returned-to-service in the second quarter of 2020 because of challenges associated with the third major segment.

¹ EB-2016-0152, Decisions with Reasons, dated December 28th, 2018, p.44, Table 16.
Unit 2 is currently in the fourth major segment; fuel load and restoring systems in order to bring the unit back online. As of November 5th, 2019, 40 of 58 systems have been returned-to-service.

Preparations for the refurbishment of Unit 3 have been progressing well. Thousands of lessons learned from the refurbishment of Unit 2 have been applied during the planning stage of Unit 3. These lessons have helped to streamline and improve planning for cost and schedule performance in preparation for the execution phase. Design and engineering are 90% complete. Comprehensive Work Packages continue to progress as planned and long lead material procurement is on track with no risks to execution. All prerequisite projects are currently on track for completion in advance of their need dates.

**DARLINGTON REFURBISHMENT THRU UNIT 2 STATUS**

**OVERVIEW**

Key Program highlights include:

- **SAFETY:** Safety performance continues to be almost 10 times better than the average construction industry performance in Ontario. The Program has worked 19.8 Million hours since October 2016 and has incurred only one Lost Time Injury.²

- **QUALITY:** The Program’s quality performance remains good overall. There were 3 high level quality events on Unit 2 refurbishment that impacted the High Confidence Schedule. All quality events have been resolved.

- **SCHEDULE:** Execution of the Unit 2 refurbishment is currently 89% complete and the work not associated with critical path is 96% complete. The Return-to-Service (RTS) date has moved from Q1 2020 to Q2 2020.

- **COST:** Life-to-date (LTD) Unit 2 and Early In-Service and Campus Plan projects (excluding the Heavy Water Storage Facility (HWSF)) costs are $5.4 billion. While Unit 2 and Early In-Service and Campus Plan projects are forecasting to be $137 million over the OEB-approved amounts, Unit 2 is forecasting to be completed on budget relative to U2EE. The overall Program, including Unit 2, remains within the $12.8 billion RQE budget. A detailed explanation for the $137 million variance is set out in the Cost section below.

**PROGRESS**

The following is a status summary as of September 30th, 2019, of the major work completed since the last report to the OEB in December 2018:

- Reactor assembly is nearly complete – installation of new Fuel Channels, Feeders, and Reactivity Mechanisms is complete.

- Turbine Generator (TG) overhaul is complete.

- Steam Generator work is complete and the Condensate System is in-service.

- Service Water and Electrical Systems are complete and in-service.

- RTS

   Work on the Moderator and End Shield Cooling Systems is complete and the systems have been filled and returned to service.

---

² A Lost Time Injury is a work injury that results in lost days (minimum of one) beyond the date of injury as a direct result of a safety incident.
Facilities & Infrastructure Projects (F&IP) and Safety Improvement Opportunities (SIO).

All F&IP and SIO projects were placed in service with the exception of the HWSF. The Shield Tank Overpressure Protection (STOP) installation was completed on Unit 2 in Q2 2019.

Integrated Implementation Plan (IIP).

Annual IIP tasks are commitments to the Canadian Nuclear Safety Committee (CNSC). All 50 tasks committed for 2018 were completed by December 13th, 2018. Eighty-five of the 99 IIP tasks committed for 2019 were completed and the remaining 14 are tied to the RTS schedule with the appropriate approvals in progress.

SAFETY

Safety is a priority for OPG. Due to this focus on safety, OPG has one of the lowest injury rates in the Canadian electricity sector. In order to maintain this safety performance, OPG continues to set challenging targets for its day-to-day operations. In Q3 2019, the Program reported a Total Recordable Injury Frequency (TRIF) of 0.49 against its internal target of 0.37 as a result of two medically treated injuries. The TRIF rate has been progressively improving throughout 2019 due to ongoing safety initiatives that target and mitigate negative safety trends. Despite the Program work being executed by contractors and trades in a very complex construction environment, OPG purposefully set the same challenging targets for the Program as for its operations and expects the same level of performance from the Program. This expectation has resulted in a Program safety performance that is almost 10 times better than the overall construction industry average as illustrated in Table 1.

After 3,426 days and 15.5 million hours worked, the Program incurred its first Lost Time Injury (LTI) in May 2019 on Unit 2 involving a worker who tripped.

OPG employs a variety of leading indicators to ensure that issues are addressed before incidents occur. OPG’s practice of proactively tracking events where no injuries occur, but where there is potential for harm, is one example of a leading indicator. OPG carefully logs and reviews each of these incidents and implements corrective actions to prevent future incidents.

PERFORMANCE METRICS SUMMARY

Table 1 provides a summary of the Program’s safety performance and includes OPG and contractor employees.

<table>
<thead>
<tr>
<th>Category</th>
<th>Measure</th>
<th>Historical Actuals</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2016</td>
<td>2017</td>
</tr>
<tr>
<td>Safety</td>
<td>Total Recordable Injury Frequency (per 200k hours)¹</td>
<td>0.64</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>Lost time Due to Injuries</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Notes:
1 TRIF is the average number of fatalities, LTIs, medical treatment injuries and restricted work injuries per 200,000 hours worked.
2 Year-to-Date (YTD)
3 OPG sets very challenging targets for its operations and expects the same level of performance from the Program.
4 This rating is the most current safety rating for the Ontario Construction Industry.

³ Compared to the Industrial Health and Safety Association injury rate.
CAMPAIGNS, PROGRAMS AND INITIATIVES

OPG’s safety performance is underpinned by the practice of monitoring low level precursor issues and proactively taking action to reduce the risk of serious events from occurring. The following are the key safety campaigns, programs and initiatives that OPG and its contractor partners launched in 2019:

- **Implementation of Cut Resistant Liners in Containment (January 2019)**
  After observing a trend related to cuts and punctures through radiation personal protective equipment inside the Unit 2 vault, Conventional Safety and OPG Refurbishment Maintenance explored and implemented new and improved gloves to replace cotton liners in order to reduce the injury frequency. Cut resistant liners are now available to staff.

- **2019 Heat Stress Campaign (April 2019)**
  The primary purpose of this campaign was to build upon previous campaigns to further increase worker awareness and ensure workers in the field could recognize signs and symptoms of heat stress.

- **RTS Self-Assessment & Subsequent Actions (May 2019)**
  An RTS Self-Assessment was completed by Conventional Safety and focused on all initial work tasks associated with returning Unit 2 back to service. The goal of the self-assessment was to evaluate any conventional safety hazards and/or areas of concern in order to provide accompanying recommendations and/or actions. The self-assessment was completed in May 2019 and all actions are complete with ongoing checks and communications until U2 RTS is complete.

- **Falling/Dropped Objects Corporate Initiative (May 2019)**
  In late 2018 and early 2019, there was an increased number of dropped object events across OPG. Additional barriers, including the use of tool tethers and a revised falling objects control checklist were rolled out in the Program in order to reduce the likelihood of dropped object events. The Program is considering the installation of alternative debris netting.

- **Safety Stand-down (May 2019)**
  A stand-down was initiated on May 20th, 2019 following a series of safety incidents. All trade staff were sent home for a 24 hour period and an action plan was developed with a focus on increased Supervisor oversight in the field and safety communications. Since the stand-down, the Program has seen a significant improvement to the reinforcement of safety behaviours.

- **Working at Heights (August 2019)**
  A Working at Heights Self-Assessment was completed by Conventional Safety in order to identify the safe work planning process and any potential deficiencies involved with working at heights inside the Unit 2 vault.

RADIOLOGICAL SAFETY

OPG’s Radiological Protection (RP) program meets regulatory requirements and industry standards. The program is implemented across OPG’s fleet, including in the Program. No worker has received a dose above either regulatory limits or OPG’s more stringent internal targets. This performance is a result of OPG’s robust nuclear safety culture and its “As Low As Reasonably Achievable” (ALARA) RP program. Additionally, many improvements have been made in the course of the refurbishment of Unit 2, allowing many lessons learned to be applied to the planning of the remaining units.

The Collective Radiological Exposure (CRE) actual at the end of 2018 was marginally above target due to the longer durations in the vault required to complete Upper Feeder and Fuel Channel installations.
other metrics are at or better than target. The 2019 performance also is above target and is again attributable to longer durations in the vault related to the feeder program extension. The Refurb ALARA committee is monitoring and challenging RP performance to ensure ALARA principles continue to apply with the objective of reducing dose to workers.

PERFORMANCE METRICS SUMMARY

Table 2 provides a summary of the Program radiological safety performance and includes both OPG and contractor employees.

<table>
<thead>
<tr>
<th></th>
<th>2017 Year End</th>
<th>2018 Year End</th>
<th>2019 End of Q3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual</td>
<td>Target</td>
<td>Actual</td>
</tr>
<tr>
<td>CRE (person-rem)¹</td>
<td>1144</td>
<td>1383</td>
<td>784</td>
</tr>
<tr>
<td>Unplanned Exposures</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Note 1 A lower number represents a lower amount of radiological exposure.

QUALITY

The refurbishment of Unit 2 involved many thousands of removal and installation activities which were required to be executed with a high degree of precision. Many of the installation activities involved precision fit-up tasks and critical and highly technical welding operations. A certain amount of rework is to be expected on a Program of this nature. Given the number of tasks, Unit 2’s Quality performance has been good overall.

As of September 30th, there have been 5 Significant Quality Events. The most significant impact to the project is attributed to a higher than planned weld rework rate during the installation of Lower Feeders. All issues were resolved and lessons learned from these issues were incorporated into planning for the remaining units.

SCHEDULE

OPG measures Program progress against two schedules:

1. A High Confidence Schedule; and

The difference between these two schedules is that the High Confidence Schedule includes additional contingency amounts that were quantified based on detailed analysis of risks. These contingency amounts are expected to be utilized over the course of the Program. The Working Schedule is used to calculate performance metrics, for example Schedule Performance Index (SPI)⁴, and manage day-to-day activities, allowing for early escalation of issues. The use of a Working Schedule and High Confidence Schedule is an industry leading best practice for large and complex projects.

⁴ This strategy provides an early indication of potential risks or issues and allows OPG to proactively manage Program performance.
PERFORMANCE METRICS SUMMARY

As a result of the challenges encountered on the Feeder installation series, the remaining schedule for Unit 2 was reassessed. This assessment indicated a potential 4 month extension to schedule in returning Unit 2 to full power, therefore the High Confidence date for completion of Unit 2 was revised from Q1 2020 to Q2 2020.

Lessons learned from Unit 2 are being applied to the planning of the remaining units to enable unit-over-unit efficiencies. Many challenges faced on the Unit 2 refurbishment, such as the dissimilar metal welds and FME issues have been resolved, and improvements to tooling have been made, all of which are expected to lead to significant execution improvements for the remaining units.

Table 3 provides a summary of the Unit 2 schedule performance as of September 30th, 2019 relative to the Original Working Schedule.

<table>
<thead>
<tr>
<th>Measure</th>
<th>2016 Year End Actual</th>
<th>2017 Year End Actual</th>
<th>2018 Q3 Actual</th>
<th>2019 Q3 Actual</th>
<th>Working Schedule Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days Ahead of / Behind High Confidence Schedule LTD 1</td>
<td>28 Days Ahead</td>
<td>10 Days Ahead</td>
<td>33 Days Ahead</td>
<td>72 Days Behind</td>
<td>N/A</td>
</tr>
<tr>
<td>Critical Path Days Ahead of / Behind Working Schedule LTD</td>
<td>19 Days Ahead</td>
<td>47 Days Behind</td>
<td>50 Days Behind</td>
<td>206 Days Behind</td>
<td>19-Sep-2019</td>
</tr>
<tr>
<td>SPI 2</td>
<td>0.97</td>
<td>0.94</td>
<td>0.92</td>
<td>0.89</td>
<td>1.00</td>
</tr>
<tr>
<td>Early Forecast Completion Date 3</td>
<td>31-Aug-2019</td>
<td>5-Nov-2019</td>
<td>8-Nov-2019</td>
<td>20-May-2020</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Notes
1 Days Ahead/Behind is calculated as progress for all work currently completed relative to the LTD allotment of Contingency Days available in the High Confidence Schedule.
2 SPI is calculated for construction, commissioning and inspection work packages only against the Working Schedule.
3 Critical Path Days Ahead/Behind and Early Forecast Completion Date are calculated as progress for all work currently completed relative to the Working Schedule and does not consider projected gains or losses for future work.
Table 4 provides a summary of the key Program milestones and the actual and forecast completion against the original planned completion and the revised High Confidence Schedule.

<table>
<thead>
<tr>
<th>Key Milestone</th>
<th>Original Planned Completion</th>
<th>Revised High Confidence Schedule</th>
<th>Actual/ Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment 1 [Defuel] Complete</td>
<td>April 27th, 2017</td>
<td>N/A</td>
<td>April 9th, 2017</td>
</tr>
<tr>
<td>Segment 2 [Removal] Complete</td>
<td>June 2nd, 2018</td>
<td>N/A</td>
<td>May 5th, 2018</td>
</tr>
<tr>
<td>Segment 3 [Install] Complete</td>
<td>August 7th, 2019</td>
<td>December 22nd, 2019</td>
<td>December 22nd, 2019</td>
</tr>
</tbody>
</table>

**COST**

**PERFORMANCE METRICS SUMMARY**

Total Program costs are currently $6.5 billion LTD. The forecast total cost at completion for Unit 2 including all Early In-Service and Campus Plan projects, but excluding the HWSF, is expected to be $5.7 billion, which is $137 million above the amounts approved by the OEB. The overall Program continues to forecast on plan at $12.8 billion.

Following the approval of the RQE in 2015, OPG continued detailed planning and preparations for execution of Unit 2 and established the U2EE as part of its phase gate planning process. Detailed planning associated with U2EE confirmed that the overall Program and associated contingencies were within the $12.8 billion set at RQE, and resulted in an increase specific to Program costs for Unit 2 and the Early In-service work and Campus Plan projects. This estimate, approved by OPG’s Board of Directors, established the detailed cost and schedule baselines by which Unit 2 performance would be monitored.

Relative to U2EE, Unit 2 expenditures as of September 30th, 2019 are $3.2 billion and forecast to be on target to achieve the U2EE estimate of $3.4 billion at completion.

The OEB approved revenue requirement in EB-2016-0152 was based on the earlier RQE forecasts per Exhibit N2, Tab 1, Schedule 1 in that proceeding as opposed to the more refined U2EE. Based on the forecast total cost at completion for Unit 2, the $137 million variance to OEB-approved amounts is attributed to:

- $89 million difference between RQE and U2EE for planned increases to Unit 2, Early In-service work, and Campus Plan projects, and
- $48 million variance above U2EE for the Early In-Service and Campus Plan projects.

As of the time of the last report, OPG was forecasting to be within the OEB-approved amounts on the basis that the Unit 2 unused contingency would be sufficient to cover the cost variances experienced on the Campus Plan projects. As a result of the challenges encountered on the Feeder installation series for Unit 2, a portion of the unused contingency was allocated to the Feeder series, which left the remaining contingency being less than the Campus Plan projects’ cost variances.

Similar to SPI, Cost Performance Index (CPI) is measured against the budget that excludes contingency. The CPI for Unit 2 is 0.84.
Table 5 provides a summary of the key Program cost performance.

<table>
<thead>
<tr>
<th>CPI</th>
<th>LTD Q3 2019 Actual Cost</th>
<th>Current Estimate to Complete</th>
<th>Current Estimate at Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.84</td>
<td>$5.4 Billion</td>
<td>$0.3 Billion</td>
<td>$5.7 Billion</td>
</tr>
</tbody>
</table>

Table 5 – Cost Performance Metrics for Thru Unit 2

Note 1 Program expenditures include Capital and Operations, Maintenance and Administration (OM&A) costs consistent with OEB-approved amounts.

In its December 28th, 2017 Decision and Order in EB-2016-0152, the OEB included Actual Versus Forecast Cumulative Capital Costs as part of OPG’s annual reporting requirements. This requirement was further defined in JT1.17C in the same proceeding as quarterly cost flows for the Unit 2 in-service amount of $4.8 billion approved by the OEB (excludes early in-service and pre-requisite projects that are included in Table 5 above). Table 6 and Figure 1 provide this information:

Table 6 provides a summary of the Actual vs. Forecast Cumulative Capital Costs.

<table>
<thead>
<tr>
<th>M$</th>
<th>OEB Undertaking JT 1.17C (Forecast)</th>
<th>Actual Cost Incurred</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTD 2016</td>
<td>2,280</td>
<td>2,118</td>
</tr>
<tr>
<td>Q1 2017</td>
<td>2,501</td>
<td>2,350</td>
</tr>
<tr>
<td>Q2 2017</td>
<td>2,721</td>
<td>2,616</td>
</tr>
<tr>
<td>Q3 2017</td>
<td>2,960</td>
<td>2,886</td>
</tr>
<tr>
<td>Q4 2017</td>
<td>3,188</td>
<td>3,175</td>
</tr>
<tr>
<td>Q1 2018</td>
<td>3,433</td>
<td>3,348</td>
</tr>
<tr>
<td>Q2 2018</td>
<td>3,674</td>
<td>3,536</td>
</tr>
<tr>
<td>Q3 2018</td>
<td>3,909</td>
<td>3,742</td>
</tr>
<tr>
<td>Q4 2018</td>
<td>4,147</td>
<td>3,955</td>
</tr>
<tr>
<td>Q1 2019</td>
<td>4,292</td>
<td>4,146</td>
</tr>
<tr>
<td>Q2 2019</td>
<td>4,435</td>
<td>4,360</td>
</tr>
<tr>
<td>Q3 2019</td>
<td>4,563</td>
<td>4,557</td>
</tr>
<tr>
<td>Q4 2019</td>
<td>4,689</td>
<td></td>
</tr>
<tr>
<td>Q1 2020</td>
<td>4,800</td>
<td></td>
</tr>
<tr>
<td>Q2 2020</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4,800</td>
<td></td>
</tr>
</tbody>
</table>

Note 1 Capital costs include Unit 2, Unit 0 and Definition Phase.
ENGINEERING

Aggregate earned value for engineering is 99% complete for Unit 2. This figure includes both contractor and OPG engineering work that is being performed for the Program.

All planned engineering work is complete for Unit 2 and the majority of engineering requirements through execution are complete. Field engineering activities continue as planned to ensure issues are resolved as they emerge and designs are modified in field as required.

Design engineering for Unit 3 is 90% complete and is on track to be substantially complete by end of 2019. Lessons learned from Unit 2 are being incorporated into subsequent designs as appropriate.

Major engineering accomplishments in the period include:

- The “System Available for Service” process has been used to successfully return systems to service in Unit 2. As of November 5th, 2019, 40 systems have been returned to service. Training for staff involved in restart activities is continuing.
- The construction/field engineering group continues to successfully focus on improving processes and enabling the timely response to field initiated changes.
- The Re-tube & Feeder Replacement (RFR) Engineering OneTeam was formed between OPG and CanAtom and has led to improved collaboration and effectiveness between the engineering functions. Based on the RFR Engineering OneTeam success, this model is being extended to other significant project bundles such as TG for the remaining units.
- All safety analyses required to support unit restart and operation at high power have been submitted to the CNSC.
- Lessons learned from previous work continue to be captured and applied to future work. The Unit 3 Vault Vapour Recovery System modification was installed in Q2 2019 with significant savings compared to Unit 2, based on incorporation of lessons learned.

In addition, the following First-of-a-Kind projects are being monitored closely:

- Shutdown Cooling System enhancements involving the addition of two new auxiliary shutdown cooling pumps. The project has recently completed the field installation phase and is moving into the commissioning phase.
- Modifications to the Emergency Service Water system, which provides an emergency supply of water in a beyond design basis event of a main steam line break. The project is currently in the latter stages of the installation phase and is scheduled to be completed prior to the return-to-service of Unit 2.
PROCUREMENT

PROCUREMENT STATUS FOR UNIT 3

At the end of Q3 2019, 99% of Purchase Orders have been issued and 71% of all the requested materials for Unit 3 refurbishment were on site, with delivery of the remaining material items on track.

CONSTRUCTION

CONSTRUCTION PROGRESS SUMMARY

The execution of Unit 2 is currently 89% complete and non-critical path activities are 96% complete. The following major accomplishments occurred within the period:

- The RFR Installation series is complete following the installation of Fuel Channels and Feeders, and loading of the fuel. Challenges with welding, tooling and human performance at the beginning of the Feeder series had a cascading effect throughout the series and impacted the RTS Schedule. The issues were resolved and lessons learned are being applied to the planning of the remaining units. The final installation work required for the RFR series is Lower Body Tubing.
- The TG Overhaul project had challenges with the final coupling vacuum testing of the Generator resulting in the TG activities being placed on hold until repairs could be performed. Following the repairs and clean-up, the coupling vacuum test was completed successfully on April 9th, 2019.
- The Auxiliary Shutdown Cooling breaker construction was completed on July 29th, 2019.
- Fourteen obsolete computers were replaced to improve the performance of the Unit 2 shutdown system.
- The STOP project was completed on all four Units. This SIO initiative was the last of five SIOs intended to significantly improve the current plant mitigation capabilities to cope with the unlikely event of a multi-unit severe accident. The STOP project added an additional safety component to prevent over pressurization of the shield tanks.

LABOUR RELATIONS ISSUES SUMMARY

There have been no labour relations impacts on the Program to date and OPG is proactively taking steps to mitigate any risks of future issues.

ENVIRONMENTAL ISSUES SUMMARY

In 2019, the Program continues to have no reportable spills or infractions. Emissions are better than target and well below all regulatory limits.

TESTING, START-UP AND COMMISSIONING

RETURN-TO-SERVICE

Preparation activities for the restart of Unit 2 are continuing and, as of November 5th, 2019, 40 of 58 systems have been returned-to-service. Over the period, the following RTS focus areas were identified:

- completion of risk challenge process for all key evolutions and integrating the results into key evolution plans;
- returning systems to service to support the Restart Control Hold Points (RCHP);
- working with contract partners on documentation submissions required to support the start-up of Unit 2; and
- finalizing station integration plans to ensure resources, plans and procedures are in place to support the successful start of Unit 2.
The RTS process is highly complex and involves eight planned RCHPs, addressing regulatory and non-regulatory checks. The first RCHP was achieved with the moderator system being filled with heavy water. This milestone was achieved event free and with zero leaks. The second RCHP for New Fuel Load was achieved on November 3rd followed by the CNSC’s approval to proceed with loading fuel into the reactor on November 5th, ahead of the need date. The next scheduled RCHP will be the Primary Heat Transport (PHT) System Fill. As Unit 2 refurbishment moves through the six remaining RCHP’s, stringent measures are in place to ensure safety and quality are maintained at all times and each system is subjected to rigorous checks and testing prior to being returned-to-service.

The RTS program was extensively reviewed by both internal and external organizations in 2019 to assess and confirm the Program’s readiness to return Unit 2 to service. OPG has incorporated opportunities for improvement identified by these assessments.

**RTS RISKS FOR UNIT 2**

The revised High Confidence schedule includes contingency days to address remaining risks and to ensure all work continues to be performed safely and with quality.

**PROGRAM RISKS AND RISK MANAGEMENT**

OPG uses a robust risk management process where risks are identified, classified, quantified and mitigated to the extent possible. In a project of this size and scope, global experience dictates that there will be uncertainties that cannot be entirely mitigated or avoided. As such, OPG maintains a detailed inventory of risks and contingency amounts in accordance with the recommended practices of the Association for the Advancement of Cost Engineering – a leading authority in the area of project cost estimation. These contingency amounts are expected to be used over the course of the Program.

The following three major risks are being actively being managed by OPG:

1. **AVAILABILITY OF SKILLED CRAFT RESOURCES / SUPERVISION FOR THE REMAINING UNITS**

   Shortage of skilled trades is a risk for the Program. OPG identified this risk early in the Program and has taken mitigating actions, which are tracked and regularly reported to senior management and OPG’s Board of Directors.

   OPG continues to address gaps in the availability of skilled trades. In particular, OPG is continuing its collaboration with Bruce Power, relevant unions, educational institutions and other stakeholders to minimize potential cost and disruptions to the Program. This collaboration involves four streams to mitigate the risk of skilled trades’ availability as outlined below:

   a) collaboration between OPG, Bruce Power, contractors and trade unions to develop enhanced skilled trades’ supply and demand data;

   b) initiatives to build capacity within the current supply of trades by streamlining processes at both OPG and Bruce Power, including coordinated security processing and training, as well as the development of a hybrid shift schedule designed to attract and retain the right resources and implement a sustainable schedule for the duration of the project;

   c) meetings held with OPG Indigenous Opportunities in Nuclear (ION) representatives and local indigenous employment offices focusing on ways to increase the level of interest of indigenous peoples in the trades; and

   d) establishing a boilermaker pre-apprentice program with Durham College.
2. TIMELY RENEWAL OF COLLECTIVE AGREEMENTS FOR UNIONIZED CONSTRUCTION TRADES

The collective agreements risk relates to the 19 Building Trade Unions. The Building Trade Union agreements are set to expire on April 30th, 2020 for all Collective Agreements both directly with OPG and through the Electrical Power Systems Construction Association. Early collective bargaining has commenced with one collective agreement having been reached with the Boilermakers thus far. The Nuclear Projects Agreements (NPA) expire December 31st, 2032 and helps mitigate Building Trade Union labour disruption risks throughout the life of the Program. The NPAs are an appendix to the current collective agreements and will be included in each renewal collective agreement occurring during the term of the NPA. Exceptions include the Operating Engineers, Canadian Union of Skilled Workers and the Labourers who either failed to agree to an NPA or maintain exit clauses.

Collective Agreements with the Power Workers Union (PWU) and the Society of United Professionals (Society) are typically effective for two to three years. The current Society collective agreement is set to expire on December 31st, 2019. A new collective agreement effective from January 1st, 2020 through December 31st, 2021 was awarded through interest arbitration on June 6th, 2019. The current PWU collective agreement was awarded through interest arbitration on April 3rd, 2019 and remains in effect from April 1st, 2018 until March 31st, 2021.

3. MANAGING THE COMMERCIAL IMPACT OF CONTRACTORS

OPG’s Commercial Management is continually monitoring its contractors and their performance given the limited number of qualified vendors and substantial work in the industry. OPG is working collaboratively with Bruce Power to ensure adequate availability of reactor components for both the Program and Bruce Power’s major component replacement project.

STAFFING

REFURBISHMENT RESOURCES

Table 7 provides a summary of the OPG Resources on the Program:

| Table 7 – Full Time Equivalent (FTE) Resources by Year (plan vs. actual) |
|-----------------------------|----------------|----------------|----------------|
| Measure                     | 2017 | 2018 | 2019 | 2020 |
| Planned at ROE              | 740  | 752  | 758  | 747  |
| Actual¹                     | 7792 | 8692 | 853  | N/A  |

Note

1. Actual FTEs for 2019 are as of September YTD.
2. 2017 and 2018 FTE numbers are being restated as they were incorrectly reported in the 2018 report.

EFFORTS TO FILL OPEN POSITIONS

OPG has a number of programs in place to attract, retain and develop qualified personnel for the Program. Management continues to use corporate-wide succession planning and talent review processes to identify and prepare future leaders to assume key roles over the life of the Program.

OPG’s Enterprise Projects Organization is focused on implementing a standardized and scalable project delivery model throughout the enterprise. This organization has developed a training program specifically designed to advance project management capability across the organization. In addition, OPG’s succession planning program and mentoring initiatives are designed to ensure that capability is sustained throughout the Program. The Program has been successful in filling positions.