# REMAINING UNITS PLANNING

## 1.0 OVERVIEW

This exhibit describes the process used for planning for the refurbishment of Units 3, 1, and 4, (the "Remaining Units"). OPG implemented a similarly detailed process to plan for the refurbishment outages of the Remaining Units as was used for Unit 2. The planning process was modified to account for scope differences, different risks such as those caused by the first-of-a-kind installation of turbine generator digital controls on Unit 3 and risks associated with the overlapping of the Remaining Units' refurbishment outages, and to incorporate Lessons Learned and Strategic Improvements.

Detailed information is provided on the following:

- Section 2.0: Discusses the process used at the time of the Release Quality Estimate ("RQE") to develop the scope of the Program. It also discusses scope differences between Unit 2 and the Remaining Units, including minor scope differences between each of the Remaining Units.
- Section 3.0: Discusses the strategic approach to planning for the Remaining Units.
- Section 4.0: Discusses the governance and process of the lessons learned program. "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. This section also gives examples of the incorporation of Lessons Learned from Unit 2 into the planning and execution of the Remaining Units.
- Section 5.0: Discusses "Strategic Improvements", which are new approaches and/or innovative methods for planning and executing the Remaining Units' refurbishments that are being implemented in addition to Lessons Learned. The section discusses how Strategic Improvements are being effectively incorporated into the planning and execution of the Remaining Units.
- Section 6.0: Discusses the collaboration initiatives with Bruce Power.

# 2.0 UNIT-OVER-UNIT SCOPE DIFFERENCES

## 2.1 Program Scope Development Process

OPG's initial scope development process was described in EB-2016-0152, and consisted of:

1. Processes used during the Definition Phase of the Program to identify and define the scope of refurbishment work required across all units. This includes scope identification and documentation using Darlington Scope Requests ("DSRs"), initial and subsequent screening of DSRs, and review and approval of scope by the Program Scope Review Board ("PSRB").
2. Further screening done by the Darlington Refurbishment Scope Review Panel to confirm that scope was in alignment with the following primary considerations:
   - required a defuelled and dewatered state;
   - required a unit outage that would be significantly longer than a standard unit planned outage; and /or
   - could be completed in a manner that was substantially safer, resulted in lower radiation dose and/or was easier to complete if accomplished during the refurbishment outage, than during a normal maintenance outage or while the unit was operating.
3. The scope change process used to review proposed scope changes, once scope for the Program was fixed, culminating in approval by the PSRB.[1]

Work bundles were used by OPG for purposes of assigning project management accountability, as well as for purposes of contracting DRP work to outside contractors. The scope of work was grouped into five Major Work Bundles:[2]

- Retube and Feeder Replacement ("RFR");
- Turbine Generators;
- Fuel Handling and Defuelling;
- Steam Generators; and
- Balance of Plant.

[1] EB-2016-0152, Ex. D2-2-6.

[2] A high-level description of the Major Work Bundles was provided in EB-2016-0152, Ex. D2-2-3. See Ex. D2-Attachment 1 for an updated description of the five Major Work Bundles.

Neither the scope of the Program nor the process used to approve scope changes has changed materially since the completion of the scope development process at the time of the RQE. The Major Work Bundles remain the same with some minor movement of scope between bundles since the RQE.

## 2.2 Scope Differences – Unit 2 to Units 3, 1, and 4

There are two areas of scope differences between the Unit 2 refurbishment and the Remaining Units' refurbishments: (1) scope that does not need to be repeated in the Remaining Units; and, (2) scope that, for strategic and/or timing reasons, was not executed for Unit 2, but is planned for execution in the Remaining Units. These scope differences are described below.

First, certain scope does not need to be repeated for the Remaining Units. Darlington is an integrated 4-unit station, therefore certain systems are common to all units and the work only needs to be done once. As the four units are of the same design, there is engineering work that does not need to be redone for each unit. Examples of scope that does not need to be repeated for the Remaining Units include:

1. Retube and feeder prerequisite engineering;
2. Service air upgrades; and,
3. Various support facilities such as washrooms and workshops.

Second, there are scope differences that result from OPG's strategic planning. As noted in EB-2016-0152, the installation of digital turbine controls and generator excitation controls is planned to be performed on Units 3, 1, and 4 during the refurbishment outages, but was excluded from the Unit 2 refurbishment scope at the time of the RQE[3] for two main reasons: (1) there was still useful life left in the existing control systems on Unit 2; and, (2) to mitigate risk, given that Unit 2 was the first unit to be refurbished and that this large first-of-a-kind ("FOAK") modification would have introduced unnecessary additional risk into the planning and execution of the Unit 2 refurbishment.

[3] EB-2016-0152, Ex. D2-2-5, p. 10.

The first installation of the turbine and generator controls upgrades will occur during the Unit 3 refurbishment. This scope is not on the critical path of the Unit 3 refurbishment outage. OPG has taken measures to mitigate the risks associated with this FOAK modification, including the installation of a full-scope simulator to allow testing and training on the new digital controls before they are installed and commissioned on the Remaining Units. Figure 1 shows a picture of the Unit 3 turbine generator set.

**Figure 1: Photograph of the Unit 3 Turbine Generator Set**

## 3.0 REMAINING UNITS PLANNING

This section explains the approach taken to plan for the Remaining Units' refurbishments. The planning strategy that OPG has adopted to account for the overlapping refurbishment outage periods that occur for the Remaining Units is discussed. Tiered milestones established to measure progress of planning are explained. The current status of each of Units 3, 1, and 4 is also provided.

## 3.1 Planning Strategy

The refurbishments of the Remaining Units will all be executed with a degree of overlap. In addition, the planning periods also overlap. To manage these overlapping planning periods, there was a need to execute the planning process for the Remaining Units differently from the planning process for Unit 2. Where it was more efficient and cost-effective to do so, the planning and preparatory work for all of the Remaining Units was performed simultaneously. Key aspects of the planning strategy for the Remaining Units are briefly discussed below.

As was done for Unit 2, a very detailed set of planning milestones was developed for each of the Remaining Units. However, because of the overlapping planning periods, the management of the planning milestones needed to be done in an integrated manner across all three Remaining Units. Further detail on planning milestones is provided in Section 3.3.

OPG's application of Lessons Learned into the schedule and cost development for the Remaining Units is a significant factor influencing planning. The fact that the Program involves multi-unit refurbishments with largely similar scopes of work for each unit creates many opportunities to apply Lessons Learned. Lessons Learned are discussed in detail, with examples, below in Section 4.

In addition to Lessons Learned, OPG has incorporated several Strategic Improvements into the planning and execution of the Remaining Units. Strategic Improvements apply broadly to the execution of the Program and are typically not incremental improvements to the same process, but are new approaches or innovative methods expected to yield a step change in performance. Strategic Improvements are discussed in detail, including with specific examples, below in Section 5.

## 3.2 Planning Process Overview

As explained in Ex. D2-2-1, OPG's detailed planning over the Definition Phase of the Program enabled the development of a four-unit budget and schedule for the successful execution of the Program, known as the RQE. The RQE was finalized in November 2015 and serves as the baseline against which the cost performance of the Program is being measured. Subsequent

to the RQE, in August 2016, OPG prepared the Unit 2 Execution Estimate ("U2EE") to update the Program budget and schedule prior to the start of the Unit 2 refurbishment outage.

As was the case for Unit 2, the overall planning process for the Remaining Units is broadly divided into a Preliminary Planning phase and a Detailed Planning phase. The phased completion of planning for each of the Remaining Units results in a more detailed cost estimate and a more refined schedule at the end of each phase. The Preliminary Planning phase culminates with a unit's preliminary cost estimate and schedule and the Detailed Planning phase culminates with that unit's execution estimate ("EE"). At each EE, the estimate for the overall Program is also refreshed. Each unit's EE is the basis upon which OPG's Board of Directors approves the full release of funds to execute the corresponding refurbishment outage.

The overall planning timeline for each of the Remaining Units is approximately three years from the start of planning to disconnection of the unit from the electrical grid (known as "breaker open") to begin the refurbishment outage. However, because some of the planning activities for Units 1 and 4 were done in parallel with those for Unit 3, the overall elapsed planning period for Units 1 and 4 spans more than three years.

### 3.3 Planning Milestones

Planning deliverables such as the preliminary cost estimate and schedule and the unit EE require timely completion of all precursor activities with the requisite quality. OPG manages completion of the precursor activities by establishing detailed planning milestones and by utilizing a tiered milestone approach where the milestones are completed in a phased manner, as described below. As previously mentioned, because the Remaining Units' refurbishment outages will be executed in an overlapped manner, the planning periods, and hence planning milestone completion requirements for the Remaining Units, also overlap. To ensure on-time completion of the planning milestones, to manage the resource demands and to minimize costs to the extent feasible, OPG adapted its process for managing planning milestones from that used on Unit 2.

The planning milestones tiers are as follows: (1) Program milestones; (2) Segment milestones; (3) Outage Window milestones; and (4) Segment 0 milestones. These tiers are briefly described in the following paragraphs. Phased completion refers to prioritized completion of milestones based on approvals needed and timing of execution of the field work for each unit.

Program milestones are high-level milestones used to track major requirements that must be completed prior to the start of each refurbishment outage. These milestones are grouped by category, including: (1) Scope development; (2) Schedule development; (3) Labour Resources planning; (4) Material Requirements planning; (5) Risk Management planning; (6) Cost Estimate development, and (7) Regulatory approvals.

Segment milestones are defined for each segment of the refurbishment outage for each unit. As noted in Ex. D2-2-2, each refurbishment outage is divided into four segments that are executed in series:

- Segment 1: Lead In – Defuelling and Containment Isolation;
- Segment 2: Removal – the reactor is disassembled;
- Segment 3: Reassembly – the reactor is rebuilt; and
- Segment 4: Plant Restoration and Start-up – Refuelling, Restoration of the Vault, Recommissioning and Return to Service.

Segment milestones are established to ensure readiness to perform the work required within the segment in accordance with each unit's refurbishment outage schedule. Examples of Segment Milestones include: (1) completion of detailed engineering; (2) ensuring material purchase orders are issued; (3) updating of resource profiles; and (4) ensuring that resources are trained and ready to execute the work, for each respective segment.

Outage Windows refer to more granular portions of the schedule than a segment. Examples of Outage Windows are: (1) Defuelling - within the Lead In Segment; (2) Feeder removals - within the Removal Segment; (3) Fuel Channel installation – within the Reassembly Segment; and (4) Bulkhead Restoration – within the Plant Restoration and Start Up Segment. Outage Window milestones promote adherence to the schedule and successful execution of work.

Outage Window milestones cover activities such as: (1) issuing the comprehensive work packages (i.e., work instructions) and checking the work protection requirements; (2) releasing and staging materials; and (3) verifying the availability of tools, equipment and facilities.

Segment 0 work refers to physical work that primarily needs to be executed in the field prior to the refurbishment start date so that the refurbishment outage goes smoothly; thus Segment 0 milestones pertain to the completion of planning activities required to enable that fieldwork execution. A typical example of Segment 0 work is fuel handling reliability improvements to ensure that the fuelling machines will be able to operate at a high reliability level during the critical path activity of defuelling the unit.

Further details on planning milestones are provided in Attachment 2, Refurbishment Unit Planning Milestones and Attachment 3, Refurbishment Unit Planning Window Milestones.

### 3.4 Unit 3 Planning and Current Status

Planning for the refurbishment of Unit 3 was executed according to the processes described above in Sections 3.1-3.3.

During the Preliminary Planning phase, detailed engineering and long-lead procurement commenced. Milestones were defined to ensure that, as the Unit 3 planning process progressed from Preliminary to Detailed Planning, costs, schedule and execution strategies were being continually refined.

The Detailed Planning phase resulted in the production of a Unit 3 EE ("U3EE") in March 2019. The March 2019 U3EE was the basis for seeking approval from the OPG Board for the release of funds needed to proceed to the start of execution of the Unit 3 refurbishment, which at that time was planned for January 15, 2020. In August 2019, as a result of the revised Unit 2 schedule forecast (see Ex. D2-2-2 for further information), OPG decided to defer the start of the Unit 3 refurbishment outage to May 2020 to minimize the overlap of the beginning of the Unit 3 and the end of the Unit 2 refurbishment outages. This change also resulted in a decision to defer the start dates of the Units 1 and 4 refurbishment outages by three months and five

months, respectively, in order to maintain approximately the same degree of overlap in the schedule. The U3EE was updated in November 2019. This planned update reflected the schedule changes as well as the addition of two key Strategic Improvements that had been in development, namely, the Hybrid Schedule and a significant tooling improvement as part of the Darlington Unit 3 Innovations Project ("D3IP") (See Section 5).

The COVID-19 pandemic, and the Government of Ontario's state of emergency declaration on March 17, 2020 in response to it, resulted in a decision by OPG to further defer the start of the Unit 3 refurbishment outage to early September, 2020. The start dates of Units 1 and 4 were also correspondingly deferred to maintain the same degree of overlap in the schedule. This decision was finalized in August 2020, and the U3EE was updated to reflect these schedule impacts, and was approved by the OPG Board of Directors. This final U3EE is the baseline against which performance on the refurbishment outage of Unit 3 is being measured. The Program cost continues to be within the $12.8B budget (excluding any ultimate impacts of COVID-19). The final U3EE is filed as Attachment 1 of Ex. D2-2-7.

The Unit 3 refurbishment outage started on September 3, 2020[4] defuelling of the unit has been completed and installation of bulkheads, which are required in order to isolate Unit 3 from the operating units, is underway.

As explained in EB-2016-0152, OPG prepares both a Working Schedule, which is used to manage the day-to-day performance of a unit's refurbishment outage, and a High Confidence Schedule, which includes contingency for certain schedule risks that may be encountered. The High Confidence Schedule is the underlying basis of OPG's public commitment to the Independent Electricity System Operator, to OPG's Shareholder and to other stakeholders, and is the schedule against which OPG publicly reports is performance.

The High Confidence Schedule duration of the Unit 3 refurbishment outage is forecast to be 40 months, with the planned return to service on January 2, 2024. The Working Schedule

[4] Unit 3 was shut down for a station planned outage from July 30, 2020 to September 2, 2020 in order to remove a single fuel channel as part of the Fuel Channel Lifecycle Management program.

duration of the refurbishment outage is forecast to be 36 months, with the planned return to service on September 3, 2023. Further details on the Unit 3 schedule are provided in Ex. D2-2-5.

### 3.5 Units 1 and 4 Planning and Current Status

Planning for Units 1 and 4 is in progress. Lessons Learned on Unit 2 that have been applied to Unit 3, are also being applied to Units 1 and 4. As Unit 3 progresses, any incremental Lessons Learned will be incorporated into the Unit 1 and 4 plans. As previously discussed, there are efficiencies inherent in planning for the Remaining Units in an integrated manner. As a result, certain Program milestones for Units 1 and 4 (e.g., completion of the Preliminary Estimate) have already been completed.

In accordance with OPG's Project Phase Gate Management (see Attachment 1), staged releases of funds are sought to proceed with planning for Units 1 and 4, culminating with a full release of funds to execute the refurbishment outage at Gate 3, at which the Unit EE is finalized. The target completion date for the Unit 1 Execution Estimate ("U1EE") is November 2021. The U1EE will act as a 'final check' of the cost and schedule duration estimates for the Unit 1 refurbishment outage that are included in the final U3EE, and will serve as the baseline against which performance on the Unit 1 refurbishment outage will be measured. The planned start of the Unit 1 refurbishment outage is February 15, 2022 with return-to-service planned for April 18, 2025. The forecast high confidence duration remains at 38 months as it was at the time of the RQE and the U2EE.

The target completion date for the Unit 4 Execution Estimate ("U4EE") is May 2023. The U4EE will act as a 'final check' of the cost and schedule duration estimates for the Unit 4 refurbishment outage that are included in the final U3EE, and will serve as the baseline against which performance on the Unit 4 refurbishment outage will be measured. The planned start of the Unit 4 refurbishment outage is September 15, 2023 with return-to-service planned for October 16, 2026. The forecast high confidence duration remains at 37 months as it was at the time of the RQE and the U2EE.

Planning for Units 1 and 4 is on track to meet the scheduled milestone dates. The current status of work on Units 1 and 4 is:

- Screening of Unit 1 scope was completed on time and in accordance with the planning milestone date, and Unit 4 scope is forecasted to be complete on time.
- Engineering is in progress for all Unit 1 and Unit 4 scope. The strategy is to replicate the engineering packages from Unit 3 and modify them for Units 1 and 4 as required based on Unit 3 Lessons Learned. Engineering is currently progressing on schedule and is 88% complete for Unit 1 and 60% complete for Unit 4.
- Procurement of materials is progressing on schedule. As of September 30, 2020, 80% of Purchase Orders had been issued and 73% of all the requested materials for Unit 1 refurbishment were on site, with delivery of the remaining material items on track to meet the planned need dates. The procurement process of long-lead materials for Unit 4 refurbishment is in progress and on track to meet the planned need dates.
- Preliminary execution schedules for prerequisite work prior to Units 1 and 4 breaker open have been issued and work activities to prepare for this work are complete.
- The Working Schedules for Units 1 and 4 are evolving through increasing levels of detail in accordance with OPG's schedule governance. As of September 30, 2020, the schedule for Unit 1 was at the Revision A1 stage, and the schedule for Unit 4 was at the Revision A Draft stage.
- Comprehensive work packages are being completed in priority sequence and are on track to be ready by the required dates.

## 4.0 LESSONS LEARNED

This section describes OPG's Lessons Learned process. Select examples of Lessons Learned which have been or are planned to be applied to the Remaining Units' refurbishments are described in the relevant sections of Ex. D2-2-5 and D2-2-6. The Lessons Learned on the feeder removal and installation work series have already been discussed at a high level in Ex. D2-2-2. Further information about Lessons Learned on the feeder program that are expected to improve OPG's performance during the Remaining Units' refurbishments is provided in Attachment 6.

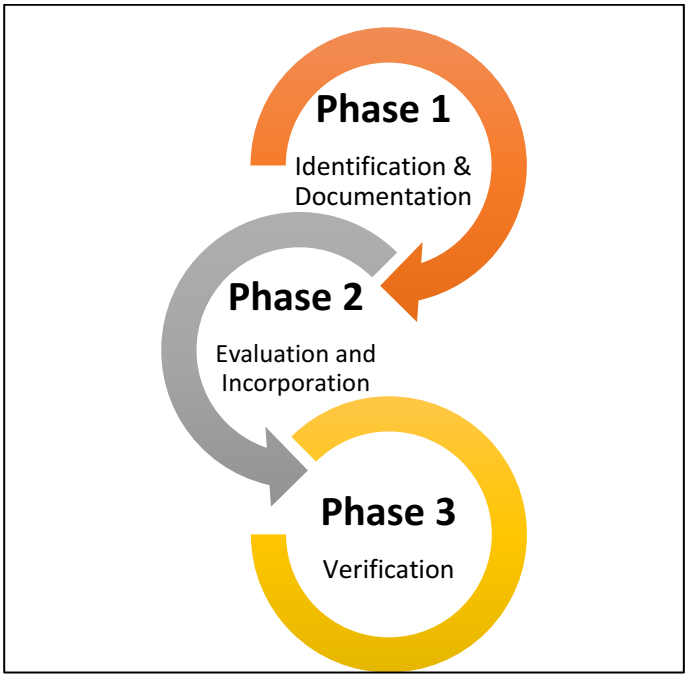
OPG and its contractors are focused on achieving unit over unit efficiencies. Both OPG and its contractors have developed Lessons Learned processes to capture and implement the knowledge and experience gained in planning and executing the work. OPG established a Lessons Learned organization to facilitate and support the Lessons Learned process. OPG also incorporated Lessons Learned leads into the Major Work Bundles to provide day-to-day support to the Lessons Learned process. CanAtom, the largest DRP contractor, has dedicated resources that actively manage Lessons Learned as part of their Performance Improvement process.

As of September 2020, OPG and its contractors have identified 4,085 Lessons Learned. The status of these Lessons Learned is provided below in Section 4.1.2.1.

## 4.1 The Lessons Learned Process

The Lessons Learned process, summarized below in Figure 2, has three major phases: (1) Identification and Documentation; (2) Evaluation and Incorporation; and (3) Verification. Each of these major phases is discussed below. The Verification phase, where OPG reviews the effectiveness of Lessons Learned implementation and verifies that the intended improvements were realized, is similar to the Post-Implementation Review process that OPG employs on projects.

**Figure 2: Lessons Learned Phases**




#### 4.1.1 Phase 1: Identification and Documentation

During the Identification and Documentation phase, OPG and its contractors identify and document Lessons Learned as soon as possible after the completion of the planning or field work execution. Lessons Learned are characterized based on their level of impact, ranging from tactical to strategic. Project Lessons Learned generally have tactical impacts and apply only to the specific process, project or activity which is being reviewed, whereas strategic Lessons Learned have broader strategic impacts to the overall Program.

Project Lessons Learned are normally gathered after work has been executed in the field, during Post-Window Lessons Learned meetings. Post-Window Lessons Learned meetings are mandatory for each work window that is to be repeated on subsequent units, and serve to identify, document and evaluate Lessons Learned in a timely manner. The focus of these meetings is on Lessons Learned applicable to the specific scope of work that was executed in that window. All key stakeholders involved in the planning and execution of the relevant work must attend. Attendees may include: OPG and Contractor Project/Field Managers, the Field Superintendent, the General Foreman, Direct Trades, Design and System Engineers,

Operations and Maintenance staff, Work Control staff and Radiation Protection staff. Should personnel changes be planned for the next unit, the next unit's personnel, if known, are also required to attend. Once the Lessons Learned are evaluated, appropriate actions are assigned for follow-up and implementation in the planning and execution phases of future units.

Strategic Lessons Learned are gathered primarily through periodic interviews with OPG and contractor staff, normally after completion of a Segment of the refurbishment outage, and result in strategic improvements such as significant process changes, alternative execution strategies or organizational changes to facilitate improved work execution. Further discussion of Strategic Improvements is provided in Section 5.0.

#### 4.1.2 Phase 2: Evaluation and Incorporation

During the Evaluation and Incorporation phase, Lessons Learned are screened, prioritized and actions are assigned for implementation. Lessons Learned are first screened to eliminate those where there is no value in pursuing them further or those that are no longer applicable. These Lessons Learned are closed, but are kept in the Lessons Learned list for that particular project for further review and disposition at the Project Gate Review meetings.

Lessons Learned that are endorsed during the screening process are categorized from highest to lowest impact as Tier 0, Tier 1, Tier 2 and Tier 3.[5] Strategic Lessons Learned are categorized as Tier 0 – Imperative to the Program, and they are managed as Strategic Improvements because of their broad impacts. The criteria which are applied to determine whether a Lesson Learned is a Tier 1, Tier 2 or Tier 3 are explained in Attachment 4.

Tier 1 and 2 Lessons Learned require the creation of a formal action, assignment of an owner and continual tracking of the status of the action against its due date. Tier 3 Lessons Learned proceed to implementation within normal processes and are tracked to completion by the responsible Project or Functional manager. Metrics and reporting on the Lessons Learned process are used to monitor the progress of implementation.

[5] For further information on the definitions of the Tiers, see Attachment 4, pp. 9-10.

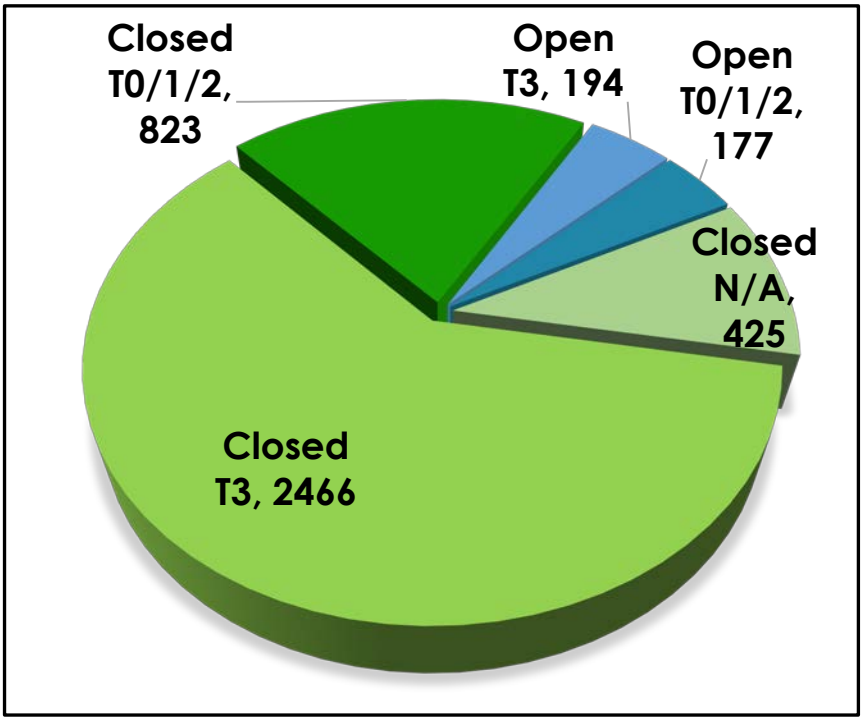
Project Gates, as described in OPG's Gated Process Governance (see Attachment 1), serve as an opportunity to assess whether Lessons Learned were incorporated. Generally, Project Gates are used to assess readiness to proceed to the next phase and apply at the Program level and to the Major Work Bundles. At Gate 3, when the execution estimates for each project are finalized, all Lessons Learned for the project are expected to have been reviewed and dispositioned. The Gate 3 Packages must include confirmation that Lessons Learned have been incorporated and managed through the Lessons Learned process.

4.1.2.1 Lessons Learned Monitoring

OPG tracks the number, type, status and benefits of each identified Lessons Learned. For example, metrics are produced on: (1) the status of Lessons Learned meetings completed by Segment of the schedule, and (2) the status of Post-Window Lessons Learned meetings.

As previously noted, as of September 2020, OPG and its contractors had identified 4,085 Lessons Learned. Of these Lessons Learned: (1) 425 were closed with no further action; (2) 2,660 were Tier 3, of which 2,466 actions have been closed (i.e., incorporated into normal work processes or closed as no further action required) with the remaining 194 actions open; and, (3) 1000 actions were Tiers 0/1/2, of which 823 actions had been closed with the remaining 177 actions open. Figure 3 is a summary of the status of Lessons Learned actions as of September 30, 2020.

**Figure 3: Status of Lessons Learned Actions**
**Unit 2 to Unit 3 by Tier Level as of September 2020**




As previously discussed, priority is placed on completing Lessons Learned for the earlier segments of a refurbishment outage, in line with when implementation of the Lessons Learned is needed. Chart 1 shows the status of completion of both the Lessons Learned actions and the effectiveness reviews of those actions by Segment of the Unit 3 refurbishment outage. The data in Chart 1 illustrate the approach of placing the priority for completing Lessons Learned on the earlier segments of a refurbishment outage first.

**Chart 1: Status of Lessons Learned Actions and Effectiveness Reviews - Unit 2 to Unit 3 as of September 2020**

| | **Lessons Learned Actions** (% Complete) | **Effectiveness Reviews*** (% Complete) | **Projected Critical Path Savings** (days) |
|---|---|---|---|
| **Segment 0** | 100 | 100 | N/A |
| **Segment 1** | 99 | 99 | 28 |
| **Segment 2** | 86 | 62 | 76 |
| **Segment 3** | 82 | 25 | 127 |
| **Segment 4** | 44 | 15 | 0** |
| **Overall** | 91 | 62 | |

*The Lessons Learned effectiveness reviews ensure that all Lessons Learned actions are appropriately closed out and documented
**No Segment 4 projected critical path savings have been identified based on Lessons Learned actions completed to date.

#### 4.1.3 Phase 3: Verification

During the Verification Phase, the effectiveness of the implementation of Lessons Learned is verified and adjustments made and/or further Lessons Learned are identified for implementation on the subsequent unit(s) to be refurbished. The schedule for the Remaining Units allows sufficient time, after the completion of a work activity on one unit and before the start of the similar work activity on the subsequent unit, for the verification process to take place.

Verification involves confirmation that: (i) the Lessons Learned were implemented for the same work activity on a subsequent unit, and (ii) the expected benefits were realized, after that work activity was completed on that unit. Any deviations from the expected benefits are noted and, if necessary, actions are put in place to ensure improved implementation of the Lessons Learned for the same or similar work activities on the next unit to be refurbished.

Attachment 4, NK-38-GUID-09701-10054, R001, Nuclear Refurbishment Lessons Learned, provides a detailed summary of the Lessons Learned process. The flowchart provided as Attachment 5, shows the details of the Evaluation and Incorporation, and Verification phases.

### 4.2 Application of Lessons Learned

To facilitate understanding of the impact of Lessons Learned on the Program, below are two examples of how Lessons Learned were applied to improve work processes:

- Scheduling - adjustments to Outage Window durations: During the Unit 2 refurbishment, it was observed that target production rates on certain critical path work series were not achieved as early as expected during execution and that a “transition-in” period was required. Also, it was observed that, “transition-out” activities required at the end of a work series were taking longer than planned. These observations led to the identification of Lessons Learned which have been evaluated for opportunities to reduce the total duration and, where appropriate, work series durations were adjusted in the Remaining Units’ schedules to account for the expected “transition-in” and “transition-out” production rates. In addition, each critical path work series was analyzed to understand the causes of any delays experienced on Unit 2 and to correct the deficiencies causing these delays. Delays that were addressed and are not expected to recur were factored out from the Remaining Units’ schedules. Where a work series was executed at better than target durations, the reasons for faster execution were analyzed and, if found to be repeatable, were fully or partially built into the Remaining Units’ schedules. Further discussion of the use of Unit 2 actual achieved production rates in the building of the schedules for the Remaining Units is provided in Ex. D2-2-5.

- Field Work Execution - Bulkhead Installation: While operating, there are certain parts of a nuclear generating unit that must be within a sealed “containment structure” at all times. On a multi-unit station such as Darlington, bulkheads are required in order to isolate the unit under refurbishment from the containment structure of the operating units. Challenges with the installation of bulkhead vertical panels led to delays experienced during the Unit 2 refurbishment outage. Lessons Learned were identified, evaluated and incorporated into the Bulkhead Installation process for Unit 3. For example, in the Remaining Units, as a result of process re-design, only one crane lift will be required to move these very heavy panels from the transport vehicle into their final position, versus five or more lifts used during Unit 2. The impact of implementing these Lessons Learned is that the bulkhead

installation work series is expected to be completed in a shorter duration than was achieved on Unit 2.

In addition to the above examples of Lessons Learned, Ex. D2-2-2 provides further examples of Lessons Learned which are being incorporated into the planning and execution of the feeder program for the Remaining Units. Improved performance on the feeder program is critical to achieving the planned improvements to schedule and cost for the Remaining Units. Details on the feeder program Lessons Learned and planned improvements are provided in Attachment 6.

## 5.0 STRATEGIC IMPROVEMENTS

Strategic Improvements are new approaches and/or innovative methods for planning and executing the Remaining Units' refurbishments. Strategic Improvements are expected to yield a step change in performance and are generally more overarching than Lessons Learned. Strategic Improvements typically arise from a combination of innovative ideas or approaches to work on the Remaining Units, from benchmarking and idea exchanges with other planned or on-going refurbishments, to leveraging technological advances.

The goal of Strategic Improvements is to continually improve safety, schedule, cost and quality performance as OPG executes the successive refurbishments of the Remaining Units. Working collaboratively with its contractors, OPG is implementing many Strategic Improvements through its Functional Support organizations to ensure that there is a clear owner and champion with responsibility to drive implementation.

### 5.1 Examples of Strategic Improvements

Six Strategic Improvements are summarized in the following sections, namely:

1. Organizational Evolution: Project Centric Organization, Workstream Specialization, and the One Team Approach;
2. Engineering Replication;
3. The Darlington Unit 3 Innovations Project;
4. Radiation Protection Improvements;

5. Training Effectiveness Improvements; and
6. Implementation of a hybrid trades labour shift schedule.

Each is described in further detail below.

#### 5.1.1 Organizational Evolution

Working with its contractors and in consideration of the Remaining Units' overlaps, OPG has implemented the Organizational Evolution Strategic Improvement which drives organizational changes to enhance project performance through improved communication and collaboration. Organizational Evolution is being implemented primarily through three changes, namely, the Project Centric Organization, Workstream Specialization and the One Team Approach.

The Project Centric Organization structure is focused on ensuring that accountabilities and decision-making are at the right level of the organization, and establishes clear escalation protocols for those times when decisions need to be escalated to a higher level. This approach also allows for a broader scope of control across the program by distributing decision-making deeper into the organization. Further details on the Project Centric Organization structure are provided in Ex. D2-2-8.

Workstream Specialization results in a shift from generalized work teams to specialized work teams. Specifically, OPG has shifted away from multifunctional, cross-trained teams moving from one work series to the next in sequence, to specialized, high-proficiency teams which will execute the same work series on each of the Remaining Units. The specialized teams better develop expertise and will be able execute their work activities at a higher level on the subsequent units. Further details on Workstream Specialization are also provided in Ex. D2-2-8.

The One Team Approach is based on recognizing that OPG and CanAtom have a variety of talent, and that in the interest of the best outcomes for the Program, each organization should provide that "best" resource to the team in the position where that person can yield the highest value in terms of project and Program outcomes. Critical project positions are filled by the best

qualified resources from within OPG and CanAtom. The incorporation of experienced OPG personnel with in-depth knowledge of the Darlington plant, of OPG's work methods, and of working within the nuclear environment, has been critical to successes experienced on Unit 2. The One Team Approach is the result of OPG and CanAtom's efforts to find efficiencies in executing the DRP under the terms of the existing contracts. The foundation of the One Team Approach is collaboration and an understanding that Program success means success for each of OPG and CanAtom individually.

Benefits of the One Team Approach include: (1) streamlining of oversight; (2) incorporation of OPG subject matter experts with detailed plant knowledge; (3) improvements in the management of planning milestones; (4) improvements in comprehensive work package preparations; (5) improved schedule management and reviews; (6) improved implementation of Lessons Learned; (7) reduction in barriers to getting work done in the field; and (8) improved timeliness and quality of decision-making. Further details on the One Team Approach are also provided in Ex. D2-2-4 and Ex. D2-2-8.

#### 5.1.2 Engineering Replication

For the Balance of Plant Major Work Bundle, OPG has adopted a revised engineering model for the Remaining Units. For Unit 2, Balance of Plant contractors were responsible for completing detailed designs and executing engineering field services, while OPG's engineering organization was responsible for modification planning and performing oversight of contractor designs. For Balance of Plant projects within the Remaining Units, given that a large percentage of the engineering would involve replication of Unit 2 design packages, OPG assumed the overall accountability for engineering design replication, utilizing augmented contractor resources as required.

The benefits of the revised approach to engineering for the Remaining Units are:

- Consolidation and reduction of total number of resources needed through the removal of duplicate oversight roles between OPG and the contractors.
- Use of staff that can readily be confirmed to be qualified to execute the work.
- Use of staff with relevant experience from Unit 2 including familiarity with Lessons Learned

from Unit 2, OPG's process, systems, infrastructure, resources, and with the Darlington station.

### 5.1.3 Darlington Unit 3 Innovations Project

The Darlington Unit 3 Innovations Project ("D3IP") refers to OPG's decision to undertake the development of FOAK tools that are expected to result in efficiencies upon deployment during the execution of Remaining Units' refurbishments.

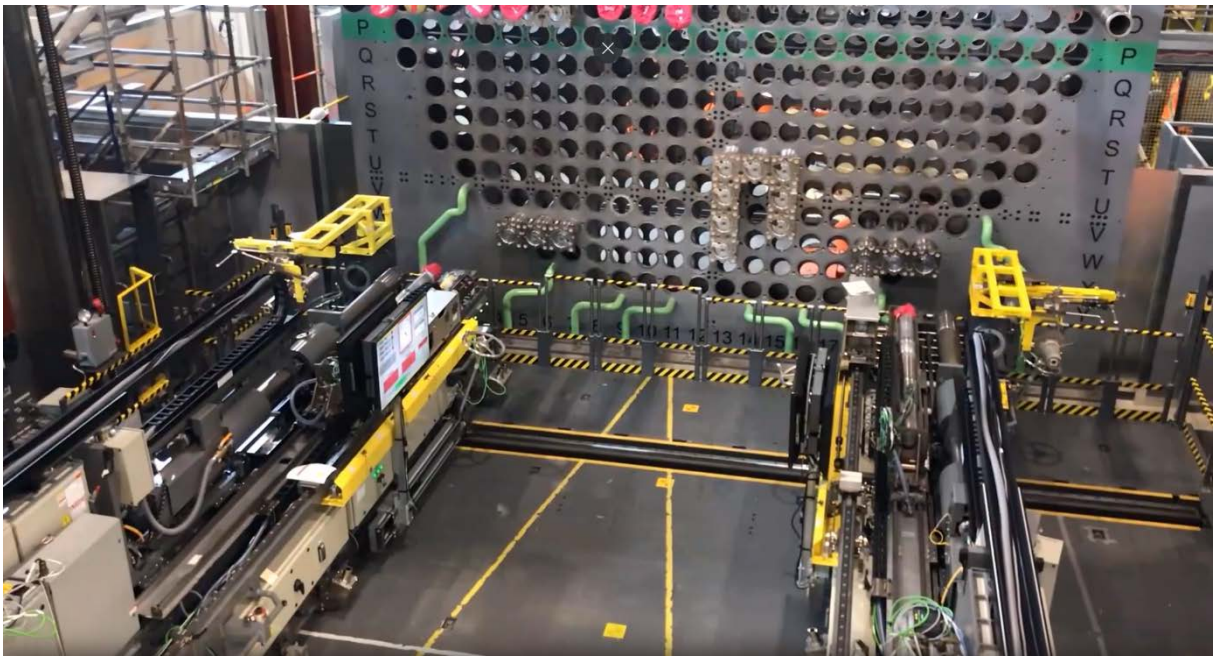
The toolset for RFR for Unit 2 consisted of many individual automated and hand tools selected based on designs, concepts and methods that had been proven through their use in other nuclear refurbishments. To mitigate schedule risks caused by long lead times (considering the research and development, design and testing required for FOAK tools) and tool performance risks, OPG, in collaboration with CanAtom, elected not to pursue the development of FOAK tools for Unit 2. For the Remaining Units, OPG working with CanAtom, pursued the development of tooling and associated process improvements where a business case demonstrating expected efficiency gains could be made.

Several initiatives have already been approved and many of the smaller initiatives implemented. These initiatives range from improvements to existing tools, to entirely new tools being developed. An example of a specific tooling improvement is a modification to the tool used to remove the dummy fuel bundles. This improvement allows work to proceed on both reactor faces simultaneously (as opposed to work on each face proceeding in sequence), thereby allowing a doubling of the production rate.

Two significant D3IP initiatives are being implemented in the Remaining Units:

1. Combined pressure tube and calandria tube removal; and
2. A new installation worktable design to be used in the calandria tubesheet bore series and calandria tube installation series, which allows double the amount of tools to be deployed for certain parts of the series. This innovation resulted, in part, from collaboration with Bruce Power (See Section 6.0). Figure 4 is a photograph of the new installation work table in the reactor mock-up facility, and shows two sets of tools being deployed simultaneously.

**Figure 4: Photograph of the New Installation Work Table in the Reactor Mock-up Showing Simultaneous Deployment of Two Toolsets**



The D3IP tooling improvements are a major contributor to the reduced durations forecast for certain critical path work activities in the Remaining Units' schedules, as described in Ex. D2-2-5.

### 5.1.4 Radiation Protection Improvements

To work on a nuclear refurbishment project, the workers must be trained and qualified to work in an environment with radiation hazards. Depending on the nature of the work, a qualified Radiation Protection Coordinator ("RPC") is required to be on shift with the crews to ensure that the work is being carried out in accordance with the radiation exposure permit, which is a component of the comprehensive work package. A radiation exposure permit defines such items as the hazards in the work area, the dose rates, the required personal protective equipment, and the maximum time of exposure. Any delays or unavailability of an RPC can delay work in the field, which impacts costs and schedules.

OPG is implementing a number of improvements to radiation protection procedures and

processes for the Remaining Units' refurbishments. These changes are expected to result in:

- Improved predictability of demand for RPCs and better alignment of radiation protection resources with the needs of the trades crews.
- Reduced waiting times for workers entering radioactive work areas.
- Enhanced working rights/responsibilities for contractors, including a new qualification which reduces the demand for radiation protection support staff, and self-issuance of electronic personal dosimeters.

OPG is also implementing improved technology in the form of personal air purifying respirators, which will allow some work that would have required more cumbersome plastic suits to be done more efficiently.

#### 5.1.5 Training Effectiveness Improvements

Starting with the critical path work series in the latter part of the Unit 2 refurbishment outage, OPG and CanAtom worked to systematically implement an improved training strategy. Implementation of this Strategic Improvement yielded immediate productivity improvements in Unit 2, beginning with the new fuel load work series. These improvements will be applied to all critical path work series' on the Remaining Units and, in conjunction with other Strategic Improvements described in this section, are expected to result in improved productivity from the trades. Training programs have been adjusted to improve proficiency in the overall work series to enhance the team's execution of the entire set of tasks in the comprehensive work package.

The key elements of the training improvement strategy can be summarized as follows: (1) improved alignment between OPG and CanAtom training organizations; (2) enhanced trainer capabilities; (3) updated and improved training protocols; (4) training schedules better aligned with execution schedules; (5) improved testing and metrics to assess training outcomes; (6) improved training documentation/records management; (7) updated reactor mock-up facilities aligned more closely with field conditions; (8) focus training on task proficiency; (9) intensively train a smaller group on troubleshooting, and the ability to understand the intricacies of the work series, contingencies, the tooling, and the overall process (facilitated by implementation

of the trades labour hybrid schedule – See Section 5.1.6); and, (10) use of industry recommended proficiency building blocks (classroom, mock-up, familiarity, repetition, understanding, timely training, self-awareness).

### 5.1.6 Trades Labour Hybrid Schedule

OPG is implementing a shift schedule for trades labour that is expected to improve productivity.

As already noted, the refurbishments of the Remaining Units will be executed with overlaps of their respective refurbishment outage periods, as well as with overlaps of Bruce Power's Major Component Replacement[6] ("Bruce MCR") outages. These overlapping refurbishments and component replacement projects place a high demand on the highly skilled resources required for these projects. Additionally, the nature of the work and the projects' long duration bring specific and unique resource risks. The experience from executing the Unit 2 refurbishment outage on a 24 hours per day, 7 days a week schedule (known as 24/7) for the trades has shown issues can arise with trades and project management team resource availability, stress management, and burnout.

For the Remaining Units, rather than apply the 24/7 schedule, OPG has elected to adopt a hybrid schedule for critical path activities. Specifically, OPG has adopted a scheduling approach for trades labour for the Remaining Units, wherein some series of critical path work would be scheduled on either a 24/5 or 24/6 basis, while other series are maintained on a 24/7 basis (this approach henceforth referred to as the "Hybrid Schedule"). The Hybrid Schedule is expected to result in a number of benefits including lower per-hour costs, improved worker productivity, reduced turnover, improved attraction and retention of local trades resources, reduced overall trades demand, and "built in" schedule margin.

The following sections provide additional details of OPG's evaluation of moving to the Hybrid Schedule.

[6] Bruce Power uses the terminology Major Component Replacement whereas OPG uses the term Refurbishment.

#### 5.1.6.1 Trades Availability, Training and Proficiency

The Hybrid Schedule is expected to lead to improvements in terms of trades availability, training and proficiency:

- *Trades Availability*: The number of trades to train and manage is reduced using the Hybrid Schedule. The 24/5 and 24/6 schedules require only two shifts (one day crew and one night crew), compared to the 24/7 schedule which requires at least three (but usually four) shifts. Additionally, there will be a high demand for skilled trades during the overlapping period of the Program and Bruce's MCR program. Reducing the demand at Darlington allows OPG more choice in trades labour, reduces the likelihood of shortages, and allows OPG to focus on training and retaining the better performers for the Remaining Units' refurbishments.
- *Improved Training/Additional Training Time for Trades*: As discussed in Section 5.1.5, improved training contributes to improved performance. A lower overall number of trades would need to be trained under the Hybrid Schedule, allowing more training time on the reactor mock-up for each tradesperson. This increased training time, in combination with other strategic changes to the training program discussed in Section 5.1.5, is forecast to increase productivity, particularly on the longer critical work series such as calandria tube installation and fuel channel installation.
- *Shorter "Learning Curve":* Achieving proficiency, particularly on work series that require many manual tasks, requires practice in the field. The 24/5 work schedule on the longer critical path series results in increased frequency with which a particular shift returns to the work activity. Each tradesperson is estimated to spend approximately twice as much time involved in that work activity, as compared to a 24/7 schedule. As a result, experiential learning will be accelerated and it is forecast that proficiency will be achieved earlier in each work series.
- *Sustainable Work Schedule:* OPG would like to employ trades who have a long-term commitment to the Program. Work activities executed on a 24/5 schedule would be done from Monday to Friday; this is expected to result in improved stress management and help to reduce burnout and fatigue, compared to a 24/7 schedule. Retention of trades, in particular highly trained and competent individuals, is expected to increase because of the Hybrid Schedule.

5.1.6.2 Project Management Team Availability, Training and Risk Mitigation

The Hybrid Schedule is expected to lead to improvements in terms of project management team ("PMT") availability and training:

- *Sufficiency of PMT Resources:* The Hybrid Schedule reduces the demand for PMT resources (e.g., Quality Control, Field Engineering, Radiation Protection, etc.), compared to a 24/7 schedule, and is expected to result in lower PMT costs.
- *Mitigation for PMT burnout:* OPG learned during the Unit 2 refurbishment that PMT resources are at risk for stress management issues, particularly those personnel expected to be available 24/7. The Hybrid Schedule affords more time off for on-call PMT resources because the likelihood of being required to work weekends is reduced.

5.1.6.3 Construction Leadership

Availability of construction leadership, in the form of forepersons, and general forepersons with mega-project experience, is limited. The Hybrid Schedule will result in a smaller trades force, which in turn will result in a lower demand for construction leadership and improved opportunity for the identification, training and retention of top performing forepersons and general forepersons.

5.1.6.4 Schedule and Cost Management

The Hybrid Schedule is expected to improve schedule and cost management:

- *Higher Confidence in Working Schedule Duration:* The Hybrid Schedule is expected to increase the probability that OPG can maintain its Working Schedule during the Remaining Units' refurbishments by facilitating improved trades availability training, and trades proficiency. In addition, when necessary, the Hybrid Schedule will often make weekends available for the performance of work to recover delays, or anticipated delays, to the Working Schedule.
- *Risk Mitigation for Near Critical Path Work:* A number of opportunities have been identified to perform near critical path work on weekends when work on the reactor face is suspended. Near critical path work can become critical path if schedule slippage occurs. Some near-critical path activities cannot be completed when critical path work on the reactor is ongoing. With weekends available to do near-critical path work, the risk of the

work moving to the critical path is reduced. Examples of near-critical path work include: (1) processing of irradiated waste containers; (2) reactor vault crane inspections and maintenance; (3) reactor vault decontamination, clean up, and housekeeping; and, (4) reactor vault scaffolding modifications.

- *Lower Average Hourly Trades Labour Cost:* The Hybrid Schedule is expected to result in reduced premium and/or overtime rate costs as there is expected to be less weekend work.

## 6.0 COLLABORATION WITH BRUCE POWER

The Government of Ontario's Long-Term Energy Plan ("LTEP") dated December 2013[7] sets out a number of principles with respect to the nuclear refurbishment process, including that OPG and Bruce Power collaborate in the sharing and application of lessons learned from their respective refurbishment programs.[8] This collaborative principle was subsequently reinforced by the Government of Ontario in its 2017 LTEP.[9] OPG and Bruce Power have exercised collaboration in the following areas:

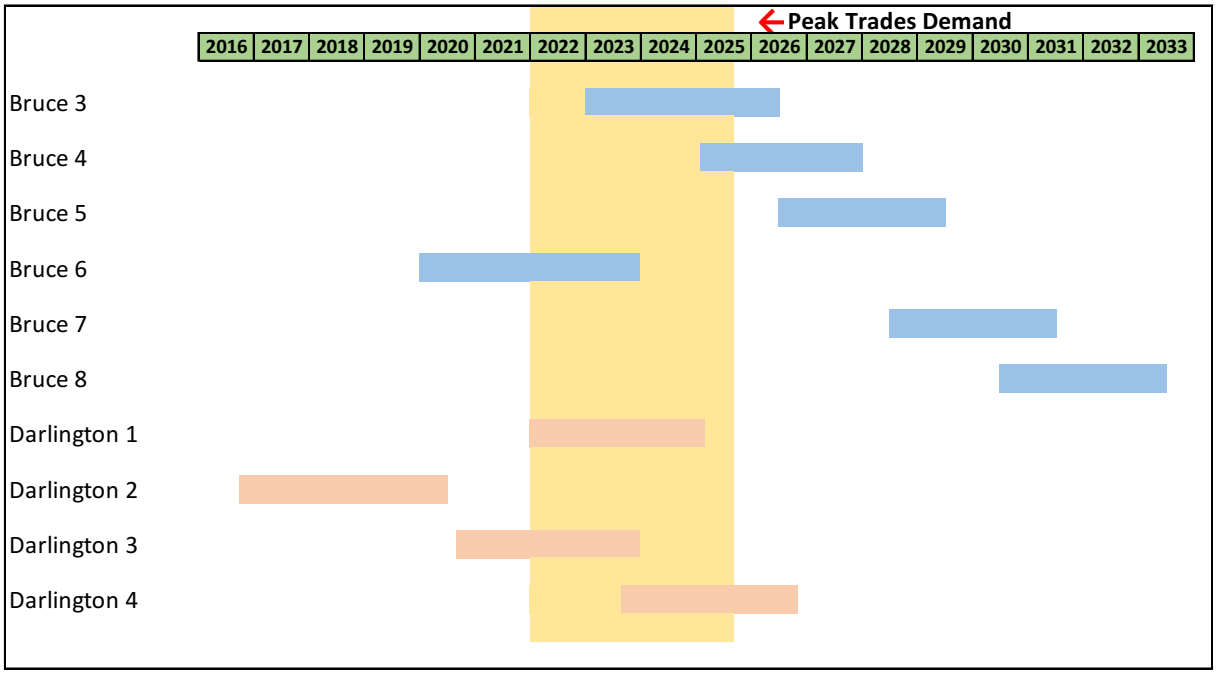
1. Asset Management and Inspection Programs
2. Procurement
3. Common Tooling
4. Replacing Major Components
5. Waste Management
6. Labour Arrangements.

Details of the accomplishments in 2017 and 2018 in these areas of collaboration are discussed in the public report published by OPG and Bruce Power in 2018 (see Attachment 7) and in the joint letter from OPG and Bruce Power to the Minister of Energy, Northern Development and Mines in November 2019 (see Attachment 8), respectively. The need and opportunity for OPG and Bruce Power to collaborate is enhanced by the fact that starting in 2020, there will be one or more Darlington unit refurbishments overlapping with one or more Bruce MCR outages until the end of the Program in 2026. Figure 5 shows the current Darlington Refurbishment schedule

[7] Government of Ontario, *Achieving Balance – Ontario's Long term Energy Plan,* December 2013, pg. 29.
[8] EB-2016-0152, Ex. D2-2-1, pg. 11.
[9] Government of Ontario, *Delivering Fairness and Choice – Ontario's Long term Energy Plan,* October 2017, pg. 47

for the Remaining Units with the Bruce Units 3 - 8 MCR outages overlaid. The peak overlapping period is in 2023 where it is planned that two units at Darlington will be in their respective refurbishment outages and two units at Bruce Power will be simultaneously undergoing their respective MCR outages. Ongoing collaboration with Bruce Power in both the planning and execution phases of the Remaining Units' refurbishment outages is expected to result in improved OPG's performance.

**Figure 5: Darlington Refurbishments and Bruce MCR Outages 2016 - 2033[10]**




[10] Adapted from Government of Ontario, *Delivering Fairness and Choice – Ontario's Long term Energy Plan,* October 2017, Figure 11, pg. 46.

## ATTACHMENTS

| | |
|---|---|
| Attachment 1: | OPG-MAN-00120-0019, Project Phase Gate Management |
| Attachment 2: | NK38-MAN-09701-10005, Sheet MLST, R002, Refurbishment Unit Planning Milestones |
| Attachment 3: | NK38-MAN-09701-10005, Sheet WIN, R000, Refurbishment Unit Planning Window Milestones |
| Attachment 4: | NK38-GUID-09701-10054, R001, Nuclear Refurbishment Lessons Learned |
| Attachment 5: | Schematic of OPG's Lessons Learned Process |
| Attachment 6: | Summary of Feeder Lessons Learned and Actions |
| Attachment 7: | Powering Ontario Together, 2018 Report on Nuclear Collaboration |
| Attachment 8: | Joint Bruce Power/OPG Letter to the Minister of Energy, Northern Development and Mines and the Associate Minister of Energy re: Bruce Power/OPG Collaboration, November 19, 2019. |