ONTARIO POWER GENERATION

**OPG Confidential Exclusive**

**FOR APPROVAL by the Board of Directors**

**August 13th, 2020**

# DARLINGTON REFURBISHMENT – FINAL UNIT 3 EXECUTION ESTIMATE

## DECISION REQUIRED

The purpose of this memo is to request approval from the Board of Directors for the Final Unit 3 Refurbishment Execution Estimate (U3EE) cost and schedule baseline:

- Commencement of the Unit 3 refurbishment execution immediately following the Single Fuel Channel Replacement (SFCR) outage, with a planned start date for defuel on **September 2nd, 2020**. In the event that the SFCR outage is completed earlier than planned, the project remains ready to start defuel earlier.
- Final Unit 3 High Confidence Cost Estimate of **$2,559 Million**, which is unchanged from the U3EE previously approved in November 2019.

## ISSUE

In November 2019, OPG's Board of Directors approved the U3EE and full release of funding to proceed with the execution of the Unit 3 refurbishment planned for May 2020 at a total cost of $2,559 Million. The estimate was developed using actual experience of Unit 2, including the completion of the Feeder program, inclusion of the Lower Body Instrumentation series, and other lessons learned and strategic improvements. The cost estimate was considered a class II estimate and preserved the overall program funding of $12.8 Billion.

Since that time, management has continued with the detailed planning and preparations for the execution of the Unit 3 refurbishment. As a result of the COVID-19 pandemic, OPG deferred the planned start of the Unit 3 refurbishment to early September 2020. The deferred start of the Unit 3 refurbishment by four months has a cascading impact on the start of future unit refurbishments, with the overall schedule maintained to refurbish all four units by the end of 2026.

In Q1 2020, the Turbine Generator project team finalized a decision to transfer two key scope packages (centreline work, and stator replacement) from the execution vendor, CanAtom, to the Original Equipment Manufacturer (OEM), General Electric (GE). In place of a stator replacement, GE will perform an in-situ rewind that was previously planned to be completed on the removed stator in an on-site warehouse. This change mitigates the risk of a significant critical significant lift in the station. CanAtom has retained significant modification scope for engineering and construction of 'first of a kind' upgrades to the turbine and excitation controls systems, including replacement of 5 generator auxiliary systems skids.

This Final U3EE sets out OPG's plans for the execution of Unit 3 refurbishment and includes an updated risk and contingency analysis that will form the basis for monitoring of Program performance. The unit's high confidence cost has been preserved at $2,559 Million as previously approved in November 2019, and the high confidence schedule duration is unchanged at 40 months. This Final U3EE also sets out the high confidence cost and schedule estimates for Unit 1 and Unit 4.

As set out below, OPG is continuing to manage the impact of COVID-19 on the DRP, which does not form part of DRP's program budget or this Final U3EE. Based on impacts known to date, OPG expects to incur costs of approximately $150 Million for the DRP as a result of the four-month deferral. Management continues to monitor and manage the trends of the pandemic, track related expenditures separately and assess any opportunities to mitigate the impact.

## ANALYSIS

This Final U3EE takes into consideration the additional planning and preparatory work executed since the November 2019 Board meeting, and incorporates the following:

- A cost estimate and schedule based on the most up to date actual experience on Unit 2, including the incorporation of lessons learned and discovery issues, with additional strategic improvements stemming from the Lean/Kaizen methodology to identify further opportunities.

- A cost estimate and schedule based on revised direct field labour productivity assumptions that incorporates a hybrid (24/5/6/7) shift schedule for critical path activities, and tooling investments that realize the full benefits of parallel Pressure Tube / Calandria Tube removal for Unit 3.
- Following the scope change decision, CanAtom, working with the OPG team, revised their TGR work strategy. The OPG & CanAtom teams have continued to work collaboratively on the details of the plan and are making good progress towards finalizing the plan, expected by late July.
- Revised risk analysis, and resultant contingency required for residual risks.
- Review of cash flows, including interest and escalation requirements, against the updated working schedule.

All of these items have been compiled into the Final U3EE class II estimate, as well as a review of the 4-unit overall cost estimate. The following sections summarize this analysis.

**1. The cost estimate for executing Unit 3 refurbishment is preserved at $2,559 Million.**

In November 2019, OPG's Board of Directors approved the U3EE and full release of funding to proceed with the execution of the Unit 3 refurbishment targeted for May 2020 at a total cost of $2,559 Million. The estimate was developed using actual experience of Unit 2 including the completion of the Feeder program, inclusion of the Lower Body Instrument Tubing series, and additional lessons learned and strategic improvements.

Since that time, management has continued with the detailed planning and preparations for the execution of the Unit 3 refurbishment. The Final U3EE has been preserved at $2,559 Million, which includes $240 Million of contingency.

To-date, $2,962 Million has been released for Units 3, 1 and 4 planning, detailed engineering and procurement of long lead materials, and the execution of Unit 3.

A summary of funding releases for Units 3, 1 and 4 is provided in **Table 1** below.

**Table 1: Subsequent Unit Funding Releases**

| Unit | Cumulative Funding Release ($M) |
|---|---|
| Unit 3 | 2,559 |
| Unit 1 | 276 |
| Unit 4 | 127 |
| Total | 2,962 |

**2. Unit 3 Scope remains unchanged.**

The scope for Unit 3 remains unchanged and is consistent with the U3EE scope presented for approval in November 2019.

As previously reported, the refurbishment scope to be completed on each unit is largely the same, however Unit 3 includes the execution of the Turbine and Generator Controls upgrade and the in-situ rewind of the Generator Stator, which were not part of the Unit 2 refurbishment.

In addition, previously approved investments in Re-tube and Feeder Replacement (RFR) tooling are expected to result in efficiencies on each of the subsequent refurbishment units.

The investment in tooling will allow for dual work tables to be used during the installation of Calandria Tubes and enable the removal of Pressure Tubes and Calandria Tubes at the same time. The resultant efficiencies gained have been incorporated in the Unit 3 execution schedule.

**3. Unit 3 Revised TG Execution Strategy.**

As previously noted in the Issues section, the centreline work and stator in-situ rewind have been assigned to GE for Unit 3, as well as Units 1 and 4. A three-unit contract amendment has been finalized for GE to perform this execution work at Darlington. GE has not performed field work at Darlington in the past, however GE has performed a successful stator rewind at Bruce Power, and performed centreline turbine/generation inspection and maintenance work outages around the world, and at dozens of nuclear plants in the United States.

Risk reviews and lessons learned from Unit 2 have been shared with GE with mitigation plans in place. Executing with GE saves OPG the cost of paying for OEM oversight for CanAtom during execution, as well as inspection activities.

The turbine excitation controls and generator auxiliary skid execution work that remains with CanAtom can be executed independently from most of the GE work, providing increased schedule flexibility for both vendors.

**4. Analysis of Unit 3 execution phase risks, opportunities, and contingency is complete.**

The $257 Million of contingency estimate approved in November 2019 was derived through a detailed analysis and probabilistic modelling of the program risk profile, and reflected the experience gained during the execution of Unit 2 and incorporates numerous lessons learned, discovery issues, and opportunities relative to direct field labour productivity. Approximately $17 Million was drawn since November 2019 and Management has determined that the remaining $240 Million is sufficient to address the remaining known risks for Unit 3.

Management has revisited the risk and opportunities profile for Units 1 and 4 to confirm that the 4-Unit contingency allotment is sufficient and within the $12.8 Billion Program commitment.

As discussed below in Section 8, no adjustment to contingency has been made related to COVID-19 impact as it is a highly uncertain and unpredictable 'black swan' event that OPG could not have forecasted.

**5. The Unit 3 Working Schedule incorporates a Hybrid Shift Schedule.**

Unit 3 project performance will be managed against a Working Schedule duration currently planned as 1,096 days or 36 months. This represents a reduction of 3 days from the U3EE duration of 1,099 day approved in November 2019. The change is a direct result of OPG's robust lessons learned program, which identified an opportunity to increase the efficiency of the return-to-service deliverables based on OPG's operating experience from Unit 2.

As noted in the November 2019 version of the U3EE, a hybrid shift schedule has been designed to attract and retain the right resources and implement a sustainable schedule for the duration of the Program. Each critical path series was assessed to determine an optimal execution strategy that incorporates 24/5, 24/6 and 24/7 shift schedules. Implementation of this strategy is expected to yield several benefits:

- Resource Retention – adoption of a 24/5 shift schedule is expected to appeal to execution resources and improve the likelihood of trades and supervisory staff retention for the duration of the Program.
- Reduced Resource Demand – reduces supervisory and trades demand by 20%, reduces burn out on long duration series, reduces overtime premiums for direct field labour and reduces the size of the overall PMT organization.
- Improves Agility in Schedule Management and Delays – included in the 1,096 schedule duration are 930 critical path working days. The difference represents weekends where tool maintenance, equipment repairs and other logistical issues will be conducted. The difference also affords an opportunity to recover time lost, if needed, and provided it is the correct business decision.

Detailed Program execution schedules have been completed and issued and a detailed Level 3 integrated cost and schedule performance baseline has been established.

A copy of the Level 1 working schedule is included in **Appendix 1**.

The planned schedule duration is based on a detailed evaluation of schedule risks, tooling and work production rates, transition times between series, and most importantly lessons learned from Unit 2 actual durations. Production targets have been established based on realistic, achievable and sustainable rates with specific initiatives focused on improving performance.

Risks and opportunities for each activity along the critical path, including discrete technical risks associated with the installation and commissioning of the new Turbine and Generator controls system have been incorporated in the schedule durations.

The High Confidence schedule will be used to assess Program success. Management will report on Unit 3 performance to the Board of Directors on a quarterly basis, against both the Unit 3 working schedule and the high confidence schedule, with clear indications of Program status and contingency utilization.

**6. The overall program budget remains within the $12.8 Billion approved plan.**

The overall 4-Unit high confidence cost estimate remains at $12.8 Billion, subject to the ultimate impact of COVID-19 impacts discussed in section 8.

Changes in the Units 1 and 4 estimates reflect anticipated risks and opportunities identified from the Unit 2 experience as well as the build-up of the Unit 3 estimate. This includes schedule savings resulting from the capital investment in tooling improvements. **Table 2** below shows the cost estimate of each unit, which has been preserved since November 2019. A 4-unit cost comparison by major bundle is provided in **Appendix 2.**

**Table 2: Refurbishment 4-Unit Estimate**

| DIVISION ($Millions) | U3EE (Nov 2019 Approved) | FINAL Unit 3 Estimate | Variance |
|---|---|---|---|
| Cost Thru Unit 2 (including D2O) | 6,131 | 6,131 | 0 |
| UNIT 3 | 2,559 | 2,559 | 0 |
| UNIT 1 | 1,954 | 1,954 | 0 |
| UNIT 4 | 2,106 | 2,106 | 0 |
| **TOTAL:** | **12,800** | **12,800** | **0** |

**7. High Confidence durations for Units 3, 1 & 4 remain unchanged. Refurbishment start dates for each unit reflects deferral in response to the COVID-19 pandemic.**

The High Confidence schedule duration for each Subsequent Unit refurbishment remains consistent with the U3EE approved in November 2019.

OPG has reassessed the Program schedule as a result of the COVID-19 pandemic. The deferral of the Unit 3 refurbishment has a cascading impact on the Subsequent Units' refurbishment start dates as no additional overlap was introduced during the schedule reassessment. However, each unit's duration continues to be the same and the overall schedule is maintained to refurbish all four units by the end of 2026. The revised four-unit high confidence schedule is shown in **Table 3** below.

**Table 3: Comparison of 4-Unit High Confidence Schedule (U3EE vs. Final U3EE)**

| Unit | High Confidence (U3EE) | | | High Confidence (Final U3EE) | | | Variance |
|---|---|---|---|---|---|---|---|
| | Start | Finish | Duration (Months) | Start | Finish | Duration (Months) | |
| U2 | Oct-16 | Jun-20 | 44 | Oct-16 | Jun-20 | 44 | 0 |
| U3 | May-20 | Sep-23 | 40 | Sep-20 | Jan-24 | 40 | 0 |
| U1 | Oct-21 | Dec-24 | 38 | Feb-22 | Apr-25 | 38 | 0 |
| U4 | May-23 | Jun-26 | 37 | Sep-23 | Oct-26 | 37 | 0 |

Subsequent Unit start dates are being planned to align series windows so that dedicated execution teams can transition from one unit to the next for their specific scope of work.

With respect to the RFR series, the execution strategy will have dedicated Removal, Installation, and Feeder Teams. Each team will be responsible for the planning and execution of their respective work programs. Subsequent Unit schedules have been planned in a way that enables these teams to transition from one unit to the next as their respective windows are completed. The strategy enables a level of proficiency to be gained resulting in improved performance overall.

The Turbine Generator scope of work has also been scheduled following the same strategy. Sufficient time has been allocated between refurbishment outages to enable a successful transition between the refurbishment units.

**8. The impact of COVID-19 is not reflected in the DRP's $12.8 Billion Program estimate.**

The COVID-19 pandemic is an unforeseen, 'black swan' event not contemplated by the DRP's planning and, as a result, is not included in the Program estimate. Based on impacts known to date, OPG expects to incur costs of approximately $150 Million for the DRP as a result of the four-month deferral of Unit 3 refurbishment execution. Given the inherent uncertainty associated with the pandemic and the inability to accurately forecast its ultimate impact on the DRP, Management continues to monitor and manage the trends of the pandemic, track related expenditures separately and assess any opportunities to mitigate the impact.

**9. Management is adequately prepared and ready to proceed with the execution of Unit 3.**

The project remains ready to begin Darlington Unit 3 refurbishment execution. Pre-requisite field work will continue to ramp up through August with COVID-19 protective measures in place, which have been effective to date.

Unit 3 Design Engineering is substantially complete at 99%, including the Turbine Generator Control System modification design. The Emergency Heat Sink modification design was also completed (7 weeks ahead of the recovery plan date) with incorporation of design changes and lessons learned from Unit 2 execution. The two remaining design engineering packages are related to Auxiliary Shutdown Cooling and Fire Protection modifications and are on track to be completed by the end of October, ahead of the need date, to incorporate operating experience from Unit 2.

Material Procurement is on track with no threats to execution. There are currently no significant issues impacting the refurbishment supply chain due to the COVID-19 pandemic – OPG continues to monitor the supply chain and is working closely with our vendor partners.

Completion of Comprehensive Work Packages (CWPs) for RFR and Balance of Plant are tracking to, or ahead of, their T-16 week milestones. As of July 24th, for the Turbine Generator bundle, 199 out of 241 CWPs are complete, with the remaining 42 CWPs tracking within the T-16 week milestone, driven by the early 2020 decision to transfer execution responsibility for major turbine centreline work from CanAtom to General Electric. The remaining CWPs are committed to be complete no later than T-4 weeks to the start of the window.

The Fuel Handling (FH) Equipment Reliability Index (ERI) is 82% versus a target of 84% at breaker open primarily due to unplanned unavailability on Trolley 3 and 4. Although the current performance is slightly below target, the recent challenges occurred on the non-refurb trolley have been corrected and are well understood. The ERI is a lagging rolling average metric and will not recover to 84% prior to Unit 3 defuel. However, the team is confident that overall system health for all FH equipment is in good standing and the Reliability Campaign, in preparation for Unit 3 defuel, is complete.

The team has also strategically planned pre-requisites in the event the SFCR outage is completed earlier than planned, allowing flexibility to ensure these items are completed earlier. Just-in-time Training for key FH Staff is on track to be completed prior to defuel.

## RECOMMENDATION / RESOLUTION

Management is requesting that the Board of Directors approve the following items related to the DRP:

- Commencement of the Unit 3 refurbishment execution immediately following the Single Fuel Channel Replacement (SFCR) outage, with a planned start date for defuel on **September 2nd, 2020**. In the event that the SFCR outage is completed earlier than planned, the project remains ready to start defuel earlier.
- Final Unit 3 High Confidence Cost Estimate of **$2,559 Million**, which is unchanged from the U3EE previously approved in November 2019.

**Recommended by:**

Dietmar Reiner
Chief Project Officer & SVP, Enterprise Projects

**Approved for submission to the Board of Directors by:**

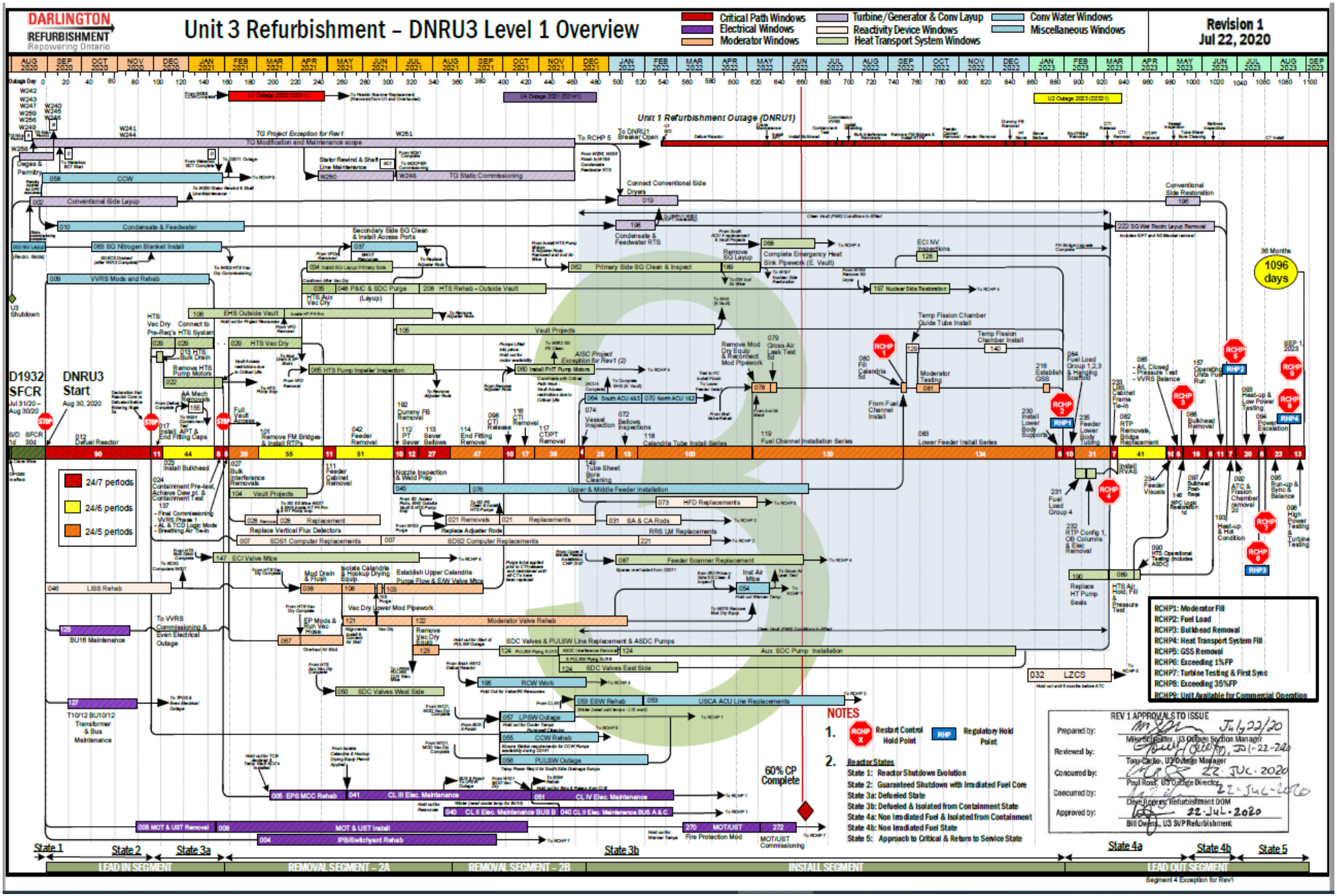
Ken Hartwick
President and CEO

This Board memo was reviewed and approved for submission to the Board of Directors by the Darlington Refurbishment Committee at their meeting of August 11th, 2020.

## APPENDICES

1. Unit 3 Level 1 Execution Schedule
2. 4-Unit Cost Summary

# APPENDIX 1: UNIT 3 LEVEL 1 EXECUTION SCHEDULE



# APPENDIX 2: 4-UNIT COST SUMMARY

| # | Division | Pre-Reqs (Unit 0/D/F&S) | Unit 2 | Unit 3 | Unit 1 | Unit 4 | Total |
|---|---|---|---|---|---|---|---|
| 1 | RFR - Retubing & Feeder Replacement | 703 | 1,460 | 1,026 | 767 | 824 | **4,782** |
| 2 | IL - Unit Islanding | 8 | 47 | 1 | 0 | 0 | **56** |
| 3 | FH - Fuel Handling | 35 | 8 | 8 | 4 | 3 | **58** |
| 4 | DF - Defueling | 5 | 25 | 8 | 3 | 2 | **43** |
| 5 | TG -Turbine Generator | 39 | 196 | 254 | 185 | 205 | **879** |
| 6 | BOP - Balance of Plant | 34 | 261 | 113 | 86 | 88 | **582** |
| 7 | SDLU - Shutdown, Layup and Services | 7 | 86 | 29 | 24 | 23 | **169** |
| 8 | SG - Steam Generator | 5 | 60 | 41 | 40 | 42 | **189** |
| 9 | RSF - Refurbishment Support Facilities | 4 | 36 | 7 | 0 | 3 | **51** |
| 10 | SP - Specialized Projects | 0 | 62 | 40 | 38 | 40 | **181** |
| 11 | WD - Waste Disposal | 0 | 12 | 10 | 10 | 10 | **42** |
| 12 | OM - NR Operations and Maintenance | 0 | 9 | 39 | 27 | 26 | **101** |
| **13** | **Sub-Total Bundle Projects** | **841** | **2,263** | **1,575** | **1,187** | **1,267** | **7,133** |
| 14 | F&IP + SIO Projects | 1,068 | 0 | 0 | 0 | 0 | **1,068** |
| 15 | OPG Execution + Functional Support | 362 | 441 | 290 | 217 | 258 | **1,569** |
| 16 | OPG Ops & Maintenance | 53 | 355 | 265 | 205 | 239 | **1,118** |
| **17** | **Sub-Total Before Contingency** | **2,324** | **3,059** | **2,131** | **1,609** | **1,764** | **10,887** |
| 18 | Interest | 440 | 358 | 189 | 129 | 147 | **1,261** |
| 19 | Contingency | 0 | 0 | 240 | 216 | 195 | **652** |
| **20** | **Total by Unit** | **2,764** | **3,417** | **2,559** | **1,954** | **2,106** | **12,800** |