BUSINESS PLANNING AND BENCHMARKING
NUCLEAR

1.0 PURPOSE

This evidence presents the business planning and benchmarking results for OPG's Nuclear Operations and provides a summary of nuclear operating costs from the 2020-2026 Business Plan in support of the application.

2.0 OVERVIEW

This application is based on OPG's 2020-2026 Business Plan, which was prepared reflecting the business planning process for the Nuclear Operations as outlined in Section 3.1 below. The methodology employed as part of that process is unchanged from the previous payment amounts application. This application reflects significant changes in OPG's Nuclear Operations, which pose unique challenges and opportunities in terms of business planning and benchmarking. Highlights of OPG's 2020-2026 Business Plan as it pertains to Nuclear Operations include the following:

- Ensuring the success of Pickering Optimized Shutdown of all six Pickering units, operating Unit 1 and Unit 4 to 2024 and Units 5-8 to 2025. Optimized shutdown will continue to provide Ontario with a clean and reliable source of baseload power while supporting summer capacity needs through to 2025. See Section 4.0 below.
- Ensuring an effective transition of OPG nuclear operations from a ten-unit fleet to four units at Darlington post-2025 in line with the corporate goal of mitigating the cost diseconomies of scale, where possible, while managing the risks and opportunities as part of the transition (Ex. F2-2-1).
- Executing site and fleet wide initiatives impacting people, processes and technology to drive station productivity, innovation and improve cost and operational performance over the IR term. See Section 3.4 below.
- Maintaining high standards of safety and environmental stewardship by targeting either best quartile performance or maximum Nuclear Performance Index ("NPI") points at both Pickering and Darlington relative to the company's Safety Cornerstone. See Section 3.3 below.

- Improving the identification and execution of project portfolio investments to enhance performance, reliability and overall value of the nuclear assets through a strengthened asset management program and Enterprise Project Management Office. (Ex. D2-1-1).
- Executing initial planning and preparation work in support of an investment decision for a proposed small modular reactor generating station at the Darlington site. This investment in clean and low-cost energy aligns with OPG's climate change goal of a net-zero carbon company by 2040 and will support Ontario's carbon reduction goals (Ex. F2-8-1).
- Investing in life cycle management and other sustaining infrastructure investments at Darlington, which will help to prepare the station for its second life and position Darlington towards the long-term goal of returning Darlington to top-quartile TGC post refurbishment. This will secure clean energy to supply over 20% of Ontario's electricity needs for the next 30-plus years (Ex. D2-1-3).

Achieving success on the business plan priorities will require building on the success of major programs undertaken within OPG over the past few years, which include; a) Unit 2 refurbishment completed and back in-service, b) safely extending the life of Pickering beyond its previously planned end of commercial operations date, c) the establishment of an Enterprise Project Management Office, which further enhanced the competency and process of managing and executing Nuclear Operations' capital and OM&A projects, and d) successful completion of various gap closure initiatives that have improved Nuclear operational and cost performance. These completed gap closure initiatives and their results are described in Attachment 1 to this exhibit.

A summary of actual and planned operating costs over the 2016-2026 period is presented in Ex. F2-1-1, Table 1.

OPG's 2020-2026 Business Plan reflects the implementation of an OPG-wide organizational realignment undertaken in the second half of 2020 with the goal of increasing cross-functional synergies and collaboration across the former Nuclear and Renewable Generation business units, which have been combined under an Enterprise Operations organization. The realignment is realizing incremental operational efficiencies in management headcount in Nuclear Operations as it prepares for post-Pickering operations.

3.0 NUCLEAR BUSINESS PLANNING AND BENCHMARKING

3.1 Gap-Based Business Planning Process

The business planning cycle for OPG's Nuclear Operations is undertaken annually as part of the overall OPG business planning process (Ex. A2-2-1). This cycle is focused on establishing strategic and performance targets for the nuclear business, in alignment with OPG's corporate-wide objectives, and identifying the initiatives and resources required to achieve these targets.

Since 2009, OPG Nuclear has used a gap-based business planning process which consists of the following steps:

- **Benchmarking:** Using industry accepted performance metrics to compare nuclear performance against industry peers in order to identify areas with the greatest potential for improvement.
- **Target Setting:** Implementing a "top-down" approach to set operational and financial performance targets consistent with continuous improvement and informed by benchmarking.
- **Closing the Gap:** Developing various fleet wide and site-specific initiatives to close the performance gaps between current and targeted results.
- **Developing the Business Plan:** Preparing input for the corporate business plan i.e., the development of cost, generation, staff and investment plans to achieve targeted results in support of the company's strategic imperatives.

Once the detailed business plan is developed and approved, OPG uses operational and financial measures to track its performance against target.

3.2 Gap-Based Business Planning – Benchmarking

The 2020 Nuclear Benchmarking Report shows OPG's benchmarking performance against industry peers based on 2019 data and uses various indicators aligned with the cornerstone values of Safety, Reliability, Value for Money and Human Performance (Attachment 2).

The 2020 Nuclear Benchmarking Report uses the same methodology and format as the previous nuclear benchmarking reports filed with the OEB based on a benchmarking initiative undertaken by OPG in 2009 with the assistance of the ScottMadden, Inc. ("ScottMadden"), a consulting firm. OPG has from time to time advised the OEB of updates to its benchmarking metrics that were required to reflect changes in industry reporting or other factors (e.g., amalgamation of Pickering A and Pickering B). The 2020 Nuclear Benchmarking Report includes four material updates relative to the 2015 Nuclear Benchmarking Report filed in EB-2016-0152:

- The Total Recordable Injury Frequency ("TRIF") (number of injuries per 200k hours worked) is a new industry standard metric from the Canadian Electrical Association replacing the previous industry standard, the All Injury Rate ("AIR"). This measure is more widely accepted and utilized by other industries outside the electricity sector. In addition to all injuries calculated under AIR, TRIF includes restricted work injuries which improves the measure's utility as an assessment of safety performance.

- 1-year On-Line Deficient Critical Backlogs and 1-year On-Line Corrective Critical Backlogs are two new metrics that focus on the backlog of Critical Deficiencies, as opposed to Non-Critical Deficiencies. Critical Deficiencies have a more significant impact on reliability. OPG has added these two metrics to improve the benchmarking assessment of OPG's reliability performance. OPG continues to benchmark 1-Year On-Line Deficient Maintenance Backlogs and 1-Year On-Line Corrective Maintenance Backlogs, which reflect the sum of Critical and Non-Critical Deficiencies.

- OPG has included several normalization adjustments to the value for money metrics (Normalized 3-Year Total Generating Cost per MWh; Normalized 3-year Non-Fuel Operating Costs per MWh; Normalized 3-Year Capital Cost per MW Design Electrical

Rating ("DER")). These metrics normalize for refurbishment costs at Darlington as well as CANDU technology (including outage duration) and age-related impacts and are based on a recommended methodology from ScottMadden as described in Section 3.2.1 below.

- OPG has included 3-year Total Generation Cost per unit (M$ per Unit) and Normalized 3-Year Total Generating Cost per unit (M$ per unit). Deriving a value for money metric on a unitized basis allows OPG to benchmark its cost performance on a capacity basis.

In 2019, OPG engaged ScottMadden to conduct an independent review of Nuclear's 2019 Benchmarking Report and process to ensure continued accuracy of reporting and consistency with industry best practices. ScottMadden's assessment found that OPG's current benchmarking methods align with previous guidance and current leading practices in the industry. The evaluation found no material issues with benchmarking report calculations or presentations of data and the review noted that OPG's nuclear business planning processes remain consistent with established OPG governance and industry leading practice. ScottMadden's assessment is filed as Attachment 3. The methodology underpinning OPG's 2020 Benchmarking Report is the same as the 2019 Benchmarking Report that ScottMadden assessed.

3.2.1 Benchmarking – Supporting Studies

In EB-2016-0152, OPG provided a calculation to normalize Total Generating Cost per MWh ("TGC/MWh") for Darlington by adding back the lost generation to account for the reduced unit output during the Darlington Refurbishment Program ("DRP"). The denominator in TGC/MWh declines because units are being refurbished but there is no corresponding decline in the numerator, as corporate support allocated, station and nuclear (now Operations and Project) support costs are largely fixed. The net impact, without adjustment, is to temporarily skew these metrics higher than would otherwise be the case.

In the EB-2016-0152 Decision and Order (p. 49), the OEB agreed that OPG's benchmarking methodology was appropriate with the exception of OPG's provided methodology for normalizing TGC/MWh. The OEB noted that ScottMadden had suggested that there were alternative approaches to account for the impact of refurbishment on TGC/MWh and indicated an expectation that OPG would file a review from ScottMadden regarding OPG's nuclear benchmarking methodologies.

In addition, OPG was aware of prior studies by ScottMadden that indicated there are various differences between CANDU reactors and Pressurized Water Reactors ("PWR") and Boiling Water Reactors ("BWR") as well as age-related differences that impact value for money performance comparisons with peers. OPG has consistently identified these factors in its Benchmarking Reports as contributing to the benchmarking gap, but was previously unable to quantify their impact.[1] While OPG's gap-based business planning process relies upon benchmarking to compare OPG's nuclear performance against industry leaders in order to identify areas with the greatest potential for improvement, OPG understands that there are limitations in assessing benchmarking results. The OEB has also recognized the limitations of benchmarking (EB-2016-0152, Decision and Order, p. 49).

Based on the OEB's expectations and in an effort to improve the usefulness of benchmarking results and address the benchmarking limitations described above, OPG engaged ScottMadden to undertake two independent studies to normalize OPG's value for money metrics to enable closer comparisons with peers. The two studies were:

a) OPG Nuclear Cost Performance Benchmarking – Methodology to Adjust for Refurbishment and Validation of Implementation (Attachment 4).
b) OPG Nuclear Cost Performance Benchmarking – A Study of Factors Impacting TGC/MWh Performance with Normalizing Adjustments to Facilitate Closer Comparison (Attachment 5).

In addition, in the EB-2016-0152 Decision and Order (p. 84), the OEB directed OPG to file a staffing benchmarking study following the Goodnight methodology. OPG engaged Goodnight Consulting Inc. ("Goodnight") to undertake this Nuclear Staffing Benchmarking Study (Attachment 6).

[1] EB-2016-0152, Ex. F2-1-1, Attachment 1, 2015 Benchmarking Report, p. 72.

Each of the three supporting studies referenced above are discussed in greater detail below.

3.2.1.1 <u>OPG Nuclear Cost Performance Benchmarking - Methodology to Adjust for Refurbishment and Validation of Implementation</u>

The purpose of ScottMadden's Methodology to Adjust for Refurbishment and Validation of Implementation study was to facilitate useful comparisons to past performance and industry peers for the operating plant at Darlington during the extended time periods in which certain units will be offline due to the DRP.

ScottMadden's views on adjusting TGC/MWh for DRP are summarized below:

- DRP is a unique "mega-program" and there is no established practice for normalizing cost metrics for this unique program.
- Normalization is necessary to facilitate benchmark comparisons to past performance and industry peers.
- OPG should continue to report unadjusted (i.e., not normalized) version of the cost metrics along with any normalized version.
- A more strongly supported and conventional approach to normalization of cost metrics is to adjust actual costs in the numerator while using unadjusted actual MWhs generated in the denominator.

ScottMadden examined various OPG cost items and OPG's corporate and nuclear support cost attributions in order to identify costs that should be adjusted to create a normalized TGC/MWh and Non-Fuel Operating Cost per MWh ("NFOC/MWh") while maintaining generation. ScottMadden's methodology indicated how each type of Darlington Station, Nuclear Support (now Operations and Project Support), allocated corporate support OM&A costs and sustaining capital expenditures could be removed for the purpose of normalizing TGC/MWh and its applicable sub-components for refurbishment. The study ultimately established a methodology to allow OPG to adjust the distribution of OM&A and capital costs while using actual generation to estimate what TGC/MWh and NFOC/MWh would be if Darlington was operating less than four units.

OPG independently applied ScottMadden's methodology to normalize TGC/MWh and its sub-components based on 2017 data. ScottMadden then reviewed OPG's work on the 2017 data (Attachment 3, Section 4) and validated that the approach OPG followed was in accordance with ScottMadden's guidance and that OPG accurately performed the calculations. ScottMadden found that OPG correctly interpreted and implemented the guidance provided.

OPG continued to apply ScottMadden's normalization methodology in deriving Darlington's Value for Money metrics in subsequent years. The 2019 results are shown in Chart 1 below.

3.2.1.2 <u>OPG Nuclear Cost Performance Benchmarking – A Study of Factors Impacting TGC/MWh Performance with Normalizing Adjustments to Facilitate Closer Comparison</u>

The objective of ScottMadden's Study of Factors Impacting TGC/MWh Performance with Normalizing Adjustments to Facilitate Closer Comparison was to determine whether and to what extent certain site characteristics of OPG's CANDU units influence TGC/MWh performance relative to industry peers and if possible, quantify and adjust these characteristics to produce normalized TGC/MWh values. ScottMadden's CANDU and age-related normalization methodology included:

- an econometric analysis of Electric Utility Cost Group ("EUCG") data; and
- a custom nuclear outage benchmarking study that sought to determine and normalize expected impacts on generation between CANDU and non-CANDU plants.

In its econometric analysis, ScottMadden analyzed nine years of EUCG data (from 2009 to 2017) for OPG and its industry peers to understand which site characteristics most influence TGC over a sustained period and to what extent. ScottMadden's analysis indicated that CANDU technology increases predicted TGC by over $250 million per year relative to non-CANDU plants and each month of average unit age increases predicted TGC by $346,000 per year. ScottMadden then adjusted the EUCG data to normalize for these factors.[2]

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[2] In addition, the ScottMadden analysis found that site capacity was a driver of TGC variability. However, ScottMadden did not adjust for site capacity to be conservative and to ensure that adjustments were easy to understand as such an adjustment would also have required a complex adjustment to generation.

ScottMadden also undertook a custom nuclear outage benchmarking study, including a confidential direct survey of nuclear operators representing 47 nuclear plants. As explained more fully in Attachment 5, the custom nuclear outage benchmarking study methodology quantified and adjusted for the impact of regularly recurring, planned maintenance outages on power generation, taking steps to arrive at an average annual value for days offline due to these planned outages. ScottMadden's analysis found that CANDU plants exhibited 4 to 22 more outage days per year compared to BWR and PWR plants, depending on the outage cycle frequency. ScottMadden adjusted for these incremental outage days by adding them back to total production for each year.

Chart 1 below summarizes the application of normalization methodologies for refurbishment (described in Section 3.2.1.1), and CANDU and age-related factors (described in Section 3.2.1.2), to the main 2019 Value for Money metrics. OPG does not apply CANDU and age-related normalization, consistent with ScottMadden's methodology, to the sub-components of TGC/MWh (i.e., Non-fuel Operating Cost per MWh or Capital Cost per MW DER). OPG accepts ScottMadden's normalization methodologies as described above as this achieves a closer comparison of OPG's TGC/MWh performance to peers.

Chart 1: Summary of Normalization Methodology Adjustments to Value for Money Metrics (2019)

Indicator	Non-Normalized	Refurbishment Normalization	CANDU and age-related Normalization	Combined Normalization
3-year Total Generation Cost per MWh	PN: $62.39 DN: $67.00	PN: N/A DN: $54.18	PN: $44.85 DN: $50.99	PN: $44.85 DN:$38.84
3- year Total Generating Cost per Unit	PN: $228.27 DN: $442.14	PN: N/A DN: $357.53	PN: $176.31 DN: $355.07	PN: $176.31 DN: $270.46
3- Year Non-Fuel Operating Cost per MWh	PN: $53.85 DN: $47.10	PN: N/A DN: $37.85	N/A	N/A
3-year Capital Cost per MW DER	PN: $30.66 DN: $116.67	PN: N/A DN: $89.78	N/A	N/A

3.2.1.3 Nuclear Staffing Benchmarking Study

At the direction of the OEB,[3] a Nuclear Staffing Benchmarking Study was undertaken by Goodnight and is included as Attachment 6.

The main conclusions of the 2019 Goodnight Nuclear Staffing Study are as follows:

- Goodnight compared OPG Nuclear staffing levels to other North American nuclear operators using an approach consistent with the methodology Goodnight used to evaluate OPG in 2011, 2013 and 2014.
- The analysis showed that OPG, as of August 2019, is 239 Full-Time Equivalents ("FTEs") (4.5%) below the total North America nuclear operator benchmark of 5,255 FTEs.
- 5,016 OPG Nuclear staff and long-term contractors were benchmarked; 2,404 OPG Nuclear personnel were excluded from benchmarking consistent with the methodology applied in prior studies.
- OPG is above benchmark staffing in 14 job functions, and below benchmark staffing in 28 functions.

OPG staffing levels have shown significant improvement by closing the gap identified initially by Goodnight in 2011[4] and then continuing to improve even after the gap was eliminated in 2016.[5] The latest study completed by Goodnight in 2019 confirms that actions taken by OPG have been effective in achieving favourable performance compared to benchmarked nuclear operators.

3.2.2 Benchmarking Results

Chart 2 is a reproduction of Table 1 from OPG's 2020 Nuclear Benchmarking Report (Attachment 1), and provides a summary of OPG's 2019 plant-level performance for each of the key performance indicators benchmarked.

[3] EB-2016-0152, Decision and Order, p. 84.
[4] EB-2013-0321, Ex. F5-1-1, Part a.
[5] In 2011, Goodnight indicated that OPG Nuclear was 17% above its industry peers, with a later update by Goodnight demonstrating that OPG Nuclear had narrowed the gap to 7.6% per EB-2013-0321, Ex. JT1.13). The Goodnight Nuclear Staffing Benchmarking Analysis published in December 2014 (EB-2016-0152, Ex. F2-1-1 Attachment 2), showed that staff reductions had further narrowed the gap to 4.1%, and as stated in EB-2016-0152, Ex. F2-1-1, OPG had eliminated the gap in 2016.

Chart 2

Comparison of OPG Nuclear Performance to Industry Benchmarks

Metric	NPI Max	Best Quartile	Median	2019 Actuals Pickering	2019 Actuals Darlington
Safety					
Total Recordable Injury Frequency (#/200k hours worked) [3]		0.81	N/A	0.11	0.00
Rolling Average[2] Industrial Safety Accident Rate (#/200k hours worked)[1]	0.20	0.00	0.01	0.02	0.04
Rolling Average[2] Collective Radiation Exposure (Person-rem per unit)[1]	80.00	38.54	70.32	70.32	83.23
Airborne Tritium Emissions (Curies) per Unit [3]		982	2,772	2,517	1,213
Fuel Reliability (microcuries per gram)[1]	0.000500	0.000001	0.000007	0.000187	0.000295
2-Year Reactor Trip Rate (# per 7,000 hours)[1]	0.50	0.00	0.00	0.24	0.00
3-Year Auxiliary Feedwater System Unavailability (#)[1]	0.0200	0.0000	0.0000	0.0039	0.0000
3-Year Emergency AC Power Unavailability (#)[1]	0.0250	0.0008	0.0016	0.0003	0.0026
3-Year High Pressure Safety Injection Unavailability (#)[1]	0.0200	0.000000	0.000000	0.00013	0.00000
Reliability					
Rolling Average[2] WANO NPI (Index)[1]		92.68	87.64	82.50	88.90
Rolling Average[2] Forced Loss Rate (%)[1]	1.00	1.08	2.43	3.39	2.56
Rolling Average[2] Unit Capability Factor (%)[1]	92.00	87.06	86.14	83.31	87.06
Rolling Average[2] Chemistry Performance Indicator (Index)[1]	1.01	1.00	1.00	1.02	1.03
1-Year Online Deficient Maintenance Backlog (work orders per unit)[1]		30	39	114	110
1-Year Online Deficient Critical Backlog (work orders per unit) [1]		0	0	5	3
1-Year Online Corrective Maintenance Backlog (work orders per unit) [1]		2	3	9	4
1-Year Online Corrective Critical Backlog (work orders per unit) [1]		0	0	1	0
Value for Money[4]					
3-Year Total Generating Costs per MWh ($ per Net MWh)[1]		34.63	41.85	62.39	67.00
Normalized 3-Year Total Generating Cost per MWh ($ per Net MWh)[1]		30.83	36.12	44.85	38.84
3-Year Total Generating Cost per Unit (M $ per Unit)[1]		275.21	310.29	228.27	442.14
Normalized 3-Year Total Generating Cost per Unit (M $ per Unit)[1]		239.49	290.39	176.31	270.46
3-Year Non-Fuel Operating Costs per MWh ($ per Net MWh)[1]		20.84	24.65	53.85	47.10
3-Year Normalized Non-Fuel Operating Cost per Net MWh ($/MWh)[1]		20.84	24.65	--	37.85
3-Year Fuel Costs per MWh ($ per Net MWh)[1]		7.03	7.69	4.22	4.38
3-Year Capital Costs per MW DER (k$ per MW)[1]		38.82	53.64	30.66	116.67
Normalized 3-Year Capital Cost per MW DER (k$ per MW)[1]		38.82	53.64	--	89.78
Human Performance					
18-Month Human Performance Error Rate (# per 200k ISAR and contractor hours)[1]		0.0000	0.0530	0.0200	0.0360

1. Best Quartile, Median and Third Quartile are from Q4 2019 best available information.
2. Indicates a 2-Year Rolling Average for Pickering and a 3-Year Rolling Average for Darlington.
3. Best Quartile, Median, Third Quartile are from the Q4 2018, which is the most current available benchmark for these metrics.

Legend

4th Quartile Performance	3rd Quartile Performance	2nd Quartile Performance	Maximum NPI points achieved or Best Quartile

Detailed discussion of the 2019 performance trends and drivers by cornerstone is provided in the OPG 2020 Nuclear Benchmarking Report (Attachment 1), and is summarized as follows:

- **Safety**

  Overall, OPG's nuclear generating stations continue to demonstrate strong safety performance. Darlington and Pickering continued to demonstrate first quartile performance in Total Recordable Injury Frequency ("TRIF"), with OPG achieving its lowest TRIF in the history of the company in 2019. OPG was the top TRIF performer in 2019 compared to its peer group.

  Darlington achieved maximum NPI results or best quartile performance for six of seven NPI safety sub-metrics, while Pickering achieved similar results on seven of seven safety sub-metrics.

  The Collective Radiation Exposure improved for Pickering resulting in maximum NPI points, and improved for Darlington while remaining in the third quartile. Positive gains were seen from site innovations such as leveraging technology to avert dose using robotic equipment and remote monitoring of systems, and the early completion of planned outages.

  The Airborne Tritium Emissions remained in the second quartile for Darlington while Pickering has improved from third to second quartile due to emission reduction initiatives that included dedicated teams to ensure daily emissions monitoring, sustaining and improving dryer performance, heavy water leak minimization, tritium program development and innovations.

  Pickering's Fuel Reliability Index ("FRI") improved in 2019 achieving maximum NPI points due to improved methods to reduce fuel bundle defects as well as elimination of the possibility of foreign materials entrance into the Heat Transport System due to Fuel Handling and Outage practices. Darlington's FRI performance continued to achieve maximum NPI points.

- **Reliability**

  Several key reliability indicators at both stations noted sustained or improved quartile performance in 2019.

  Significant improvements were recorded for On-line Deficient Maintenance Backlogs, and On-line Corrective Maintenance Backlogs for both stations relative to 2018. Pickering's On-line Deficient Maintenance Backlogs registered a 59% reduction compared to the previous year, while Darlington improved by 11%. In addition Pickering achieved a 47% improvement in On-line Corrective Maintenance Backlogs.

  Darlington's unit capability factor ("UCF") improved to first quartile while its NPI ranking remained in the second quartile relative to 2018 and its forced loss rate ("FLR") remained consistent at third quartile. Pickering improved to the third quartile and achieved its best ever NPI value as a combined six-unit station. Pickering's FLR and UCF also improved with the station achieving its best ever performance for those metrics as a combined six-unit station. While Pickering's FLR remains above the median quartile, it has shown considerable improvement year-over-year, from double digit values in 2014 to single digits currently.

  Darlington's Chemistry Performance Indicator experienced some challenges in 2018 due to Unit 3 condenser tube leaks which caused an increase in boiler conductivity and feedwater iron levels during start-ups following the unit outages. As Chemistry Performance Indicator is a 3-year rolling average, the event from 2018 continued to impact 2019 performance. A number of initiatives are being implemented to further improve performance. Pickering improved from fourth quartile to third and has shown an improving trend since 2014.

- **Value for Money**

  Darlington's TGC per MWh performance was in third quartile in 2019 after normalizing for refurbishment costs, CANDU technology and age-related factors (as described in Section 3.2.1.1 and Section 3.2.1.2). Darlington's TGC/MWh performance (non-normalized) was in the fourth quartile. These non-normalized results were driven largely by significant capital expenditures, which are necessary for reliable post-refurbishment operation, and, reduced generation during the DRP. Darlington achieved top quartile performance in Fuel Cost per MWh.

Pickering's normalized TGC per MWh improved in 2019 by $4.44/MWh and was in fourth quartile (normalized and non-normalized). Pickering's performance was partly impacted by requirements for Pickering Extended Operations. Pickering units are the smallest in the peer group with a capacity of 540 MW per unit compared to the peer group average of 1,026 MW. Improved performance in 2019 reflects higher generation and associated OM&A cost reduction due to fewer outage days as well as decreased capital investment and improved Fuel Costs/MWh. Pickering maintained best quartile performance in Fuel Cost per MWh and Capital Cost per MW DER.

Pickering's TGC per generating unit continued to demonstrate strong performance, placing among the best in the peer group in the first quartile, while Darlington's normalized TGC per generating unit was second quartile.

- **Human Performance**

  OPG Nuclear's human performance strategy focuses on and reinforces the correct behaviors during all phases of station operations and maintenance. Darlington improved its Human Performance Error Rate ("HPER") in 2019 as compared to 2018 and remained in second quartile. Pickering improved to second quartile in 2019 from fourth quartile in 2018. OPG is targeting building industry-leading Human Performance practices through a Mobile Observation and Coaching Application analysis tool for early detection of signs of decline in Human performance, and specialized training with the use of a simulator to teach Human Performance concepts and behaviours.

OPG has made improvements in many areas and continues to identify and implement opportunities for further improvement as discussed in Section 3.4 below

3.3 Gap-Based Business Planning – Target Setting

Top-down targets are designed to demonstrate continuous improvement and drive OPG Nuclear Operations closer to top quartile industry performance. Targets are set for each year of the business plan and are measured annually to assess performance for the given year.

2022-2026 Targets

OPG's Chief Nuclear Officer ("CNO"), in consultation with OPG's Nuclear leadership team, provided direction on top-down performance targets for each nuclear station for the 2020-2026 business planning period, based on the applicable corporate targets. The top-down targets for this business plan recognize the following drivers of operating costs and generation, including:

a) Lost generation due to the refurbishment of four units at Darlington.
b) The need for capital expenditures within the Nuclear Operations' project portfolio to position Darlington for strong performance post refurbishment (as discussed at Ex. D2-1-2).
c) Pickering investments that are being optimized and planned outages are being undertaken to ensure it safely runs to planned shutdown in 2024 for Pickering Units 1 and 4 and to end of 2025 for Pickering Units 5-8.
d) In alignment with OPG-wide initiatives, the need to implement wide scale cost efficiencies to achieve the base operating cost reductions set out in the Business Plan. These cost reductions will mitigate, to a significant extent, the diseconomies of scale that will result within OPG as a result of the planned Pickering shutdown. (Ex. A2-2-1). Initiatives in support of these demanding targets are being developed in such areas as: optimization of maintenance work programs, resource optimization leveraging attrition, streamlining processes, and maximizing viable technology innovations, including increased use of artificial intelligence. OPG's specific nuclear fleet-wide initiatives are described below in Section 3.4.

The top-down approach that established the operational and financial targets was also informed by historical performance, targets set in prior years and the latest benchmarking results. Charts 3 (Pickering) and Chart 4 (Darlington) set out OPG's nuclear operational and financial targets for 27 benchmark performance indicators for the 2020-2026 period. OPG views these targets as challenging but achievable.

Chart 3

Annual Operational and Financial Targets for Pickering

Benchmarking Indicators	WANO Max NPI	Best Quartile [1]	Median Quartile [1]	Pickering – Annual Targets					
				2020	2021	2022	2023	2024	2025
Safety									
Total Recordable Injury Frequency(#/200k hours worked)		0.81	N/A	0.20	0.13	0.1	0.09	0.09	0.08
Industrial Safety Accident Rate (#/200k hours worked)	0.20	0.00	0.01	0.10	0.10	0.10	0.10	0.10	0.10
Collective Radiation Exposure (person-rem per unit)	80.00	38.54	70.32	121.7	94.5	101	99.5	72.7	19.5
Airborne Tritium Emissions (Curies) per Unit		982	2,772	2,333	2,250	2,200	2,200	2,070	2,000
Fuel Reliability (microcuries per gram)	0.000500	0.000001	0.000007	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Reactor Trip Rate (# per 7,000 hours)	0.50	0.00	0.00	0.5	0.5	0.5	0.5	0.5	0.5
Auxiliary Feedwater System Unavailability (#)	0.02	0.0000	0.0000	0.02	0.02	0.02	0.02	0.02	0.02
Emergency AC Power Unavailability (#)	0.025	0.0008	0.0016	0.025	0.025	0.025	0.025	0.025	0.025
High Pressure Safety Injection Unavailability (#)	0.02	0.00000	0.00000	0.02	0.02	0.02	0.02	0.02	0.02
Reliability									
WANO NPI (Index)		92.7	87.6	77.6	74.7	76.9	75.7	80.3	85.6
Forced Loss Rate (%)	1.00	1.08	2.43	3.5	3.5	3.5	3.5	3.5	3.5
Unit Capability Factor (%)	92.0	87.06	86.14	76.0	80.0	74.1	79.4	83.3	93.2
Chemistry Performance Indicator (Index)	1.01	1.00	1.00	1.02	1.01	1.03	1.01	1.01	1.00
On-line Deficient Mtce Backlog (work orders/unit)		30	39	115	57	52	46	39	39
On-line Deficient Critical Mtce Backlog (work orders/unit)		0	0	7	0	0	0	0	0
On-Line Corrective Mtce Backlog (work orders/unit)		2	3	10	2	2	2	2	2
On-Line Corrective Critical Mtce Backlog (work orders/unit)		0	0	0	0	0	0	0	0
Value for Money									
Normalized Total Generating Cost per MWh ($/Net MWh),**2		30.83	36.12	50.37	44.31	46.15	40.77	36.32	23.73
Total Generating Cost per MWh ($/Net MWh)**		34.63	41.85	70.57	63.24	67.06	60.10	55.42	46.62
Normalized Total Generating Cost per Unit (M$ per Unit)**2		239.49	290.39	183.79	170.04	164.64	155.26	139.41	70.15
Total Generating Cost per Unit (M$ per Unit)**2		275.21	310.29	238.30	225.46	220.97	212.52	197.61	129.31
Non-Fuel Operating Cost per MWh ($/Net MWh) **		20.84	24.65	63.02	56.24	60.78	54.60	50.03	40.87
Fuel Cost per MWh ($/Net MWh)		7.03	7.69	4.02	3.83	3.90	4.01	4.17	4.52
Capital Cost per MW DER (k$/MW) ***2		38.82	53.64	23.10	21.93	15.17	10.18	8.39	6.60
Human Performance									
Human Performance Error Rate (# per 200k ISAR hours)		0.0000	0.0530	0.06	0.066	0.066	0.04	0.04	0.04

** TGC/MWh and Non-Fuel Operating Cost per MWh exclude OPEB, Pension and Corporate Asset Service Fees to align with the industry standard.
*** Design Electrical Rating (DER)
Note 1: Best Quartile and Median Quartile for Value of Money metrics are based on 2019 year end
Note 2: Normalization methodologies are applied as described in section 3.2.1 and summarized in Chart 1
Note 3: Nuclear Performance Index (NPI) is a Composite index of ten WANO indicators related to safety and production performance. NPI is calculated using a 2 year rolling average for PN and a 3 year rolling average for DN.

Note 4: Value for money targets are indicative and will be updated for final cost allocations reflected in this application (Ex. A2-2-1, Attachment 1, p. 49).

Chart 4
Annual Operational and Financial Targets for Darlington

Benchmarking Indicators	WANO Max NPI	Best Quartile [1]	Median Quartile [1]		Darlington – Annual Targets						
					2020	2021	2022	2023	2024	2025	2026
Safety											
Total Recordable Injury Frequency(#/200k hours worked)		0.81	N/A		0.20	0.17	0.1	0.09	0.09	0.08	0.08
Industrial Safety Accident Rate (#/200k hours worked)	0.20	0.00	0.01		0.10	0.10	0.10	0.10	0.10	0.10	0.10
Collective Radiation Exposure (person-rem per unit)	80.00	38.54	70.32		30.63	126.2	21.1	73.9	40	78.2	31.8
Airborne Tritium Emissions (Curies) per Unit		982	2,772		970	970	970	970	970	970	970
Fuel Reliability (microcuries per gram)	0.000500	0.000001	0.000007		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Reactor Trip Rate (# per 7,000 hours)	0.50	0.00	0.00		0.5	0.5	0.5	0.5	0.5	0.5	0.5
Auxiliary Feedwater System Unavailability (#)	0.02	0.0000	0.0000		0.02	0.02	0.02	0.02	0.02	0.02	0.02
Emergency AC Power Unavailability (#)	0.025	0.0008	0.0016		0.025	0.025	0.025	0.025	0.025	0.025	0.025
High Pressure Safety Injection Unavailability (#)	0.02	0.00000	0.00000		0.02	0.02	0.02	0.02	0.02	0.02	0.02
Reliability											
WANO NPI (Index)		92.7	87.6		93.7	84.3	93.1	77.54	86.9	84.75	85
Forced Loss Rate (%)	1.00	1.08	2.43		2.85	3.79	2.12	1.2	5.99	6.42	4.27
Unit Capability Factor (%)	92.0	87.06	86.14		91.06	76.0	85.8	78.1	81.8	68.2	89.4
Chemistry Performance Indicator (Index)	1.01	1.00	1.00		1.02	1.01	1.01	1.01	1.01	1.01	1.01
On-line Deficient Mtce Backlog (work orders/unit)		30	39		101	90	75	65	60	41	30
On-line Deficient Critical Mtce Backlog (work orders/unit)		0	0		2	0	0	0	0	0	0
On-Line Corrective Mtce Backlog (work orders/unit)		2	3		2	2	2	2	2	2	2
On-Line Corrective Critical Mtce Backlog (work orders/unit)		0	0		0	0	0	0	0	0	0
Value for Money											
Normalized Total Generating Cost per MWh ($/Net MWh),**2		30.83	36.12		39.05	58.74	47.45	62.71	44.81	60.27	40.65
Total Generating Cost per MWh ($/Net MWh)**		34.63	41.85		62.16	94.26	106.15	153.88	115.53	108.41	65.45
Normalized Total Generating Cost per Unit (M$ per Unit)**2		239.49	290.39		274.78	352.45	324.33	392.99	292.79	325.81	286.41
Total Generating Cost per Unit (M$ per Unit)**2		275.21	310.29		416.40	531.18	670.80	865.68	691.61	542.19	438.86
Normalized Non-Fuel Operating Cost per MWh ($/Net MWh) **2		20.84	24.65		34.52	55.45	47.55	71.30	52.71	63.75	41.64
Non-Fuel Operating Cost per MWh ($/Net MWh) **		20.84	24.65		40.51	66.14	69.92	109.07	80.29	79.60	48.61
Fuel Cost per MWh ($/Net MWh)		7.03	7.69		4.74	4.08	4.10	4.35	5.15	5.11	4.89
Normalized Capital Cost per MW DER (k$/MW) ***2		38.82	53.64		109.68	125.42	149.82	155.25	106.03	104.27	78.49
Capital Cost per MW DER (k$/MW) ***2		38.82	53.64		129.03	154.33	231.31	259.24	205.17	135.00	91.29
Human Performance											
Human Performance Error Rate (# per 200k ISAR hours)		0.0000	0.0530		0.033	0.039	0.039	0.019	0.019	0.019	0.019

** TGC/MWh and Non-Fuel Operating Cost per MWh exclude OPEB, Pension and Corporate Asset Service Fees to align with the industry standard.
*** Design Electrical Rating (DER)
Note 1: Best Quartile and Median Quartile for Value of Money metrics are based on 2019 year end
Note 2: Normalization methodologies are applied as described in section 3.2.1 and summarized in Chart 1
Note 3: Nuclear Performance Index (NPI) is a Composite index of ten WANO indicators related to safety and production performance. NPI is calculated using a 2 year rolling average for PN and a 3 year rolling average for DN.

Note 4: Value for money targets are indicative and will be updated for final cost allocations reflected in this application (Ex. A2-2-1, Attachment 1, p. 49).

The following summarizes the rationale for the targets set for each of the four cornerstones for the period 2020-2026, specifically:

- **Safety Cornerstone:** For the safety cornerstone, OPG is targeting either best quartile performance or maximum NPI points at both stations, except for Collective Radiation Exposure and Airborne Tritium at Pickering, where the focus will be on improvement, while recognizing that both metrics are significantly impacted by the number of planned outage days.

- **Reliability Cornerstone:** For the reliability cornerstone, OPG is targeting a FLR of 3.5% at Pickering across 2020-2026, based on past improvements and expected sustained equipment reliability, which compares favourably to an average FLR of 8.5% over the period 2010-2015, an average of 4.0% over the period 2016-2019 and the target of 5.0% in EB-2016-0152 (Ex. E2-1-1, Section 3.3). Pickering's UCF is targeted to improve from 2022 onwards. Darlington's UCF and FLR fluctuate over the IR term due to the expected increase in FLR after each unit is returned to service post-refurbishment. Based on industry operating experience, post-refurbishment FLR is assumed to be 12% in year one following return to service, 6% in year two and 2% in year three, before return to the top-quartile target of 1%. Prior to refurbishment, OPG continues to target 1% FLR at each Darlington unit in order to drive continuous improvement. Online Deficient and Corrective Maintenance backlogs will remain a focus for continued improvements at both Pickering and Darlington. The online corrective critical and deficient critical maintenance backlog metrics are expected to be in the top quartile throughout 2020-2026.

- **Value for money:** As Pickering progresses toward the planned shutdown, the station is expected to improve significantly to first quartile normalized TGC per MWh performance by 2025, reflecting improved reliability and reduced capital investment requirements. By 2025, Pickering's normalized TGC per MWh measure is planned to have improved by over $15/MWh compared to 2019 results. For Darlington, the TGC per MWh over the period 2020-2026 is expected to be temporarily affected by the increased capital spending supporting continued preparation for Darlington second life operations and reduced generation. By 2026, Darlington is expected to achieve second quartile normalized TGC/MWh performance, reflecting the cost targets set in the 2020-2026 Business Plan for mitigating the reallocation of shared costs to

Darlington and other operations following the Pickering shutdown. With the achievement of these cost targets, the 2026 goal for normalized TGC/MWh performance is expected to be a stepping stone toward further improvement in the station's value for money metrics as it enters steady-state post refurbishment operations and returns the sustaining capital program to prior levels.

- **Human Performance:** For the human performance cornerstone, OPG is targeting an improved HPER at Darlington, while remaining in the second quartile. Pickering HPER is targeting improvements during the business planning period and is expected to achieve median quartile from 2023 onwards.

3.4 Gap Based Business Planning - Gap Closure and Resource Plan

The operational and financial targets established by the target setting process are the basis for site and support group business planning. As part of that process, fleetwide and site improvement initiatives are established to close performance gaps to targets over the business planning period. The fleetwide improvement initiatives, which are described in Section 3.4.2, are intended to improve efficiency, operational performance and cost effectiveness.

3.4.1 Prior Gap Closure Initiatives

In its EB-2016-0152 submission, OPG identified six Nuclear gap closure initiatives: i) Parts Improvement, (ii) Outage Improvement, (iii) Equipment Reliability, (iv) Human Performance, (v) Nuclear Inventory, and (vi) Workforce Planning and Resourcing. Attachment 1 provides details about these prior initiatives and benefits realized.

3.4.2 Current Fleetwide Improvement Initiatives

OPG's 2020-2026 Business Plan (Ex. A2-2-1, Attachment 1) sets out the resource requirements (cost, staff and investment plans) for Nuclear. As stated above and in Ex. A2-2-1, OPG's operating cost profile in the 2020-2026 Business Plan is based on challenging but achievable OM&A targets that will position Darlington towards top-quartile TGC performance, post refurbishment.

The Nuclear business remains focused on continuously improving its operational performance and cost effectiveness at the Darlington and Pickering stations. The 2020-2026 targeted cost structure for the business, builds on productivity improvements and cost savings accomplished to date as well as a range of change strategies over the planning period This includes initiatives aimed at continuing to drive better outage performance, improving equipment reliability, reducing maintenance backlogs, implementing integrated asset management planning, enhancing maintenance programs and strengthening the digital infrastructure.

In addition to managing improvements, OPG will make greater use of innovation, leveraging proven technologies in the nuclear industry to change how work programs are executed. This will be enabled by OPG's Digital Strategy (see Ex. D3-1-1). Investing in technology to create efficiencies is consistent with customer feedback as obtained through the customer engagement process (see Ex. A2-2-1). In order maximize the value of these initiatives, OPG will focus on empowering leaders and strengthening an overall innovation mindset to help drive business efficiencies.

Consistent with the above, the key nuclear initiatives discussed below are designed to bring improvements across a range of areas broadly characterized as people, processes and technology. The initiatives will strengthen operational performance and cost effectiveness of the nuclear fleet, helping to drive the cost savings needed to meet the 2020-2026 Business Plan commitments. The initiatives are also designed to mitigate risks to enable a successful transition from a ten unit fleet to a four unit fleet. In recognition of the transformational period for the organization that is the next IR term, OPG will adopt an agile approach to achieving its performance goals by pursuing a range of potential opportunities, building on successes, and developing alternative plans and mitigation actions as required. As discussed in Ex. A2-2-1, the targets for this business plan recognize that a "check and adjust" approach will be necessary to advance the significant changes in the organization, while ensuring continued safe and reliable fleet operations.

3.4.2.1 <u>Nuclear Specific Initiatives</u>

Investments are integrated to ensure improvements are executed and sequenced appropriately. Initiatives focus on changing how we execute our work programs by leveraging proven technology that is used in the Nuclear industry. Investing in technology to create efficiencies is also consistent with customer feedback as obtained through the customer engagement process (see Ex. A2-2-1).

The initiatives discussed below will help OPG to successfully transition from a ten unit fleet to a four unit fleet with the planned shutdown of Pickering in 2024/2025 and support achievement of Nuclear cost savings and business plan targets. OPG will adopt an agile approach to achieving its financial and operational performance goals by pursuing a range of opportunities, building on successes, and developing alternative plans and mitigation actions as required.

Right Work, Right Time, Right Value

The Right Work, Right Time, Right Value ("RWRTRV") initiative focusses on improving plant reliability by improving maintenance productivity. Another key area of focus is on improving work management performance by transitioning to the use of digital work management tools and artificial intelligence in work management and outage planning processes. Key improvement actions and anticipated results for this initiative are:

- Expanding the "Fix it Now" maintenance team and optimizing assessment of minor maintenance. The benefit of the Fix-it-Now team is increased agility in executing priority work. This team is empowered with cross-functional members to tackle urgent issues more efficiently. Similarly, minor maintenance work is being optimized to ensure assessment is based on a graded approach, which improves efficiency and reduces the comprehensive requirements that are applied to complex work. These are industry best practices and trends that are being further expanded at OPG, improving work management performance, reducing backlogs, and supporting improved plant reliability. Maximizing the Fix It Now team will improve minor maintenance execution and drive reductions in both targeted critical and deficient maintenance backlogs.

- Utilizing the Monitoring and Diagnostic Center ("M&D Center") to develop predictive failure models and transitioning components of its time-based maintenance program to condition-based maintenance. The objective of condition-based maintenance is to establish continuous equipment condition monitoring through the use of high performance diagnostic tools that can combine the power of on-line process and equipment performance data acquisition with advanced diagnostic methodologies, including advanced pattern recognition technology (a form of artificial intelligence ("AI")), to avoid operations and maintenance costs and improve plant performance. As part of the continued evolution of the M&D Center, sensors and remote monitoring technologies are being installed on plant equipment, which will provide real time data and analysis to ensure maintenance is done promptly and resource utilization is maximized (see also Ex. D2-1-3, Section 3.1, Project #83828). This will allow the prioritization of maintenance activities and optimal use of resources to ensure high plant reliability.

- As part of continuous improvement and in keeping with industry best practices, a collaborative review of the preventative maintenance ("PM") program will be performed by Engineering, Maintenance, Operations, and Work Management staff to ensure that Maintenance resources are focused on execution of the highest-value activities. Lower risk/lower value work will be removed from the PM program and similar tasks or related activities will be bundled together to increase efficiencies in execution.

- Along with the AI modelling in the M&D Centre, OPG will continue to explore opportunities for using AI to improve work management. The use of AI for work management is a new concept for the nuclear industry and is enabling both Pickering and Darlington to continually drive improvements to their work management programs. OPG is leveraging new technologies and processes as they are adopted in the nuclear industry and applying successes to future work. This includes using AI to maximize maintenance resources by effectively coordinating on-line and outage shift schedules, assisting in the assessment of work packages, and logging and monitoring of foreign material exclusion. OPG has already realized improvements in the outage scoping process with batch work assessing capabilities that reduce human performance issues as errors are automatically corrected. OPG will continue to seek further opportunities to apply AI to support planning of outage scope and the efficient execution of outage work.

The RWRTRV initiative's improvements support cost effectiveness as well as improved operational performance and efficiencies in areas of maintenance, outage performance, backlog reductions and equipment reliability.

Leaders Driving Business Results

The Leaders Driving Business Results initiative focusses on managers driving business efficiencies through innovation. The initiative provides managers with tools and training to make sound decisions that will improve the performance of their teams and support improvement in value for money metrics through readily available information. Key improvements and anticipated results include:

- Established automated centralized business data and reports providing managers with more efficient reporting and access to information to make better informed and more timely decisions. As an example, OPG has implemented a suite of online reporting dashboards providing managers with the ability to see up-to-date operational and cost information, including overtime trend data to better manage their budgets. These dashboards also support building broader awareness of business acumen and how decisions impact TGC per MWh.

- To support this transition, training and workshops will continue to ensure that all managers have the required knowledge and skills to use these tools and manage their teams to drive and sustain innovation and performance improvement.

People Powering the Future

As discussed in Ex. F4-3-1, the planned shutdown of Pickering will result in a transformational change to OPG's workforce, with an expected reduction of over 3,000 employees. The People Powering the Future initiative focusses on ensuring work programs are resourced appropriately in accordance with the 2020-2026 Business Plan while minimizing the organizational and financial impacts associated with the transition to post-Pickering operations.

In preparing for this transition, OPG is developing strategies to ensure there is proper knowledge retention and transfer in order to minimize any impact to work programs and operations. These changes are also expected to support a leaner organization post planned Pickering shutdown, in line with the business plan cost targets. As the organization makes these changes, it is important to ensure that the right individuals and skills are available, within the provisions of collective agreements. OPG is also ensuring that workforce strategies are designed to manage the financial cost of the downsizing process.

Key improvement actions and anticipated results for this initiative include:

- Implement the changes required to support the organizational design for OPG post-Pickering shutdown, including streamlining and reducing demand for engineering support as already demonstrated thorough the organizational realignment and the centralization of the engineering function.

- Continue to leverage headcount reductions through attrition, where possible, retain vacancy controls and implement targeted staffing plans.

- Optimize the resource mix and utilization of staff to support an effective transition to a post-Pickering organization while ensuring safe and reliable operations, including for post-shutdown activities at Pickering.

4.0 PICKERING OPTIMIZED SHUTDOWN

4.1 OVERVIEW

In EB-2016-0152, OPG presented the Pickering Extended Operations initiative aimed at operating Pickering Units 1 and 4 to 2022 and Pickering Units 5-8 to 2024 (EB-2016-0152, Ex. F2-2-3). OPG expects this initiative will be completed by 2021 at a total cost of $307M, consistent with the forecast presented in EB-2016-0152.

This application reflects OPG's plans to safely optimize the shutdown of Pickering by operating all six units until September 2024, five of the six units through 2024 and the remaining four units until December 2025, as per the 2020-2026 Business Plan ("Optimization"). OPG will require CNSC approval to operate the remaining four units past 2024 until December 2025.

On August 14, 2020, the Province of Ontario issued a press release announcing its support of OPG's plan to pursue Optimization (Attachment 7). The IESO's Annual Planning Outlook published in December 2020 also assumes Pickering shutdown in 2024/2025. Optimizing the shutdown of Pickering mitigates capacity uncertainties during the refurbishments of the Darlington and Bruce stations.

4.2 WORK AND COSTS REQUIRED FOR OPTIMIZATION

The work related to the Pickering Extended Operations initiative demonstrates that it is feasible for Pickering to safely operate to the optimized shutdown plan of 2024/2025.

Optimization involves incremental activities to demonstrate to the CNSC the station's continued fitness of service to safely and reliably operate to the planned shutdown dates through to 2025, and to make other necessary improvements in support of this plan. The estimated cost of this work, which is incremental to normal operating costs, is $50M over 2020-2024 ("Enabling Costs"). Further details on the Pickering Optimized Shutdown work and Enabling Costs are described below.

4.2.1 Pickering Optimized Shutdown Work

In advance of recommending Optimization, OPG completed an initial technical assessment of the Pickering units' continued ability to operate to the Optimization's proposed shutdown dates. The initial technical assessments serve as the basis for the detailed scope for the Enabling Costs. The main elements of this scope of work are for: 1) the Periodic Safety Review ("PSR") revision; 2) the Fuel Channel Life Cycle Management Plan ("FC-LCMP"), and 3) Component Condition Assessments.

Periodic Safety Review Revision

The current Power Reactor Operating Licence for Pickering was issued in August 2018 for a 10 year term and is set to expire on August 31, 2028. As part of Pickering's re-licensing in 2018, a PSR was completed to evaluate the plant against the requirements that would apply to a newly-built nuclear power plant. The evaluation identified potential nuclear safety enhancements to the plant design or programs. The safety enhancements were then assessed to identify the alternatives that can be reasonably and practicably implemented to improve safety, and these results were documented in the Integrated Implementation Plan ("IIP"). The licence issued in August 2018 will allow OPG to operate all Pickering units until 2024 with a commitment by OPG to implement the results of the IIP to ensure the station's continued safe and reliable commercial operation, to be followed by the safe storage project (i.e., until the units are placed in a safe-stored state). The CNSC also approved fuel channel operation past 247,000 Equivalent Full Power Hours ("EFPH") up to 295,000 EFPH.[6]

While 295,000 EFPH is sufficient to allow OPG to operate the Pickering Units 5-8 to 2025, for the units to operate beyond 2024, OPG is also required to complete a reassessment of the continued validity of the PSR, revise the IIP actions as required, and notify the CNSC of the results of both by December 31, 2022, in support of an application for a licence amendment. OPG will continue, leading up to the CNSC submission, to validate of technical analysis (Fuel Channel Life Cycle Management; Component Condition Assessments) to support CNSC approval to operate Pickering units to 2025. The PSR results would then be reviewed by the CNSC.

Fuel Channel Life Cycle Management Plan

The major limiting component for operations is the life expectancy of the fuel channels. Technical assessments on the fuel channels' fitness-for-service continue through the FC-LCMP and ongoing inspections, and include incremental fuel channel scope required to address known degradation in order to enable operation to the planned shutdown dates through to 2025. The ongoing work program consists of analysis and work activities to assess

[6] Work undertaken through the Fuel Channel Life Extension project and the Pickering Extended Operations initiative underpinned OPG's successful application to the CNSC to allow Pickering to operate to 295,000 EFPH.

fuel channel fitness-for-service for the planned operating durations and to develop methods for assuring that each Pickering unit can meet its extended service life target. This work program builds on the Fuel Channel Life Management and Fuel Channel Life Extension projects in support of Pickering Extended Operations.

Component Condition Assessments

While the technical fitness-for-service of other major components, separate from the fuel channels, is not considered life limiting, Component Condition Assessments will be conducted to validate their fitness-for-service to the planned shutdown dates in 2024 and 2025. Planned outages will involve maintenance and inspection of steam generators, feeders, and "balance of plant" components (including fueling machine maintenance). Examples of the work expected to be performed include steam generator water-lancing, feeder thickness inspections and feeder replacements.

4.2.2 Enabling Costs

The costs associated with completing the above work are included within OPG's Nuclear Base, Outage and Project OM&A exhibits and associated tables, as summarized in Chart 5 below.

Chart 5: Optimization – Enabling Costs ($M)

Line No.	Cost Item	2020 Budget	2021 Budget	2022 Plan	2023 Plan	2024 Plan	2025 Plan	Total	Reference
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
1	Base OM&A	2.2	4.6	5.8	2.7	4.8	0.0	20.1	Ex. F2-2-1 Table 1
2	Outage OM&A	0.1	1.2	2.6	2.2	13.5	0.0	19.7	Ex. F2-4-1 Table 1
3	Project OM&A	0.2	2.0	7.8	0.0	0.0	0.0	10.0	Ex. F2-3-1 Table 1
4	Total Pickering Optimization	2.5	7.9	16.2	5.0	18.4	0.0	50.0	

Numbers may not add due to rounding

Further details are found in each of the referenced exhibits above.

Normal operating activities and their associated costs will continue through to 2025 with amounts forecast for 2022 through 2025 included in the IR term costs. There are no costs to operate Pickering post 2025 in the 2020-2026 Business Plan.

Any differences between forecast and actual Enabling Costs incurred to achieve Optimization will be recorded in the Capacity Refurbishment Variance Account for disposition in a future proceeding. This variance account is discussed in Ex. H1-1-1, Section 5.6.

ATTACHMENTS

Attachment 1: Prior Gap Closure Initiatives

Attachment 2: OPG 2020 Nuclear Benchmarking Report

Attachment 3: ScottMadden Evaluation of OPG Nuclear Benchmarking

Attachment 4: OPG Nuclear Cost Performance Benchmarking – Methodology to Adjust for Refurbishment and Validation of Implementation (ScottMadden)

Attachment 5: OPG Nuclear Cost Performance Benchmarking – A Study of Factors Impacting TGC/MWH Performance with Normalizing Adjustments to Facilitate Closer Comparison (ScottMadden)

Attachment 6: 2019 Goodnight Nuclear Staffing Benchmarking Analysis

Attachment 7: Province of Ontario Press Release dated August 14, 2020

Note: Attachments 1-7 may be marked “Confidential”, however, OPG has determined all Attachments to be non-confidential in their entirety.

Attachment 1 – Prior Initiatives

The following provides an update of the objectives, description of activities undertaken and benefits achieved of the six key fleet wide initiatives as identified in EB-2016-0152, Ex. F2-1-1 Section 3.5: (i) Parts Improvement, (ii) Outage Improvement, (iii) Equipment Reliability (iv) Human Performance, (v) Nuclear Inventory and (vi) Workforce Planning and Resourcing.

Parts Improvement Initiative

Objective

The objective of the Parts Improvement Initiative was to ensure the right parts are available at the right time and in the right place to improve OPG's ability to consistently schedule and execute the most important work in the plant, which maintains operational focus by improving plant and equipment reliability and improves efficiency.

Description

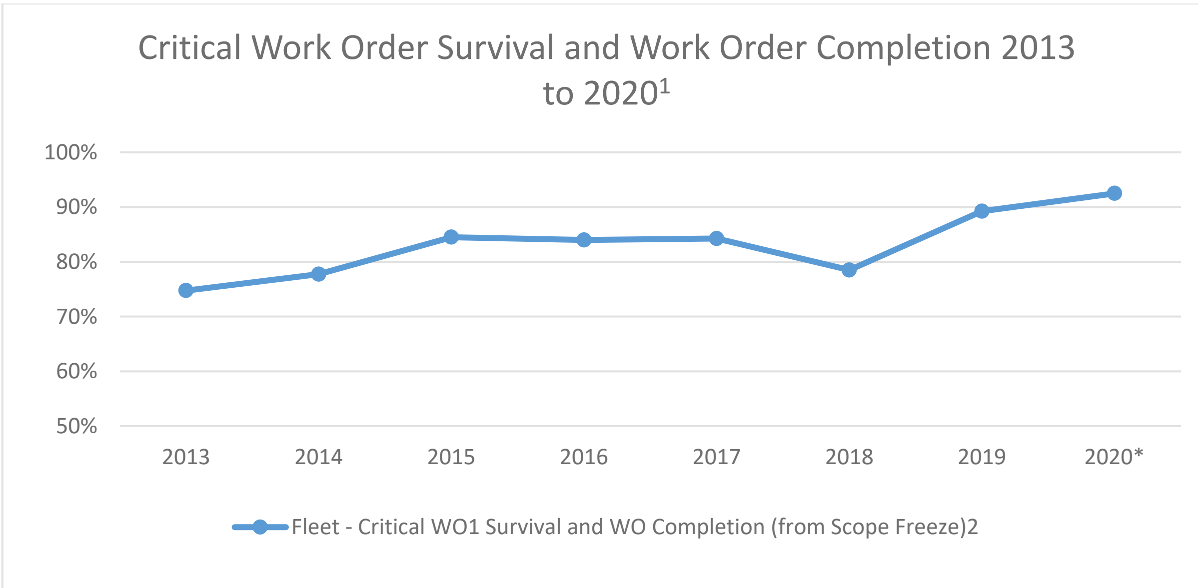
1. The initiative recognized that there was a breadth of contributing factors and need for behaviour change to address the inadequate parts availability. Led by a cross-functional team of knowledgeable subject matter experts, this multi-year project had a number of focus areas, including improving the accuracy of information about our nuclear assets to improve planning. For example, applying correct criticality ratings allows for accurate prioritization of work. Further, reclassifying critical components reduced the percentage of critical components in the plants from 28.0% to 19.5% across the fleet, enabling focused efforts on critical work and reducing focus on less critical work.
2. Aligning cross-functional groups with priority work in order to focus collective effort on maximizing throughput for our work program and balancing work to resources to better execute work plans.
3. Ensuring repeatable and transparent processes more efficiently meet our milestones and objectives.
4. Implementing an obsolescence program to ensure a robust, working obsolescence management capability. This allowed resolution of obsolescence issues impacting over 3,700 end-uses, 550 critical components, and 89 single-point vulnerabilities.

Benefits Realized

Based on the results achieved, the Parts Improvement initiative was successfully closed out in 2019. To measure overall initiative effectiveness, OPG used a metric called "Critical Work Order Survival/Completion from Scope Freeze to Execution", a standard work management measure in the industry. By way of background, a key factor to managing the duration of planned outages is to control scope changes prior to the commencement (execution) of planned work. To this end, OPG procedures establish a "scope freeze" approximately 6 weeks prior to planned work startup, with the assumption that all approved work in place as of the scope freeze should proceed to completion.

Historically, as shown in Figure 1 below, the Critical Work Order Survival/Completion from Scope Freeze to Execution, measured as a percentage of work orders that survived the planning period and were successfully completed, was challenging. This reflected that a high percentage of approved work (including critical work orders) were not completed due to parts availability. However, the improvements made through this initiative reduced challenges with parts availability. This resulted in much improvement at both Darlington and Pickering, improving from 76% in 2013 to 93% as of Q2 2020.

Figure 1



1. Prior to 2016 only Critical WO1 Survival was tracked. Starting in 2016 OPG modified the measure to include WO Completion

2. Critical WO was Critical 1 & 2 equipment until 2017Q3, then Critical 1 only as per INPO AP-913

* 2020 is as of Q2 2020. All other years are Q4 Data.

Outage Improvement Initiative

Objective

The objective of the Outage Improvement Initiative was to reduce generation losses due to outage durations exceeding business plan targets. To improve outage performance, this initiative focused on improvements to the outage planning process, tooling, scope of work, and training.

Description

1. **Outage Planning Process:** An improvement to the outage planning process included transitioning Pickering from a 24 month to a 30 month outage cycle. The transition required component condition assessments, CNSC regulatory requirement reviews and changes to the generation plan. Following evaluation of issues impacting outage performance, improvements were also made to outage processes such as emergent issue resolution, outage shift schedules, risk management and fuelling machine outage readiness**.**
2. **Tooling:** OPG implemented two outage tooling improvements by transitioning to machine delivered scrape and implementation of universal delivery machine efficiencies. Utilizing these tools reduced planned outage durations to complete the inspection and setup for this outage activity, resulting in outage execution efficiency and also reduced radiation dose for employees.
3. **Outage Scope of Work:** Unanticipated outage scope of work can contribute to outages exceeding business plan duration. In addition, too much scope may have been added to an outage resulting in the outage duration exceeding plan. Outage scope of work improvements focused on right sizing the outage scope and improving scope stability. Right sizing outage scope occurs through continuously reviewing OPG's aging and life cycle management programs for fuel channel, reactor components and feeder inspections as well as steam generator maintenance. One example was the reevaluation of the requirement to complete a Low Level Drain state. The reevaluation determined this activity was not required and therefore two Low Level Drains were

removed from scope that had been scheduled for Unit 6 in 2017 and Unit 7 in 2018, and will not be rescheduled into future outages.

In other instances, scope was added to outages to improve subsequent outages. For example, in one outage, scope was added to fix select channels that require grapple to refuel, which provided outage duration improvements in subsequent outages on the same unit.

4. **Training:** Improvements include work control team leaders sessions on leadership, collaboration and sharing of best practices across the fleet.

Benefits Realized

Based on the results achieved, the Outage Improvement initiative was successfully closed out and outage improvement initiatives are incorporated into the Right Work Right Time Right Value initiative.

Efficiencies and improvements in outage planning and execution were one of the contributors to the reduction of planned outage days at both Pickering and Darlington over 2017-2019. Further details are set out in Ex. E2-1-1.

Equipment Reliablity

Objective

The objective of the Equipment Reliability initiative which commenced in 2015 was to focus on improving equipment reliability at Darlington and Pickering, in order to reduce OPG's forced loss rate ("FLR"). Equipment reliability has been a major contributor to OPG's historical FLR.

Description

The initiative was focused on preventive maintenance with the goal of improving equipment reliability program execution, improving cross-functional alignment with goals and targets, and improving condition-based maintenance.

Benefits Realized

This initiative has driven significant improvement in equipment reliability at both Pickering and Darlington. The initiative has been successful in such areas as improving component life cycle management plan execution, an improved preventative maintenance program, developing effective equipment reliability tools, and developing a leading system health program.

The initiative achieved two major successes. First, the initiative tracked its performance against the Equipment Reliability Index ("ERI"), an industry benchmark.[1] In 2015, Pickering and Darlington had ERI scores of 69 and 76 respectively. In 2019, Pickering and Darlington achieved their best ever ERI scores of 94 at Pickering (versus target of 86) and 95 at Darlington (versus target of 92).

Second, OPG has seen a significant decline in FLR at Pickering from 10.7% in 2014 to 1.6% in 2019, averaging 5.0%.from 2014 to 2019. Darlington's FLR has averaged 2.7% from 2014 to 2019.

[1] The ERI is a North American benchmark for assessing equipment reliability performance. The index uses key leading indicators projecting degradation in plant operations or reliability of key station equipment.

Based on the results achieved, the Equipment Reliability initiative was successfully closed out in 2019. Additional initiatives targeted at more specific equipment reliability issues were identified, including system/component monitoring through the Monitoring & Diagnostics Centre. These specific items have been included in the Right Work, Right Time, Right Value initiative.

Human Performance Initiative

Objective

The Human Performance strategic initiative was designed to reduce human performance events that have adverse consequences, such as impact to safety of workers or the public, damage to plant equipment and systems, financial impact, or reputation.

A variety of individual and team behaviours, management practices, leadership engagement, processes and values affect worker performance and influence the probability and consequences of human error, which can result in human performance consequential events.

Description

The Human Performance Initiative in the 2016-2018 Business Plan was made up of 3 key strategic initiatives, with subsets of actions.

1. **Leadership Accountability** – It is expected that leaders' behaviours promote excellence and nuclear professional behaviours at all levels of the organization.
    i. Improved documentation: The Human Performance program is executed through a series of documents that support management of human performance and lay the framework for improving and sustaining performance.
    ii. Management review boards perform oversight of shift crew performance and work program effectiveness. These meetings are scheduled on a quarterly basis, and drive self-critical review of crew performance, work program strengths, areas for improvement, and any required corrective actions. Improvement initiatives are tracked locally at sites via established oversight forums.
    iii. Managers use assessment tool as an aid to determine what individual behaviours, team behaviours, organizational factors contributed to an event and identify "lessons learned".

2. **Supervisory Effectiveness** – Supervisors positively shape field worker behaviours by providing effective coaching and feedback. They reinforce positive behaviours and results as well as provide candid feedback on performance gaps and development areas.

3. **Procedure Use and Adherence** – Nuclear procedures reflect a vast collection of operational experience, but they are only effective when they are followed. Following procedures as written positions OPG to achieve results in a consistent manner with known outcomes and reliable results. An awareness campaign was initiated to ensure that individuals at all levels value, and follow procedures to prevent events. Also measures are in place to provide oversight and monitoring of procedure adherence events that have resulted in significant errors or near misses.

Benefits Realized

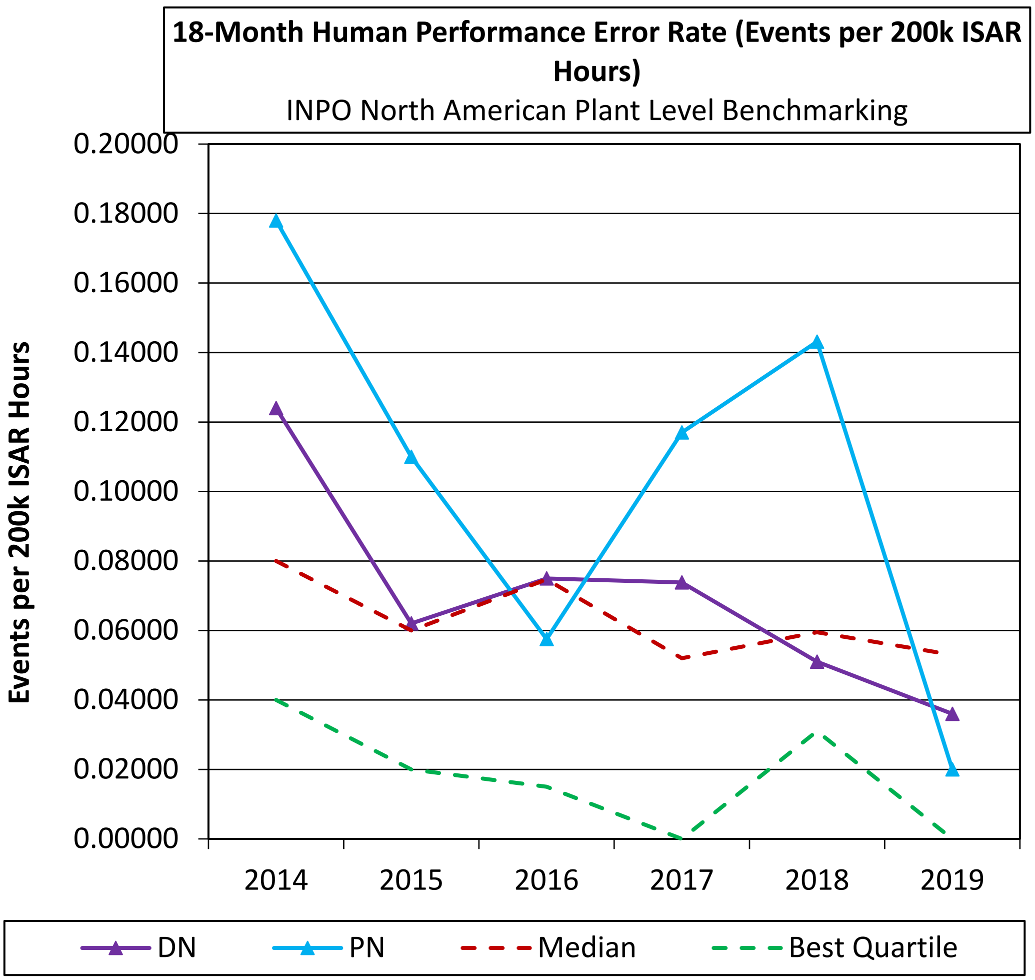
Based on the results achieved the Human Performance Improvement initiative was successfully closed out in 2017. However OPG continually seeks to reduce the potential for human performance events that have adverse consequences and continues ongoing tracking through lost generation and human performance error rate.

a) **Lost generation:** Improving Human Performance can reduce lost generation due to events triggered by human error. In 2015, approximately $65M in lost generation at both Pickering and Darlington Nuclear Generating Stations combined were attributed to Human Performance issues that resulted in outage delays and extensions, and work management inefficiencies. At the end of 2019, less than $5M in lost generation at Pickering and Darlington combined was attributed to Human Performance events.

b) **Human Performance Error Rate:** OPG benchmarks its human performance error rate against peers using an industry standard metric referred to as the 18 month Human Performance Error Rate ("HPER"), which tracks the number of site level human performance events in an 18-month period per 200,000 Industrial Safety Accident Rate and Contractor Hours.

As shown in Figure 2 below, Darlington's and Pickering's HPER has shown a favourable trend over the 2014-2019 period.

Figure 2



Nuclear Inventory Initiative

Objective

The purpose of this initiative was to establish targeted inventory growth rates that would minimize excess nuclear materials and supplies inventory. A reduction in the growth of inventory reduces the potential for additional obsolescence provision and added OM&A expense. This also reduces warehousing requirements and related expenses of carrying excess inventory.

The benefit of optimizing the inventory on hand and reducing the growth rate, while maintaining an expected order fulfillment service level, achieves better utilization of capital, that requires less OM&A expense in support of end of life obsolescence provision.

Description

Cross-functional teams reviewed different aspects of the inventory challenge. These teams worked to review stock modeling parameters which supported the procurement and order fulfillment workflow. Additionally, effort was made to identify and disposition slow moving and obsolete inventory.

Among the actions taken were:

1) Improving the tracking of the initiation, revision and cancellation of Material Requests (“MRs”). OPG was able to improve its management of required inventory by undertaking a procurement and order fulfillment review that allowed material to be “unreserved” from inventory for work that was no longer in scope and consequently allowing this inventory to be available for upcoming valid demand.

2) Improved balancing of supply with valid demand to minimize excess inventory by improving automated controls and implementing ongoing synchronization between the master production schedule requirements (outage/online station work management system) with material resource planning signals within our Enterprise Reporting Program Asset Suite 7 software.

3) Innovative tools and processes that provide improved visibility into available in-stock material during the design phase for the Darlington refurbishment such that final approved designs would consume existing OPG inventory first rather than triggering a new procurement.

Benefits Realized

Actual Darlington materials and supply inventory over the 2017-2019 period reflects inventory held for cyclical outages at Darlington[2] and expenditures on operational spares/inventory transfers arising from the Darlington Refurbishment Program ("DRP"). Targeted growth rates established in 2015 did not reflect the impact of inventory held for cyclical outages or operational spares/inventory transfers related to the DRP.

Figure 3 below provides actual and targeted growth rates for Pickering, Darlington and OPG Nuclear combined. As shown in Figure 3, Pickering's trend is improving as its material and supply inventory growth rate was at or below (i.e better than) target in 2018 and 2019. Darlington did not achieve its targeted growth rate in 2017 and 2019 but was below (i.e. better than) target in 2018. A factor driving inventory growth at Darlington was the higher than forecast growth in capital expenditures, resulting in increased purchases of materials including spare parts. In addition, the target growth rates for Darlington shown in Figure 3 excluded the impact of cyclical outages or capital spares/inventory transfers from the refurbishment of Unit 2 that are reflected in the actual growth rates.

Optimizing nuclear inventory and reducing the growth rates continues to be pursued as part of OPG's focus on continuous improvement. Further discussion on the 2020-2026 Business Plan target growth rates for materials and supplies inventory is provided in Ex. B1-1-1, Section 3.2.4.

[2] Cyclical outage costs are costs for various inspection and maintenance activities on units undergoing refurbishment associated with a planned outage in accordance with OPG's aging and life cycle management programs, that are in addition to and separate from the refurbishment of the units, as further discussed at Ex F2-4-1.

Figure 3

Targeted and Actual Inventory Growth Rates

Target	2017	2018	2019
PNGS	1.50%	0.50%	0.00%
DNGS	3.00%	2.00%	2.00%
All Facilities	2.00%	1.09%	0.82%
Actual			
PNGS	4.10%	0.50%	-0.20%
DNGS	6.60%	-0.40%	15.90%
All Facilities	5.68%	-0.04%	6.26%

Workforce Planning and Resource Initiative

Objective

The objective of this initiative was to develop and implement a resource stratetgy in order to support the safe operation of the plants during the Darlington Refurbishment Program, as well as planning for the shutdown of Pickering. The initiative was overseen by a Resource Planning and Control Team ("RPCT") that was established in 2016.

Description

The RPCT continues to function today to ensure deliverables are met to manage preparation activities in support of Pickering Optimized Shutdown by ensuring that headcount is within business plan guidelines, while at the same time mitigating risks and long term operational impacts.

The RPCT critically reviews and approves resourcing strategies to ensure staffing plans for key functional areas optimize the allocation of resources across the Nuclear fleet, including Darlington Refurbishment. Staffing plans are presented to the RPCT for approval and define opportunities for movement of staff between sites and functional areas, as well as recommend both internal and/or external hiring based on OPG's Business Plan and workforce planning assumptions.

The staffing plans provide a 10-year outlook designed to reduce the impact of Pickering planned shutdown on employees and plant operations, while mitigating costs. The plans include these important objectives:

- Ensure an adequate number of qualified employees are available, including to facilitate DRP and the continued safe operation of Darlington and Pickering;
- Minimize external regular hiring into the Society of Energy Professionals ("Society") and Power Workers' Union ("PWU") bargaining unit so as to minimize the requirement for staff turnover and/or involuntary layoffs;
- Use Society ETEs and PWU Term employees to minimize the requirement for staff turnover and involuntary terminations when Pickering ceases commercial operations; and
- Facilitate the ongoing transfer of qualified regular Pickering employees to work at Darlington, Nuclear Waste Management, or other OPG locations where the resource demand extends beyond Pickering closure.

Benefits Realized A measure of the success of the workforce planning and resource initiative can be seen in the results from the Goodnight 2019 Nuclear Staffing Benchmarking study (see Ex. F2-1-1, Attachment 6). Goodnight benchmarked OPG Nuclear staffing to other North American nuclear operators and established that OPG is 239 Full-Time Equivalents ("FTEs") (4.5%) below the North American FTE benchmark of 5,255 FTEs, a consistent improvement since 2011 (see Section 3.2.1.3 for further details).

An "Operations Voluntary Deployment" process has successfully moved nuclear operators from Pickering to Darlington through a staged approach starting in 2018. This allows managers to proactively plan in advance for deployments by bringing in required external term employees to backfill for the Pickering transfer. Starting in 2016, maintenance successfully began deploying employees from Pickering to Darlington.

The Workforce Planning and Resource Initiative has since been incorporated into the People Powering the Future initiative with the objective to ensure an adequate number of qualified employees are available to facilitate DRP and the continued safe operation of Darlington and Pickering while minimizing external regular hiring by utilizing PWU Terms and Society ETE and facilitating the transfer of qualified regular Pickering employees to other OPG locations (e.g., Darlington).

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1.0 EXECUTIVE SUMMARY

OPG benchmarked favourably relative to its peers in 2019 in a number of key nuclear cornerstone areas, while certain metrics were impacted by plant life extension activities (i.e., Pickering Extended Operations) and refurbishment at Darlington.

Safety

Under the Safety cornerstone, OPG's nuclear generating stations continued to achieve strong performance in a majority of the safety performance metrics. Improvements at Pickering and Darlington since 2014 contributed to OPG Nuclear achieving its lowest Total Recordable Injury Rate (TRIF) in the history of the company in 2019. OPG was the top TRIF performer in 2019 compared to its peer group.

OPG Nuclear Stations continue to lead in Safety with stronger results

Darlington Nuclear Generating Station (DNGS) achieved maximum WANO Nuclear Performance Index (NPI) results or best quartile performance for six of the seven NPI sub-metrics under the Safety cornerstone. Pickering Nuclear Generating Station (PNGS) improved to show maximum WANO NPI results or top quartile performance for all seven NPI sub-metrics under the Safety cornerstone.

Collective Radiation Exposure (CRE) performance improved. PNGS benefited from an optimized outage plan and improved performance resulting in maximum NPI points achieved. DNGS dose improved from last year, and remains in the third quartile. Positive gains were seen from site innovations such as leveraging technology to avert dose using robotic equipment and remote monitoring of systems, and the early completion of planned outages contributed to the positive change. The innovative enhancements are also expected to continually improve performance.

Airborne Tritium Emissions at PNGS and DNGS continue to be less than one percent of regulatory limits, and both sites achieved second quartile performance. 2019 PNGS performance improved, advancing to the second quartile, as previous years' issues, such as tritiated water in the Fuel Transfer Conveyor Tunnel being vented to monitored stacks, leaks and dryer performance were resolved. DNGS performance remained in the second quartile, despite being challenged with leaks and dryer performance issues. Repairs to equipment are expected to help improve results.

Pickering's Fuel Reliability Index (FRI) jumped from fourth to first quartile, and achieved maximum Nuclear Performance Index (NPI) points. Enhancements made over the past few years improved the ability to locate and mitigate the very few fuel bundles with a defect. DNGS continues to achieve first quartile performance. No fuel issues of significance arose in 2019. Continual focus on improving FRI performance by preventing potential fuel defects includes improving methods of surveillance and eliminating foreign materials from entering into the Heat Transport System due to Fuel Handling and Outage practices.

Reliability

Several key performance indicators improved across the fleet even while OPG's nuclear facilities are transitioning through Darlington refurbishment and Pickering life extension.

Pickering achieved its best ever performance as a six-unit station for NPI, FLR and UCF.

OPG Nuclear Stations have significantly improved in reducing maintenance backlogs.

Pickering's performance metrics showed favourable results in 2019 when compared to 2018, including the Nuclear Performance Index (NPI), Forced Loss Rate (FLR), and Unit Capability Factor (UCF), which all recorded best ever performance as a combined six-unit station[1] due to improved equipment reliability and optimized outage performance. Significant improvements were recorded for On-line Deficient Maintenance Backlogs (59% improvement compared to 2018), and On-line Corrective Maintenance Backlogs (47% improvement compared to 2018). PNGS On-line Corrective Critical Backlog declined to fourth quartile due to the standby generator and fuelling machine repair work orders, which were completed in January of 2020. PNGS Deficient Critical backlogs also improved by 44%, which was largely attributed to a deliberate focus on scheduling deficient critical maintenance. The backlog improvement has been supported by the move to a Condition Based Maintenance Program from a time based system.

UCF at DNGS improved to first quartile in 2019 due to strengthened equipment reliability and certain DNGS backlog metrics showed improved performance (e.g., On-line Deficient and Corrective Maintenance Backlogs). DNGS improved their On-line Corrective Maintenance Backlogs by reducing the number of outstanding work orders/unit relative to 2018 as a result of continued station focus, overall maintenance efficiency and improved schedule quality.

The 2019 NPI of 82.5 was the best NPI achieved by PNGS, and a 7.6 gain from 2018, which placed station NPI in third quartile. Longer planned outage durations, which are necessary to extend the life of the Pickering station, directly impact Unit Capability Factor (UCF) and Collective Radiation Exposure (CRE), and thus preclude the station from obtaining full points in NPI despite showing excellence in nuclear safety and consistently achieving full points in associated sub-metrics. DNGS continued with second quartile performance in 2019 and was impacted by forced outages caused by the Heat Transport and Secondary side leakages along with Fuel Handling bridge repairs. Actions have been taken to increase scope in future outages for the instrument line visual inspections to minimize heat transport system leaks to containment. A Fuel Handling Life Extension and Reliability plan addresses the most critical fuel handling scope to sustain Forced Loss Rate performance.

Chemistry Performance Index (CPI) results were impacted by transients following outage start-up. Darlington had condenser tube leaks while Pickering experienced high chloride and sodium levels. Both PNGS and DNGS reported values remained unchanged from 2018 at 1.02 and 1.03 respectively, and Pickering improved into the third quartile compared to the peer group. Initiatives to further improve CPI across the fleet include chemistry data trending and the implementation of

[1] The units at Pickering A and Pickering B were amalgamated in 2012.

new innovations for improved chemistry control, reliability and safety such as new personal protective equipment for hydrazine vapour hazards at Pickering as well as film forming amine and EPRI Smart Chemistry online analyzer application at Darlington.

Value for Money

DNGS Total Generating Cost (TGC)/MWh performance was in the third quartile in 2019 after normalizing[2] for refurbishment as well as CANDU technology (including outage duration) and age-related impacts. Before normalization, DNGS was in the fourth quartile, driven largely by cost impacts for life post-refurbishment and reduced generation associated with refurbishment work. DNGS continues to sustain top quartile performance in Fuel Cost/MWh while capital investment requirements for life post-refurbishment impacted its Capital Costs per MW Design Electrical Rating (DER) which moved to fourth quartile.

PNGS normalized (TGC)/MWh performance in 2019 improved by $4.44/MWh when compared to 2018. PNGS TGC/MWh before and after normalizing (for CANDU technology, including outage duration and age-related impacts) showed similar improvement and remained within the fourth quartile. Pickering managed cost pressures over the 2014-2019 period with a compound growth rate of -1.9%. Improved performance in 2019 reflects higher generation and associated OM&A cost reduction due to fewer outage days as well as decreased capital investment and improved Fuel Costs/MWh. Fuel Cost/MWh continued to maintain top quartile performance compared to peers. PNGS Capital Cost/MW DER maintained best quartile performance.

TGC/MWh was impacted by life extension and refurbishment.

PNGS TGC per generating unit continued to demonstrate strong performance, placing among the best in the peer group in first quartile, while DNGS normalized TGC per generating unit was in second quartile.

Human Performance

Human performance showed improvements at both sites. Of note, PNGS performance moved from the fourth to second quartile in 2019. DNGS results improved and it continued to perform in second quartile.

Industry-leading practices and innovation helped improve human performance at Pickering and Darlington

Adopting industry-leading practices and innovation helped achieve these results, including use of analytical tools for early detection of declining performance, and specialized training using a simulator to teach Human Performance concepts and behaviours.

[2] See section 4.0 for more information about the TGC/MWh normalization methodology.

Benchmarking Results – Plant Level Summary

Table 1 provides a summary of 2019 performance compared to benchmark results.

Table 1: Plant Level Performance Summary

Metric	NPI Max	Best Quartile	Median	Pickering (2019 Actuals)	Darlington (2019 Actuals)
Safety					
Total Recordable Injury Frequency (#/200k hours worked) [3]		0.81	N/A	0.11	0.00
Rolling Average[2] Industrial Safety Accident Rate (#/200k hours worked)[1]	0.20	0.00	0.01	0.02	0.04
Rolling Average[2] Collective Radiation Exposure (Person-rem per unit)[1]	80.00	38.54	70.32	70.32	83.23
Airborne Tritium Emissions (Curies) per Unit [3]		982	2,772	2,517	1,213
Fuel Reliability (microcuries per gram)[1]	0.000500	0.000001	0.000007	0.000187	0.000295
2-Year Reactor Trip Rate (# per 7,000 hours)[1]	0.50	0.00	0.00	0.24	0.00
3-Year Auxiliary Feedwater System Unavailability (#)[1]	0.0200	0.0000	0.0000	0.0039	0.0000
3-Year Emergency AC Power Unavailability (#)[1]	0.0250	0.0008	0.0016	0.0003	0.0026
3-Year High Pressure Safety Injection Unavailability (#)[1]	0.0200	0.000000	0.000000	0.00013	0.00000
Reliability					
Rolling Average[2] WANO NPI (Index)[1]		92.68	87.64	82.50	88.90
Rolling Average[2] Forced Loss Rate (%)[1]	1.00	1.08	2.43	3.39	2.56
Rolling Average[2] Unit Capability Factor (%)[1]	92.00	87.06	86.14	83.31	87.06
Rolling Average[2] Chemistry Performance Indicator (Index)[1]	1.01	1.00	1.00	1.02	1.03
1-Year Online Deficient Maintenance Backlog (work orders per unit)[1]		30	39	114	110
1-Year Online Deficient Critical Backlog (work orders per unit) [1]		0	0	5	3
1-Year Online Corrective Maintenance Backlog (work orders per unit) [1]		2	3	9	4
1-Year Online Corrective Critical Backlog (work orders per unit) [1]		0	0	1	0
Value for Money[4]					
3-Year Total Generating Costs per MWh ($ per Net MWh)[1]		34.63	41.85	62.39	67.00
Normalized 3-Year Total Generating Cost per MWh ($ per Net MWh)[1]		30.83	36.12	44.85	38.84
3-Year Total Generating Cost per Unit (M $ per Unit)[1]		275.21	310.29	228.27	442.14
Normalized 3-Year Total Generating Cost per Unit (M $ per Unit)[1]		239.49	290.39	176.31	270.46
3-Year Non-Fuel Operating Costs per MWh ($ per Net MWh)[1]		20.84	24.65	53.85	47.10
3-Year Normalized Non-Fuel Operating Cost per Net MWh ($/MWh)[1]		20.84	24.65	--	37.85
3-Year Fuel Costs per MWh ($ per Net MWh)[1]		7.03	7.69	4.22	4.38
3-Year Capital Costs per MW DER (k$ per MW)[1]		38.82	53.64	30.66	116.67
Normalized 3-Year Capital Cost per MW DER (k$ per MW)[1]		38.82	53.64	--	89.78
Human Performance					
18-Month Human Performance Error Rate (# per 200k ISAR and contractor hours)[1]		0.0000	0.0530	0.0200	0.0360

1. Best Quartile, Median and Third Quartile are from Q4 2019 best available information.
2. Indicates a 2-Year Rolling Average for Pickering and a 3-Year Rolling Average for Darlington.
3. Best Quartile, Median, Third Quartile are from the Q4 2018, which is the most current available benchmark for these metrics.

Legend

4th Quartile Performance	3rd Quartile Performance	2nd Quartile Performance	Maximum NPI points achieved or Best Quartile

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Background

This report presents a comparison of OPG Nuclear's performance to that of nuclear industry peer groups both in Canada and worldwide. The results of this report are used during business planning to drive top-down target setting with business improvement as the objective.

Performance Indicators

Good performance indicators used for benchmarking are metrics with standard definitions, reliable data sources, and utilization across a representative portion of the industry. Good indicators allow for benchmarking to be repeated year after year in order to track performance and improvement. Additionally, when selecting an appropriate and relevant set of metrics, a balanced approach covering all key areas of the business is essential. In accordance with these criteria, key performance indicators have been selected for comparison to provide a balanced view of performance and for which consistent, comparable data is available. These indicators are defined in Section 7.0, and divided into categories aligned with OPG Nuclear's four cornerstones of safety, reliability, value for money, and human performance.

Each indicator reflects a particular duration of historical performance in accordance with peer group expectations. For example, EUCG data for Value for Money metrics are based on three-year average performance, whereas WANO NPI safety and reliability metrics reflect multi-year rolling averages based on each station's outage cycle. For NPI metrics, Darlington and Pickering's results reflect a three-year and two-year outage cycle, respectively.[3]

Industry Peer Groups

Peer groups were selected based on performance indicators widely utilized within the nuclear industry. Overall, six different peer groups were used as illustrated in Table 6 of Section 7.0 and panel members are detailed in Tables 7 to 12 of Section 7.0.

Report Structure

Sections 2.0 to 5.0 of the report focus on the four OPG Nuclear cornerstone areas, with detailed comparisons at the plant, and where applicable, unit level.

Section 6.0 of the report provides an operator level summary across a few key metrics. The operator level analysis looks at fleet operators, primarily across North America, utilizing a simple average of the results (mean) from each of their units/plants. While the operator level summary can be informative, it is more appropriate to look at OPG's two nuclear facilities individually given that they are at different stages of their lifecycle, have different sized units and reflect different generations of CANDU technology. This view is consistent with ScottMadden's Evaluation of 2019 OPG Nuclear Benchmarking, in which ScottMadden recommended that OPG focus on site-level comparisons of performance for Pickering and Darlington rather than operator-level comparisons. The detailed data in sections 2.0 to 5.0 of the report provide a more complete picture of plant by plant performance.

[3] The planned outage cycle for each unit at Pickering is transitioning from a 24-month to a 30-month outage cycle. Pickering continues to assume a 24-month rolling average for benchmarking to be consistent with WANO reporting expectations.

Section 7.0 provides an appendix of supporting information, including common acronyms, definitions, panel composition details and a WANO NPI plant level performance summary of OPG nuclear stations against the North American panel.

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2.0 SAFETY

Methodology and Sources of Data

The majority of safety metrics were calculated using data from WANO. Data labelled as invalid by WANO were excluded from all calculations. Indicator values of zero are not plotted or included in calculations except in cases where zero is a valid result. Current data are obtained and consolidated with previous benchmarking data. The Embalse plant has been excluded since it was taken offline since December 31, 2015 for refurbishment.

The Total Recordable Injury Frequency (TRIF) was calculated using data from the Canadian Electricity Association (CEA). Median information and individual company information are not available for this metric. Therefore, only trend and best quartile information have been presented. The peer group for this metric is limited to Group I members of CEA (Section 7.0, Table 10).

Airborne Tritium Emissions per unit data were collected from the CANDU Owners Group (COG) as displayed in the historical trend line chart. The peer group for this metric is all CANDUs who are a member of COG. As noted, there is a one-year lag for the industry values associated with this metric.

Nine metrics are included in this benchmarking report reflect safety performance, including seven of the ten metrics, which comprise the WANO Nuclear Performance Index: Industrial Safety Accident Rate, Collective Radiation Exposure, Fuel Reliability Index, Automatic Reactor Trips, Auxiliary Feedwater Safety System Unavailability, Emergency AC Power Safety System Unavailability, and High Pressure Safety Injection Unavailability. The remaining WANO NPI metrics are included in Section 3.0 under the Reliability cornerstone. In addition to the WANO sub-indicators listed above, the CEA Total Recordable Injury Frequency and the COG Airborne Tritium Emissions per unit are included in this section of the report.

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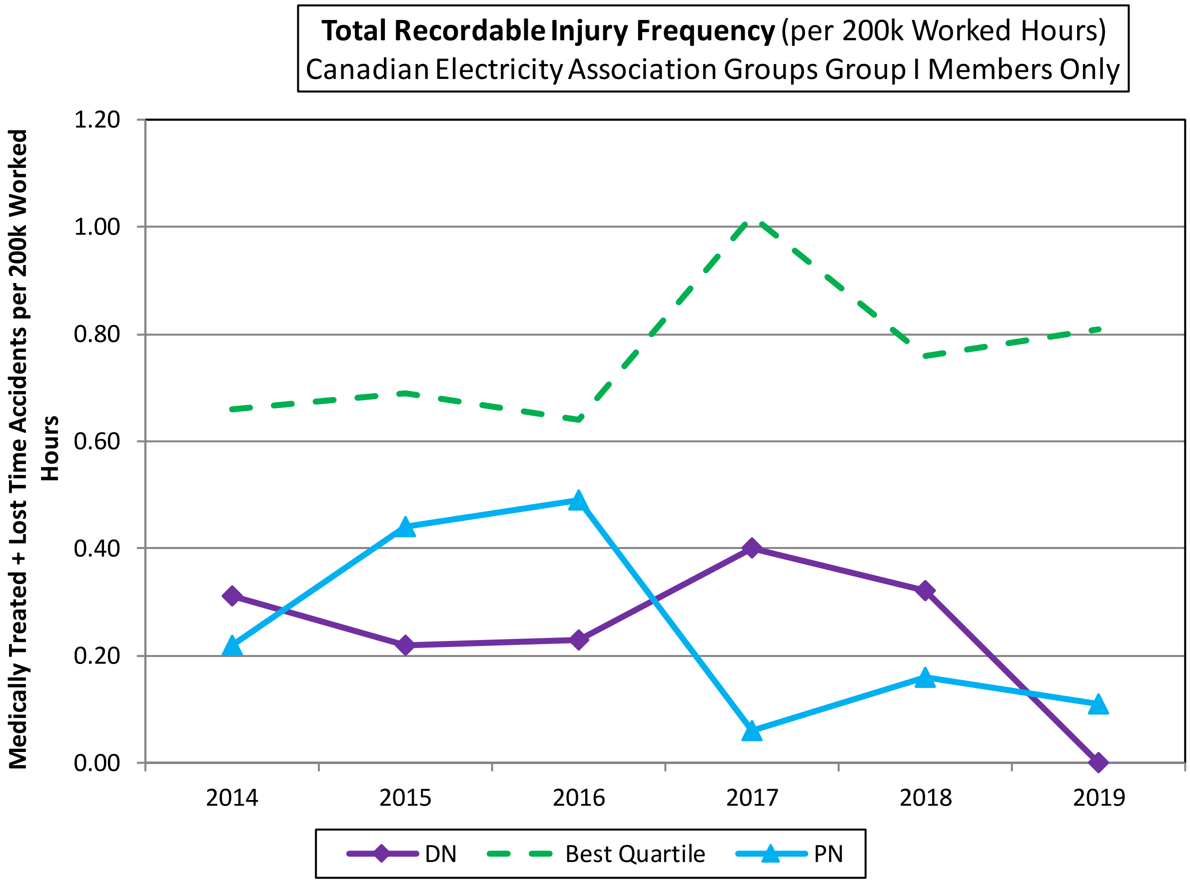
Total Recordable Injury Frequency



Observations – Total Recordable Injury Frequency (TRIF) (Canadian Electricity Association - CEA)

2019 (Annual Value)

- In 2019, OPG Nuclear achieved its lowest TRIF in the history of the company.
- Pickering, Darlington, and OPG Nuclear as a fleet all performed better than the CEA top quartile value of 0.81.
- Darlington's TRIF had its best performance ever and showed a significant improvement in performance compared to 2018 from 0.32 to 0.00 in 2019.
- Pickering's TRIF has also shown a steady improvement from 0.16 in 2018 to 0.11 in 2019.
- OPG benchmarks against CEA Group 1 (a sub-set of all CEA members), which incorporates organizations with more than 1,500 employees, including most provincial utilities.
- OPG was the top performer of all Group 1 members in 2019.

Trend

- Darlington, Pickering and OPG Nuclear have consistently performed significantly better than the benchmark value and improved over the trend period.

Factors Contributing to Performance

- Conventional Safety performance trends are monitored and action plans to support continuous improvement are implemented. These action plans incorporate Human Performance based objectives, which are aimed at positively improving employees' risk based decision making processes.
- OPG encourages a proactive reporting culture that seeks to identify and address hazards before they lead to employee injuries. Proactive reporting is tracked, trended and managed via the Station Condition Record process.
- OPG continues to progress an organization-wide '*iCare Enough to Act*' initiative aimed at renewing employee commitment to their own and each other's safety and well-being, including Nuclear conventional safety trainings, safety communications, and in-field safety observations via an *iCare* Snapshot program.

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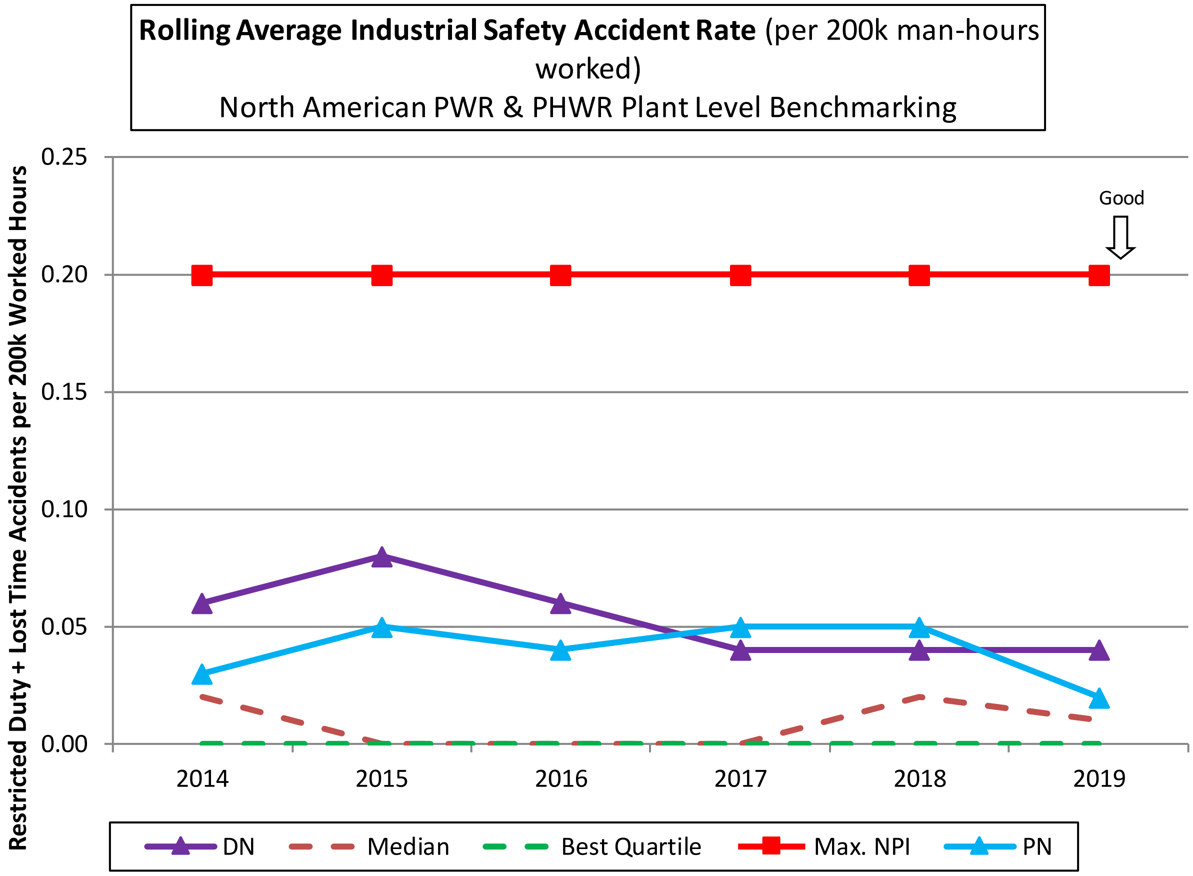
Rolling Average Industrial Safety Accident Rate



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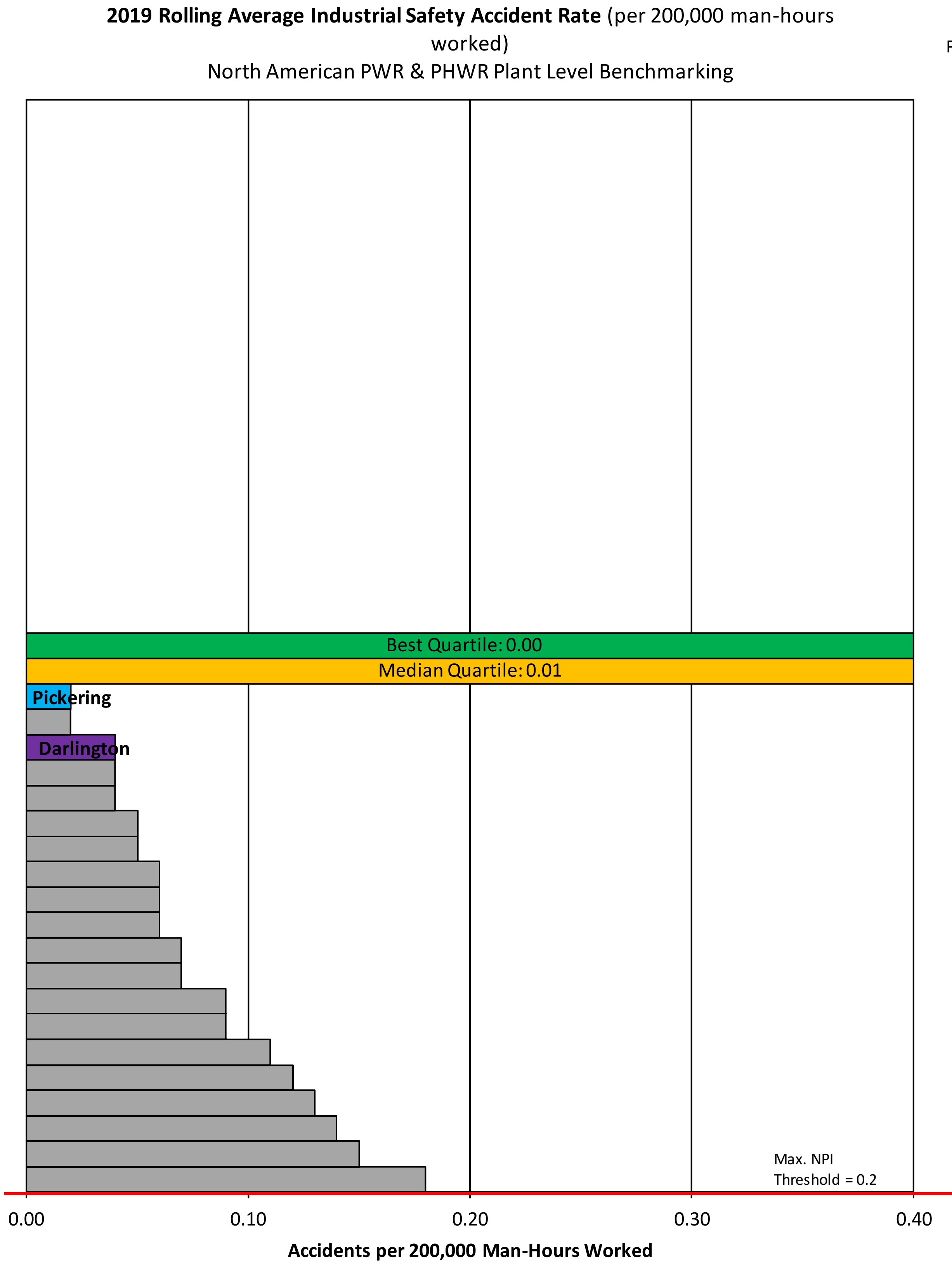

Observations – Rolling Average Industrial Safety Accident Rate (ISAR) (World Association of Nuclear Operators - WANO)

2019 (Rolling 2 Year Average Pickering, Rolling 3 Year Average Darlington)

- WANO top quartile in 2019 remained unchanged from 2018 at 0.00 (i.e. zero ISAR events). Median performance was 0.01, which was a decrease from 0.02 in 2018.
- Both Pickering and Darlington achieved maximum Nuclear Performance Index points for ISAR in 2019.
- Pickering ISAR performance showed improvement from 2018 to 2019 (0.05 to 0.02).
- Darlington ISAR performance remained steady from 2018 to 2019 (0.04 to 0.04).

Trend

- Darlington's ISAR rolling average showed an overall improved performance over the trend period.
- Pickering's ISAR rolling average has shown a generally stable performance over the past five years.
- The ISAR median has seen a slight decrease in 2019 to 0.01 and shows steady performance since 2014. The industry best quartile has remained at zero for the past six years.

Factors Contributing to Performance

- ISAR is a measure of "permanent utility personnel" and does not include contractors. Many of the utilities in the benchmarking group utilize contractors to a greater extent than OPG Nuclear for higher risk work activities (e.g. outages). This can negatively impact OPG Nuclear's ISAR in comparison to the reported industry benchmark quartile and median.
- OPG Nuclear continues to monitor performance trends in the area of conventional safety and implements timely and specific action plans to support continuous improvement. These action plans incorporate Human Performance based objectives, which are aimed at positively improving employees risk based decision making process.
- OPG continues its aim to address safety as a value beyond compliance. To support a 'value-based mindset', OPG Nuclear has emphasized personal reasons why everyone must choose to work safely. An 'iCare' branding has been applied in multiple training forums, safety communications, and in safety observations in the field.

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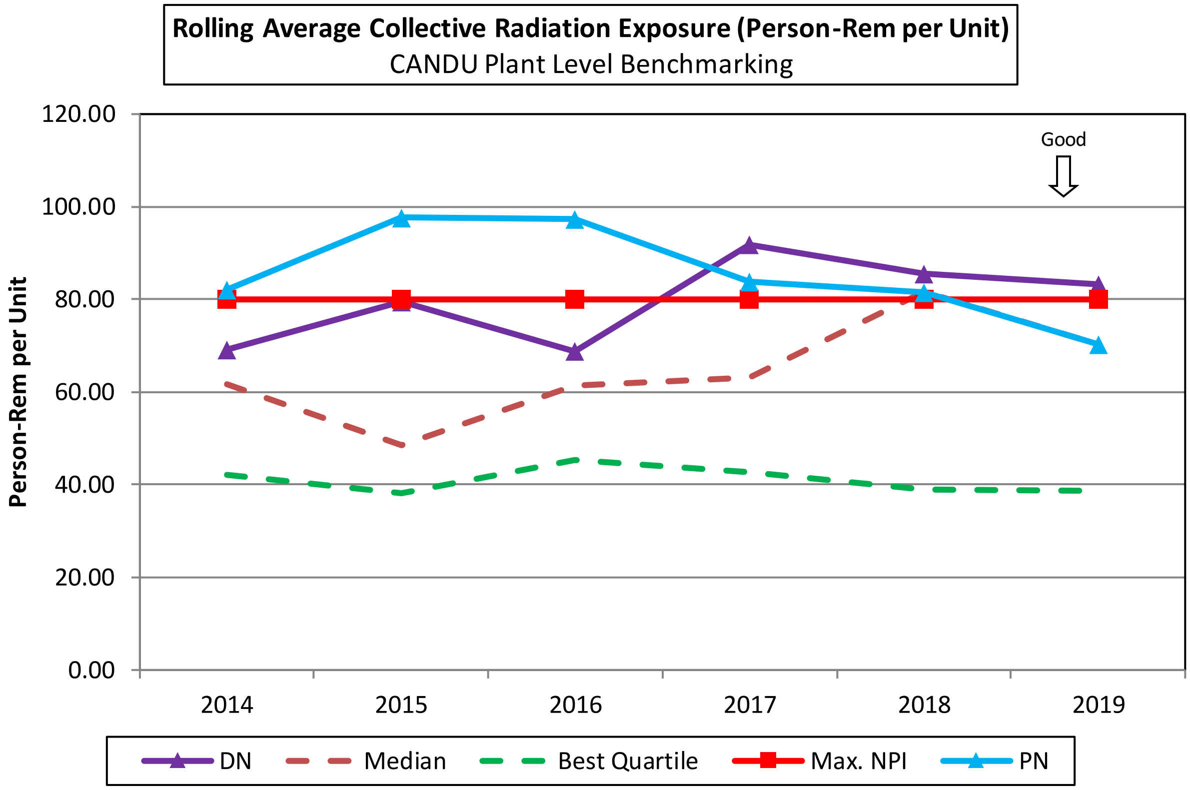
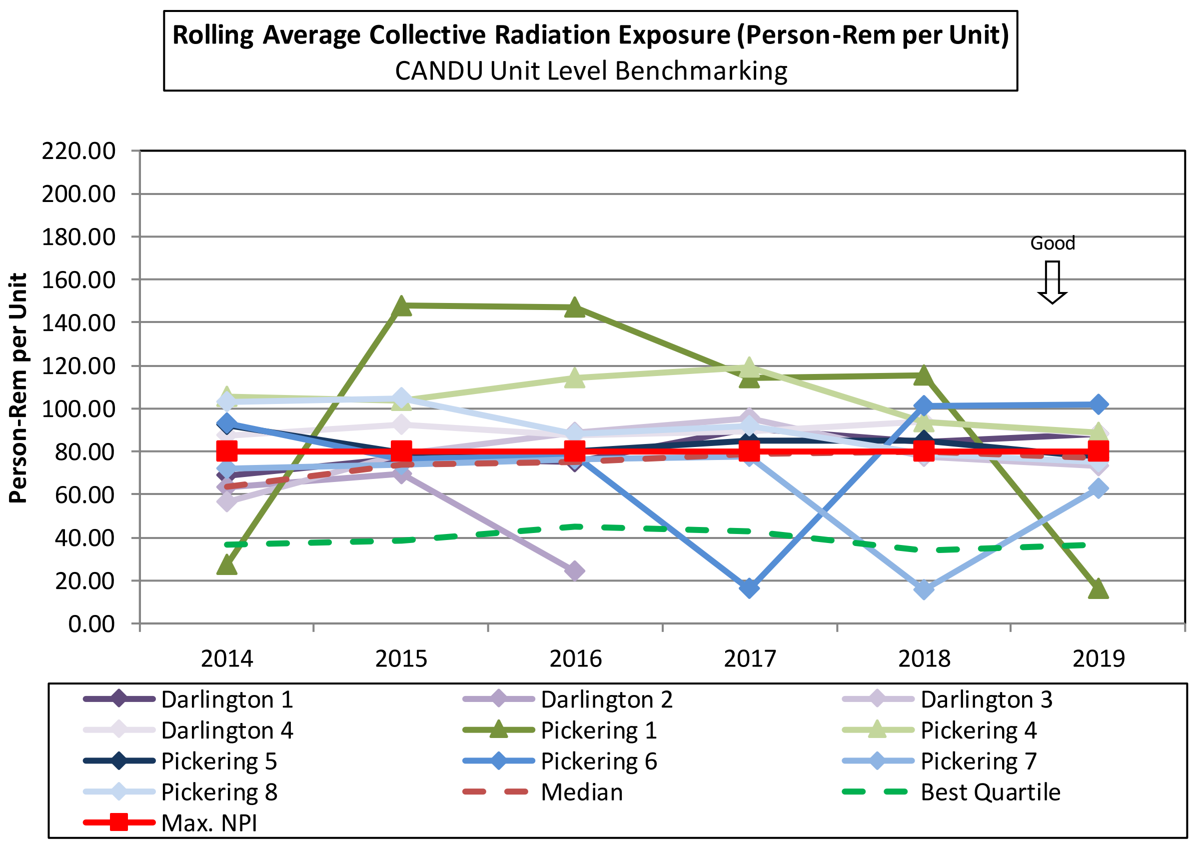
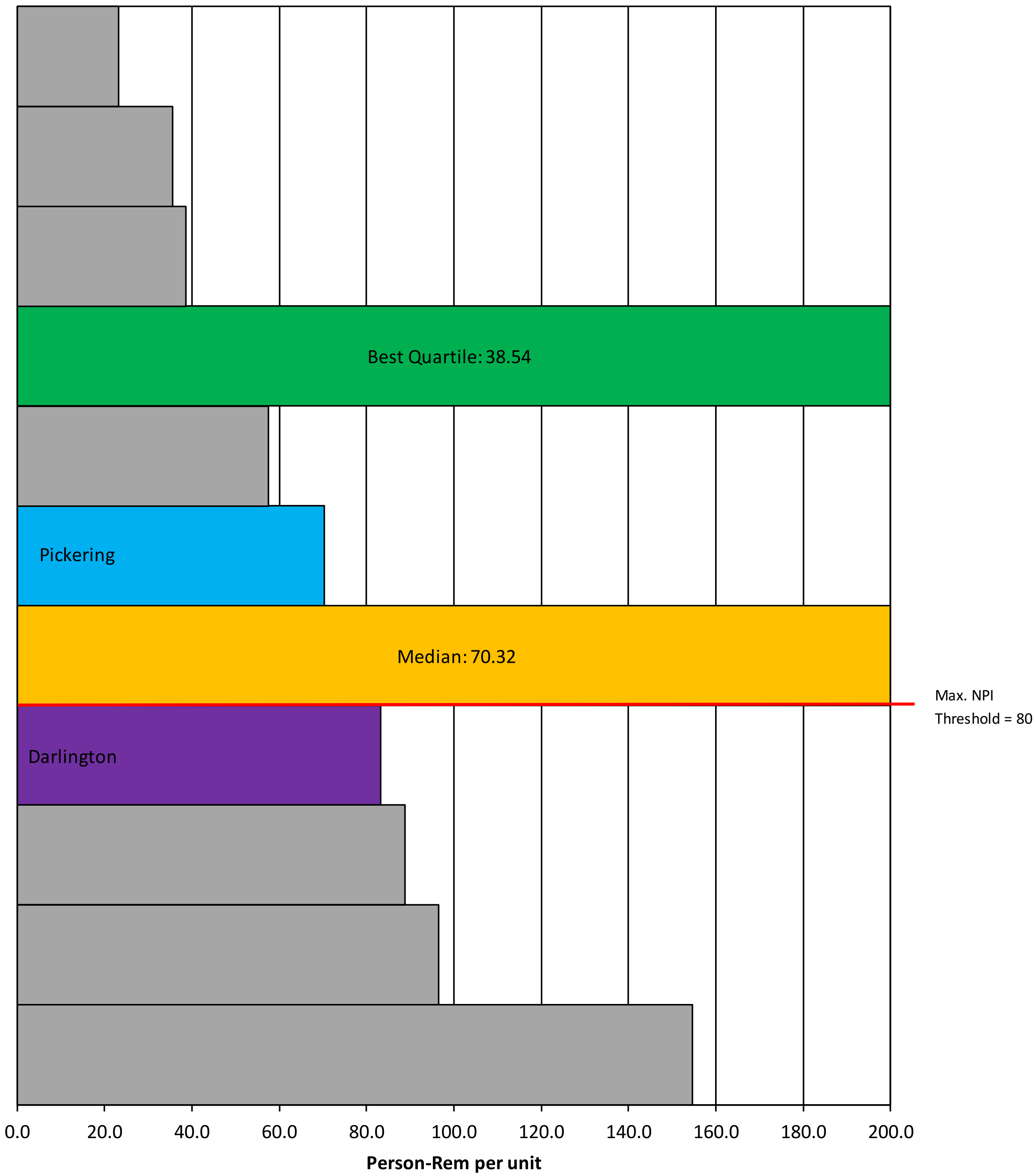
Rolling Average Collective Radiation Exposure

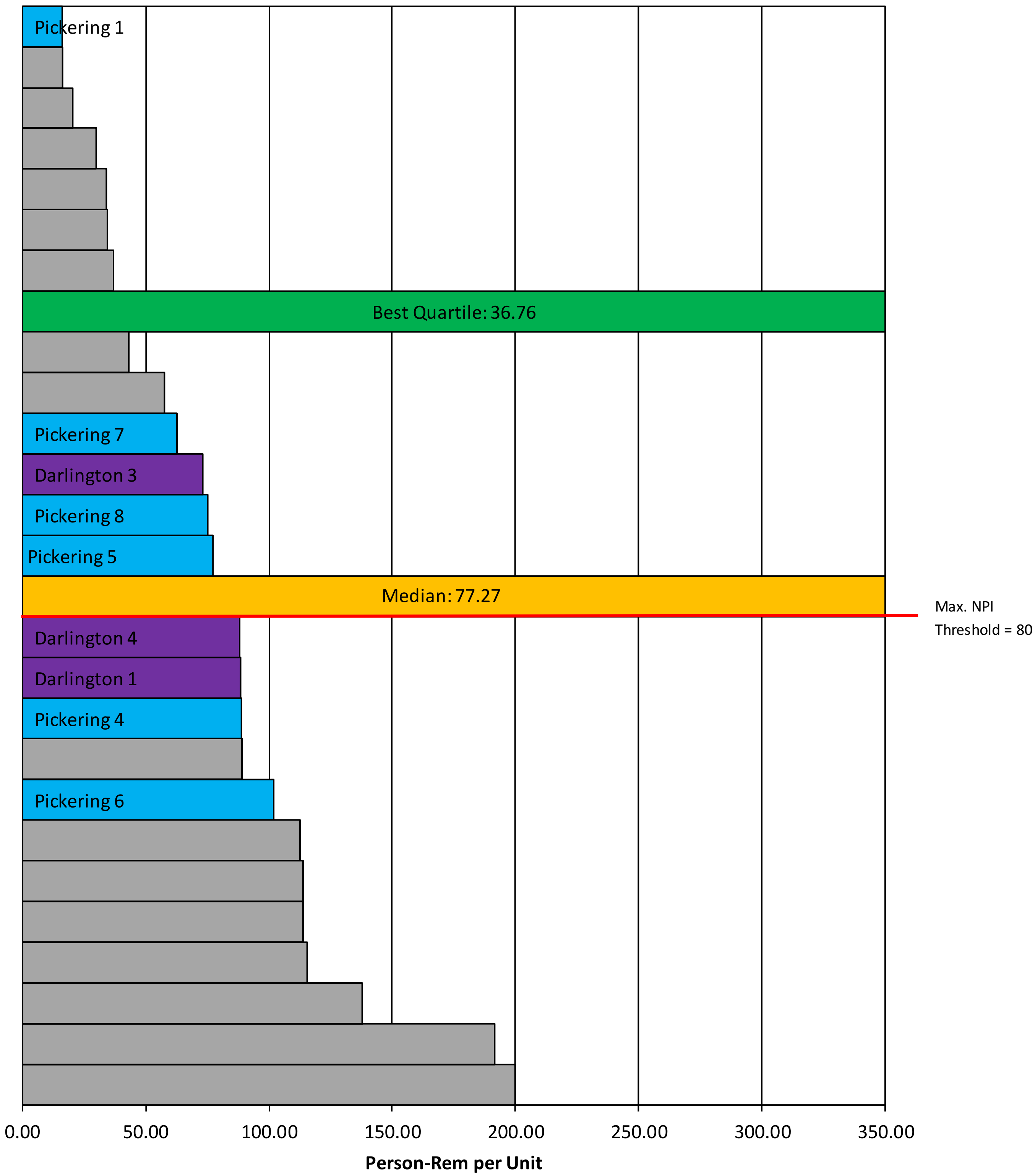




2019 Rolling Average Collective Radiation Exposure (Person-Rem per Unit) CANDU Plant Level Benchmarking



2019 Rolling Average Collective Radiation Exposure (Person-Rem per Unit) CANDU Unit Level Benchmarking



Observations – Rolling Average Collective Radiation Exposure (CANDU)

2019 Value (Rolling 2 Year Average Pickering, Rolling 3 Year Average Darlington)

- CANDU plant-level - The 2019 best quartile value was lower than the 2018 value (38.54 vs. 38.93 person-rem/unit, respectively). The 2019 median value was also lower than the 2018 value (70.32 vs. 81.65 person-rem/unit, respectively). Full NPI Points were obtained at 80 person-rem/unit or less; no points were earned at 140 person-rem/unit or more.
- At the plant level, PNGS dose performance was 70.32 person-rem/unit and achieved the maximum NPI points.
- At the plant level, DNGS dose performance was 83.23 person-rem/unit. Darlington Unit 2 began a long-term refurbishment outage on October 15, 2016. Dosage associated with Refurbishment activities has been excluded from benchmarking.

Trend

- Pickering plant-level CRE performance has improved since 2014 and achieved the maximum NPI value in 2019.
- After rising in the early part of the trend period, Darlington plant-level CRE performance improved in 2018 and 2019.
- Installing the post-Fukushima enhancement project in operating units concluded in 2016. As a result, dose related to this nuclear project was reduced during the 2019 3-year rolling average period. Also, dose improvement was complemented by the success of dose reduction initiatives.

Factors Contributing to Performance

- The following factors play a significant role in the CANDU reactors' CRE performance: planned outage scope and outage duration, forced outages, tritiated ambient air in accessible and access-controlled areas, effectiveness of mitigation measures, initiatives implemented to reduce identified sources of radiological hazards, and human performance during execution of radiological tasks.
- *Number of Planned Outages*: The number of planned outages, work scope as well as outage duration significantly contributed to plant level and unit rolling average CRE performance. In 2019 the following outages occurred:
    - PNGS**:** two planned outages (Unit 5, Unit 7), and three forced outages (Unit 1, 5 and 6).
    - DNGS**:** one planned outage (Unit 4), and three forced outages (two on Unit 3 and one on Unit 4).

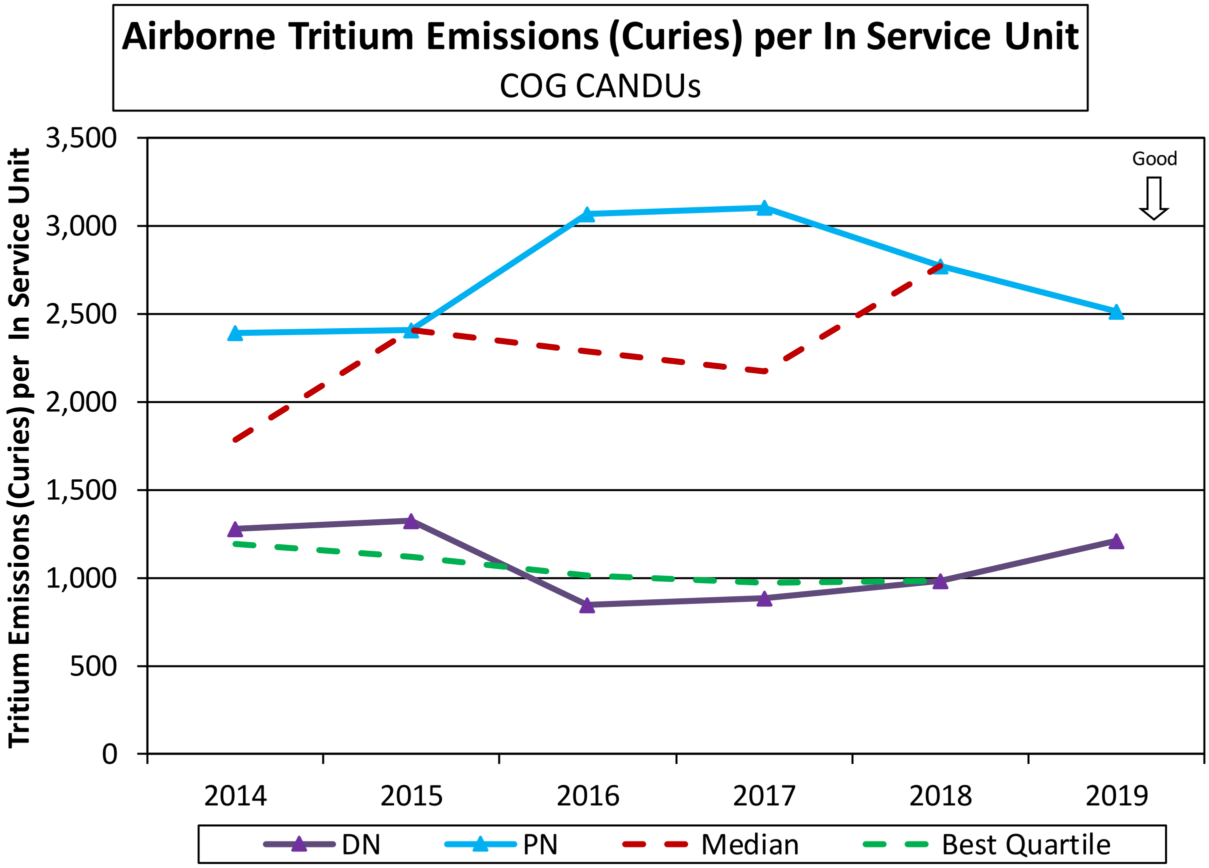
Rolling Average Collective Radiation Exposure (CANDU) - continued

- *Outage Scope/Duration*: The CRE reflects total work scope performed during the year and it varies year by year. Therefore, an increase or decrease in the rolling average CRE may be attributable to work scope, not necessarily deficiencies in Radiation Protection program and dose reduction initiatives. The rolling average is also impacted by longer outage duration. For example PNGS is impacted due to the amount of life extension work and scope required to extend life to 2024/2025.

Initiatives: Key nuclear fleet-wide and site-specific dose reduction initiatives have been implemented:

- o Improved Radiation Protection (RP) worker practices through the Radiation Protection Excellence Index. This index is based on nine individual RP human performance metrics, enabling various departments at both PNGS and DNGS to assess their respective performance and create action plans that are targeted to drive excellence.
- o The implementation of Lanxess Dose Reducing Resin was installed during PNGS outages for Unit 5 and Unit 7 and DNGS Units 1 and 3 to reduce primary heat transport source term.
- o Remote reading of radiation instrumentation provides real-time information of non-radiological conditions and minimizes time and dose.
- o Leveraging technology to avert dose using robotic equipment and remote monitoring of systems and for intrusive fuel channel inspections (machine delivered scrape) to reduce human hour exposure while executing high radiological hazard work on reactor face platform.
- At DNGS, implemented specialized Emergency Coolant Injection line permanent galvanized steel bands and temporary magnetic tungsten shielding to reduce hot spot hazard levels during unit outages.
- Installed Remote Area Tritium Monitors in the East and West Fuelling Facility Auxiliary Areas to monitor and trend airborne tritium to minimize internal dose for Fuel Handling Staff.
- Installation of a Radiation-Resistant Online Periscope camera in Darlington Unit 4 to identify leaking closure plugs or any Fuelling Machine issues on the reactor face.

Airborne Tritium Emissions per In Service Unit



Notes:

- Median and Best Quartiles are plotted till 2018 as the 2019 results were unavailable at the time of benchmarking.
- Darlington values exclude Tritium Removal Facilities emissions consistent with COG benchmarking results.

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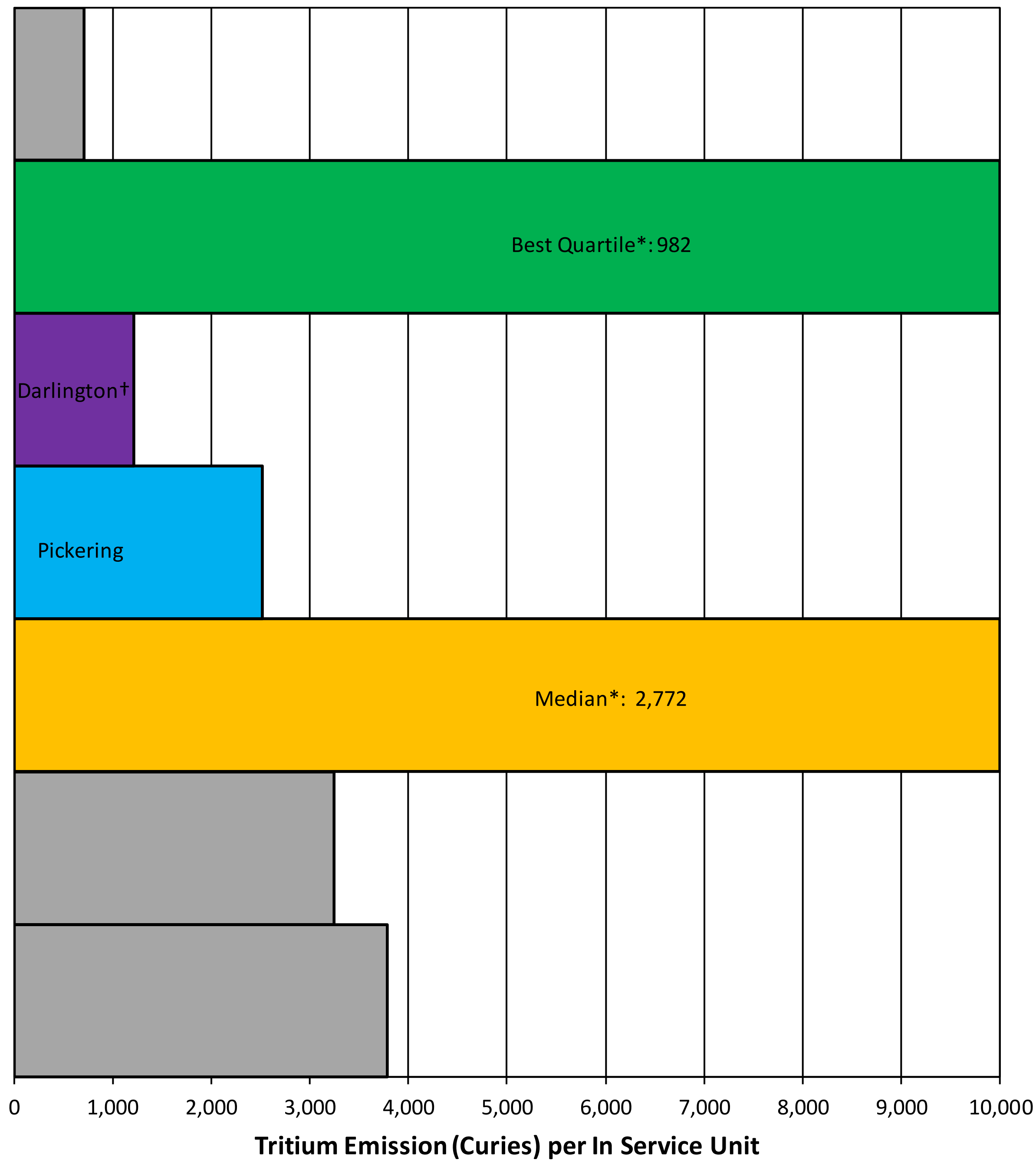
2019 Airborne Tritium Emissions (Curies) per In Service Unit
COG CANDUs



* Industry data based on 2018 as it is the best available information at the time. Pickering and Darlington results are 2019.
†Excludes emissions from Tritium Removal Facility.
Notes:

- Two plants are excluded as one plant's 2018 data is unavailable and another plant has been offline since December 31, 2015 for refurbishment.

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Observations – Airborne Tritium Emissions (Curies) per In Service Unit

2019 (Annual Value)

- Curies per in service unit at best quartile CANDU plants was 982 or lower and the industry median threshold was 2,772 curies per in service unit.
- Darlington's 2019 performance remained in the second quartile with 1,213 curies per in service unit. Emissions from Darlington Unit 2 are not included in this benchmarking report due to the shutdown of Unit 2 in October 2016 for refurbishment.
- Pickering's performance improved from third quartile in 2018 to second quartile in 2019 with 2,517 curies per in service unit.

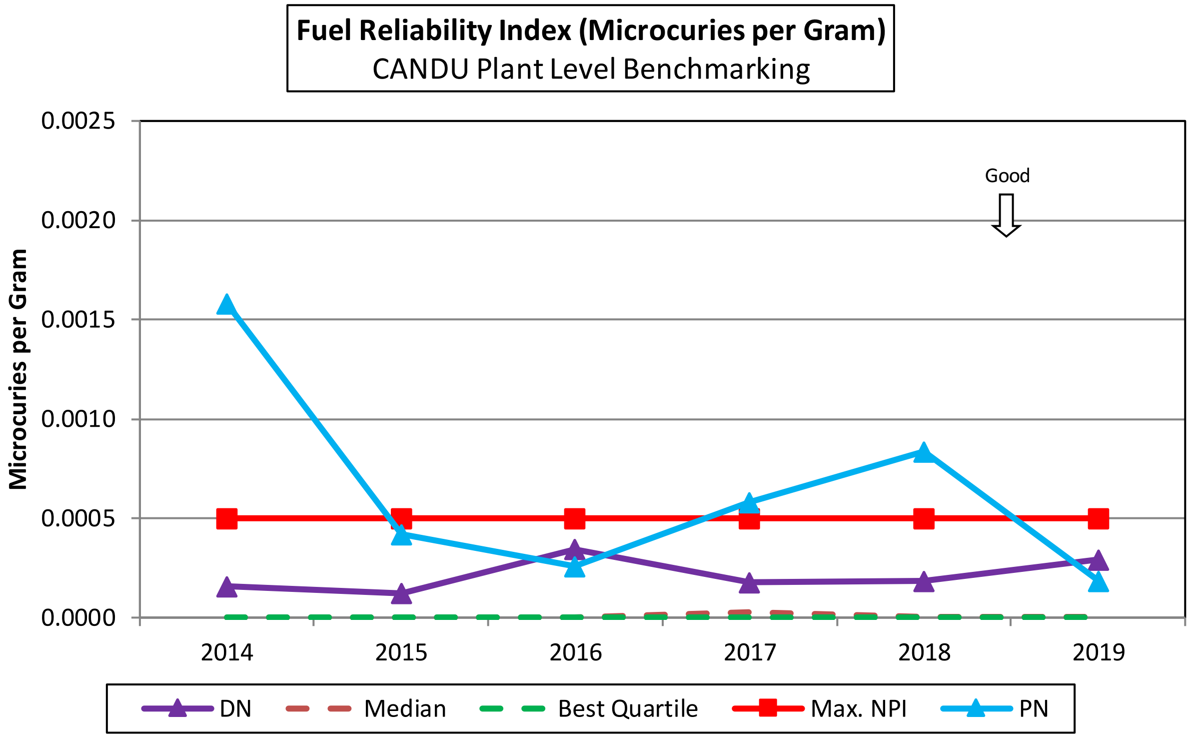
Trend

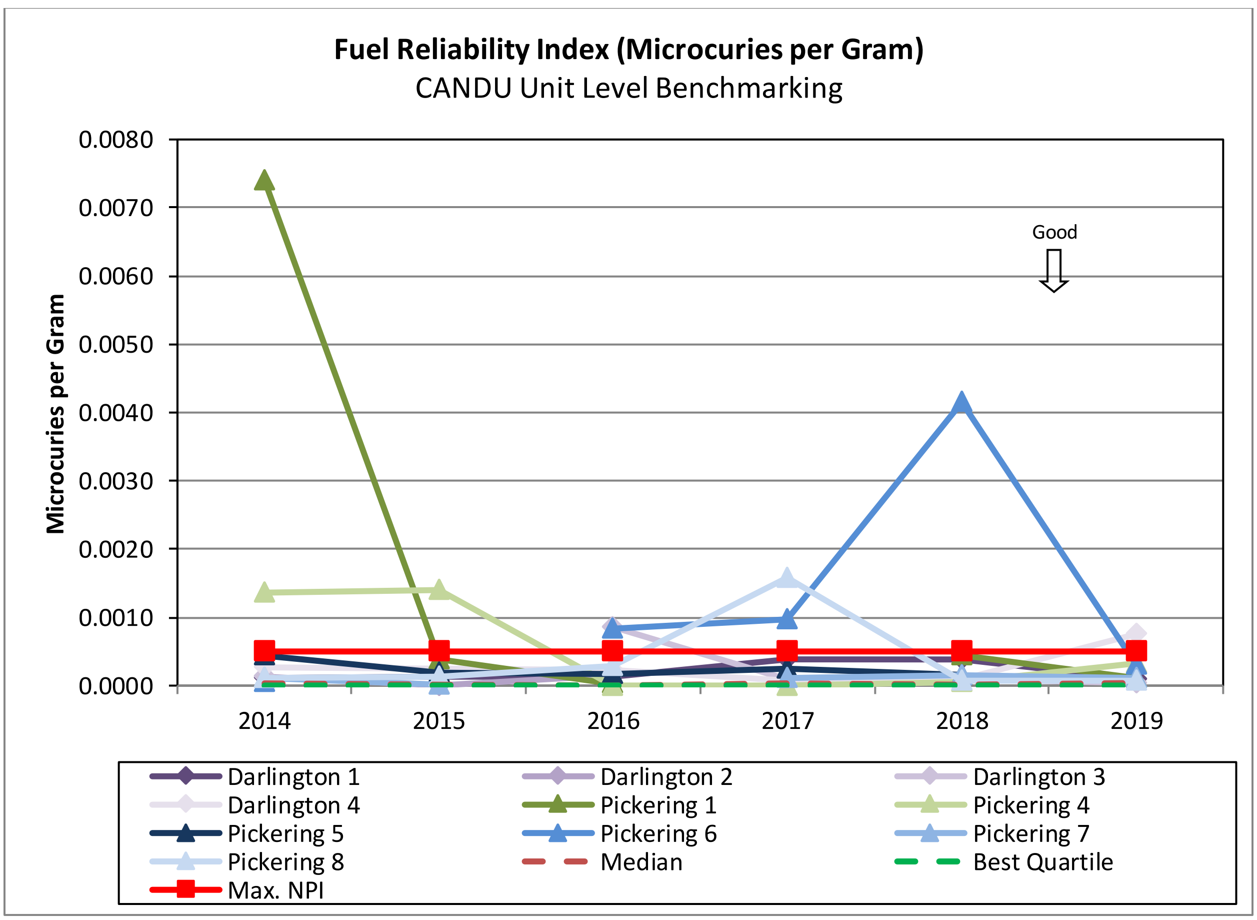
- Darlington and Pickering tritium emissions to air continue to be less than one per cent of the regulatory limits.
- After increasing in the early part of the trend period, performance at Pickering improved since 2017. Increased emissions in 2016 and 2017 were primarily due to tritiated water in the Fuel Transfer Conveyor Tunnel being vented to monitored stacks, equipment and system leaks, and dryer performance issues.
- Performance at Darlington in 2019 was consistent with the level seen at the beginning of the trend period. Emissions at Darlington increased in 2019 compared to 2018, mainly due to the planned outage activities in Unit 4, and dryer performance and leaks issues.
- The industry trend line graph shows that industry best quartile performance has been decreasing generally since 2014.

Factors Contributing to Performance

- Key factors affecting performance at DNGS and PNGS include the following:
    - Leaks from various equipment or systems,
    - Declining vapour recovery dryer performance,
    - DNGS Unit 4 outage activities including moderator heat exchanger drain work,
    - Increased unit source term (e.g., higher moderator tritium concentrations),
    - Focus on tritium emission reduction initiatives include dedicated teams to ensure daily emissions monitoring, sustaining and improving dryer performance, heavy water leak minimization, tritium program development and innovations,
    - Other improvement initiatives include OPG's ongoing participation in COG to determine best environmental practices.

Fuel Reliability Index





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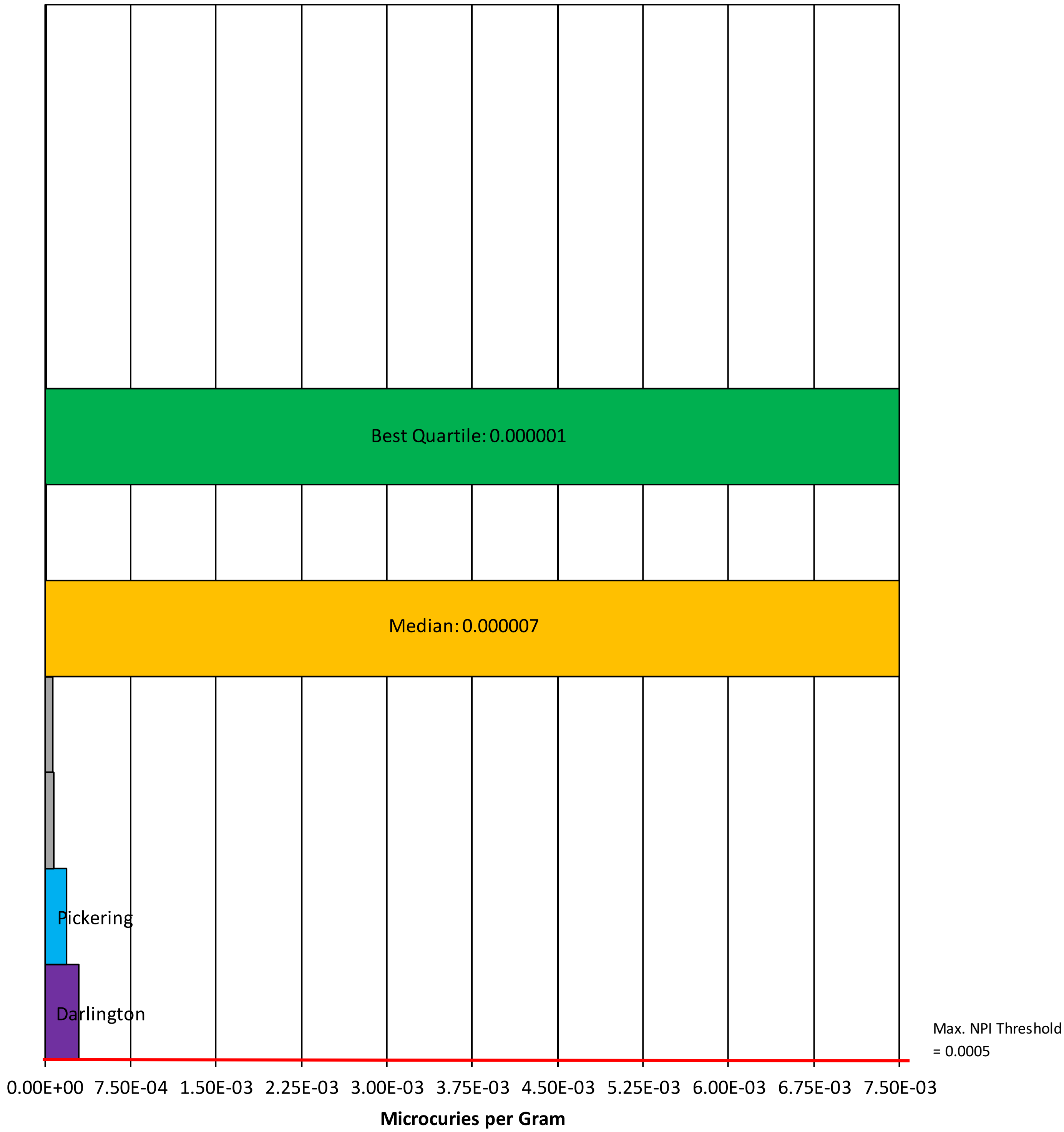
2019 Fuel Reliability Index (Microcuries per Gram)
CANDU Plant Level Benchmarking



Observations – Fuel Reliability Index (FRI) (CANDU)

2019 (Most Recent Operating Quarter)

- The best quartile value for Fuel Reliability Index (FRI) performance for CANDU plants was 0.000001 μCi/g and the median value was 0.000007 μCi/g.
- FRI performance at PNGS was 0.000187 μCi/g and 0.000295 μCi/g for DNGS in 2019.
- First quartile rating was achieved for both PNGS and DNGS, as results achieved maximum NPI points.
- Post-discharge fuel inspections for PNGS and DNGS indicated that the overall condition of fuel inspected was acceptable and consistent with previous years.
- Fuel inspections for PNGS confirmed four fuel defects in 2019, and no fuel issues of significance arose.
- Fuel inspections for DNGS confirmed one fuel defect occurred in 2019. No fuel issues of significance arose at Darlington in 2019.

Trend

- The best quartile for CANDU plants remained consistent at 0.000001 μCi/g from 2014. The median values for CANDU plants has generally improved from 2014 and remains quite low at 0.000007 in 2019.
- PNGS FRI performance has generally improved since 2014 while DNGS has remained relatively steady. Favourable FRI performance is due to the low incident rate for fuel defects in recent years.

Factors Contributing to Performance

- Four defects were confirmed at PNGS in 2019. In a previous year, a team was formed to investigate the fuel defects incidents and the cause was found to be primarily due to debris fretting.
- Actions taken at PNGS that drove this improvement include:
    - Improved the methods of surveillance and elimination of the possibility of foreign materials entrance into the Heat Transport System due to Fuel Handling and Outage practices,
    - Developed a fuel defect guideline for Pickering,
    - Increased scope of Heat Transport System grab sampling and analysis when defects are in-core,
    - Improved capability of detecting the defected fuel bundles during the discharge from the fuelling machines, and
    - Improved the capability of the in-bay inspection of the suspected fuel bundles to be defected.

Fuel Reliability Index (CANDU - FRI) – continued

- Darlington had only one fuel defect in 2019. Steps have been taken that have led to improved FRI performance and prevent the potential of fuel defects, including the following:
  - Greatly improved Foreign Material Exclusion practices during the Darlington Unit 2 refurbishment activities.
  - New fuel with tighter tolerances for mass was received and is being used,
  - OPG-supplier co-operation resulted in installation of an automatic loader of fuel pellets complete with a "go/no go" pellet diameter monitor,
  - Close monitoring of existing fuel bundle inventory and core load.

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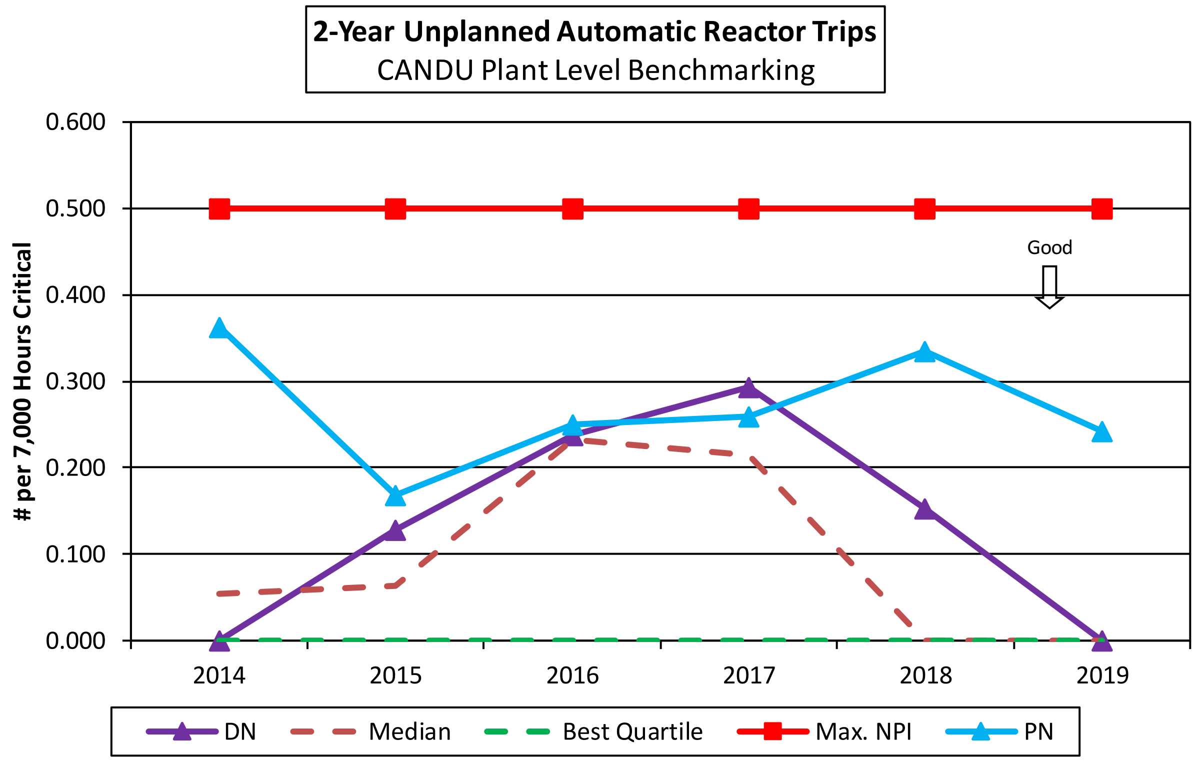
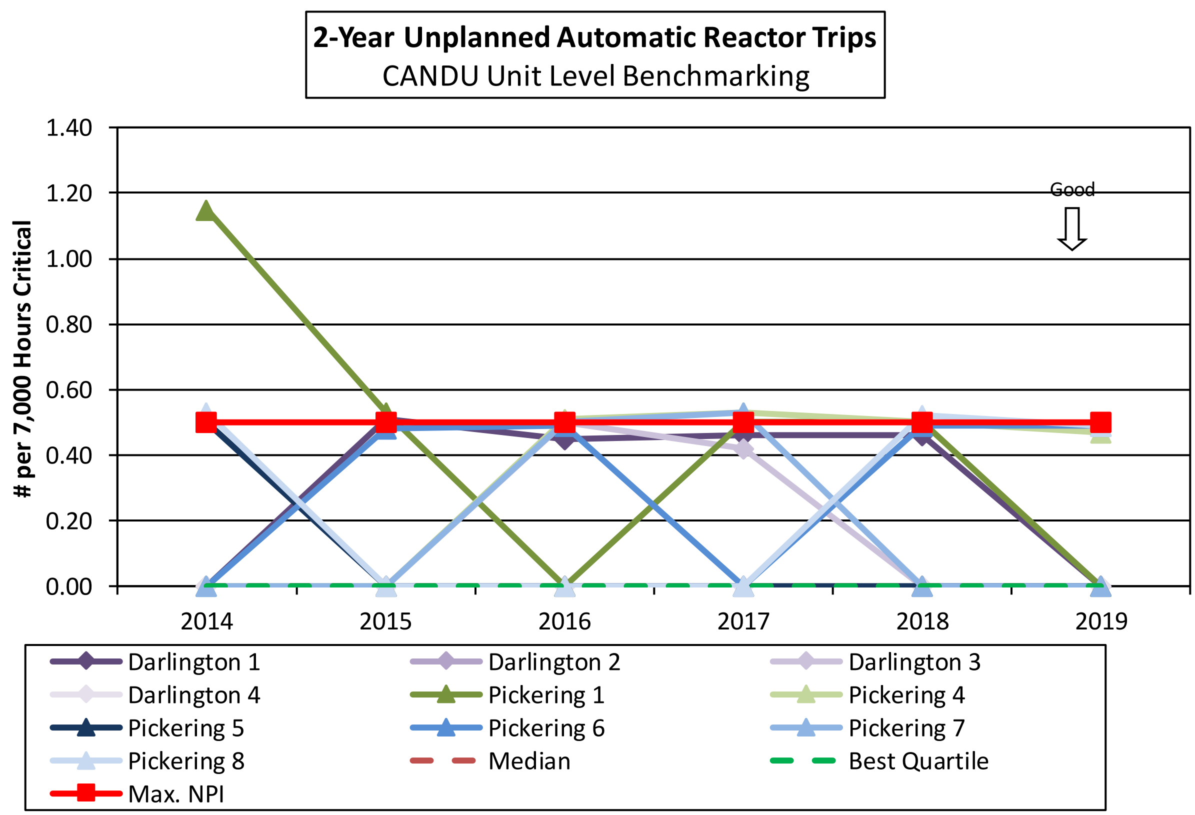
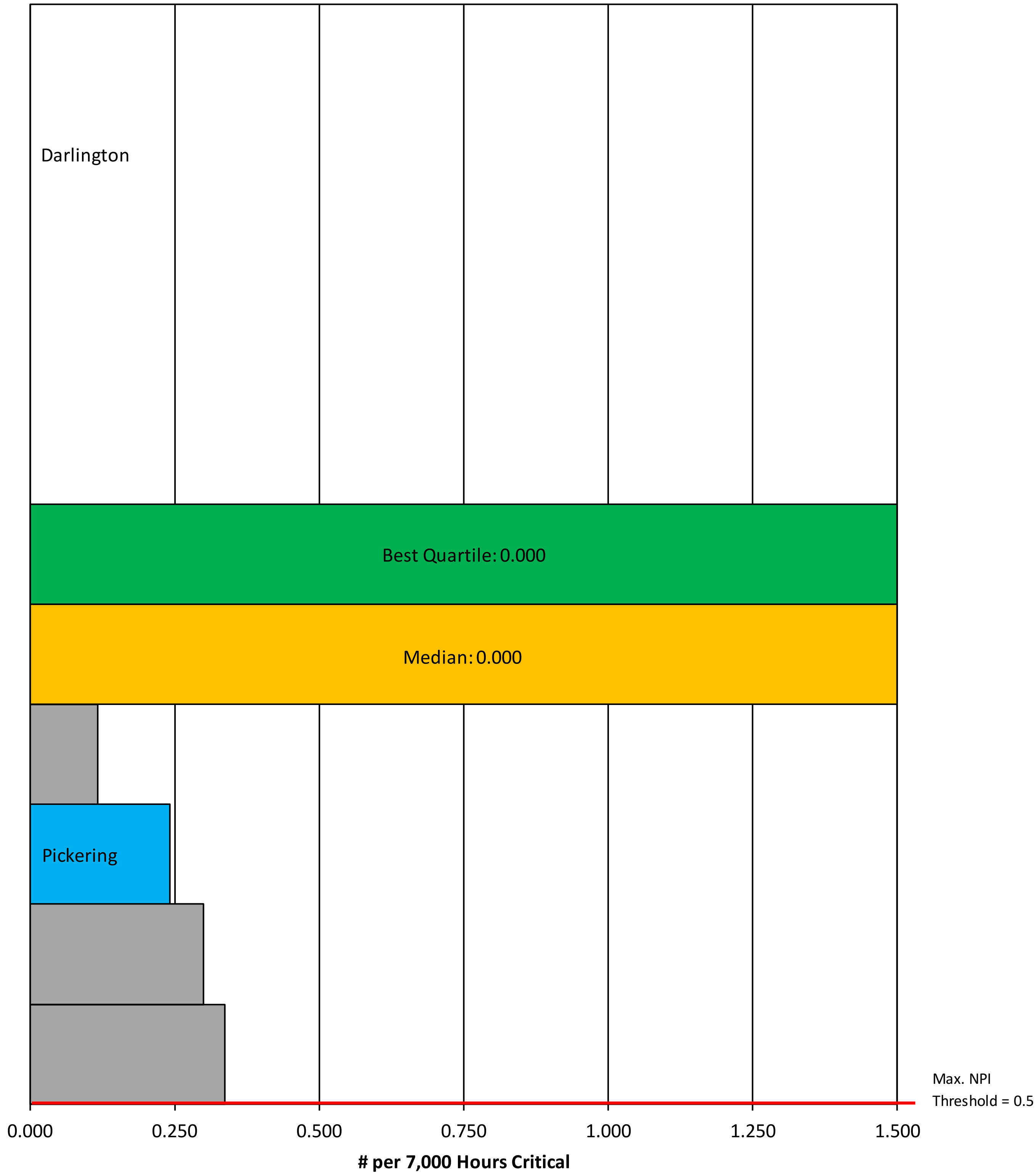
2-Year Unplanned Automatic Reactor Trips





2019 2-Year Unplanned Automatic Reactor Trips
CANDU Plant Level Benchmarking



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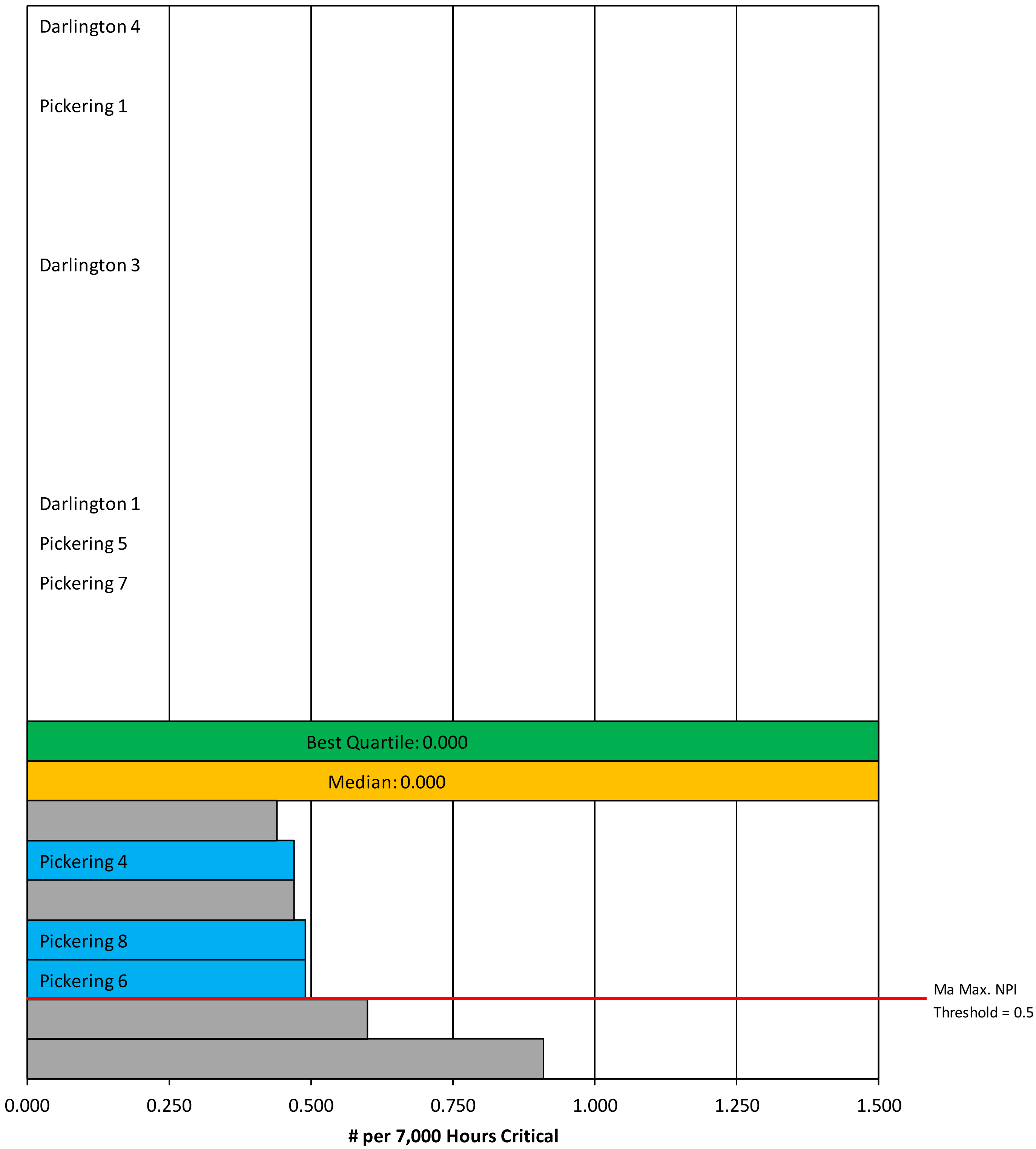
2019 2-Year Unplanned Automatic Reactor Trips
CANDU Unit Level Benchmarking



Observations – 2-Year Unplanned Automatic Reactor Trips (CANDU)

2019 (2-Year Rolling Average)

- The 2-year rolling average unplanned automatic reactor trip best quartile and median for CANDU plants as well as individual units was 0.00.
- At the plant level, Pickering's trip rate of 0.24 achieved the maximum NPI points.
- At the plant level Darlington's trip rate of 0.00 was below the maximum NPI threshold value of 0.50 and achieving top quartile status. Darlington Unit 2 began a long-term refurbishment outage on October 15, 2016 and has been excluded from benchmarking results.
- In 2019, both PNGS and DNGS had no unplanned automatic reactor trips.

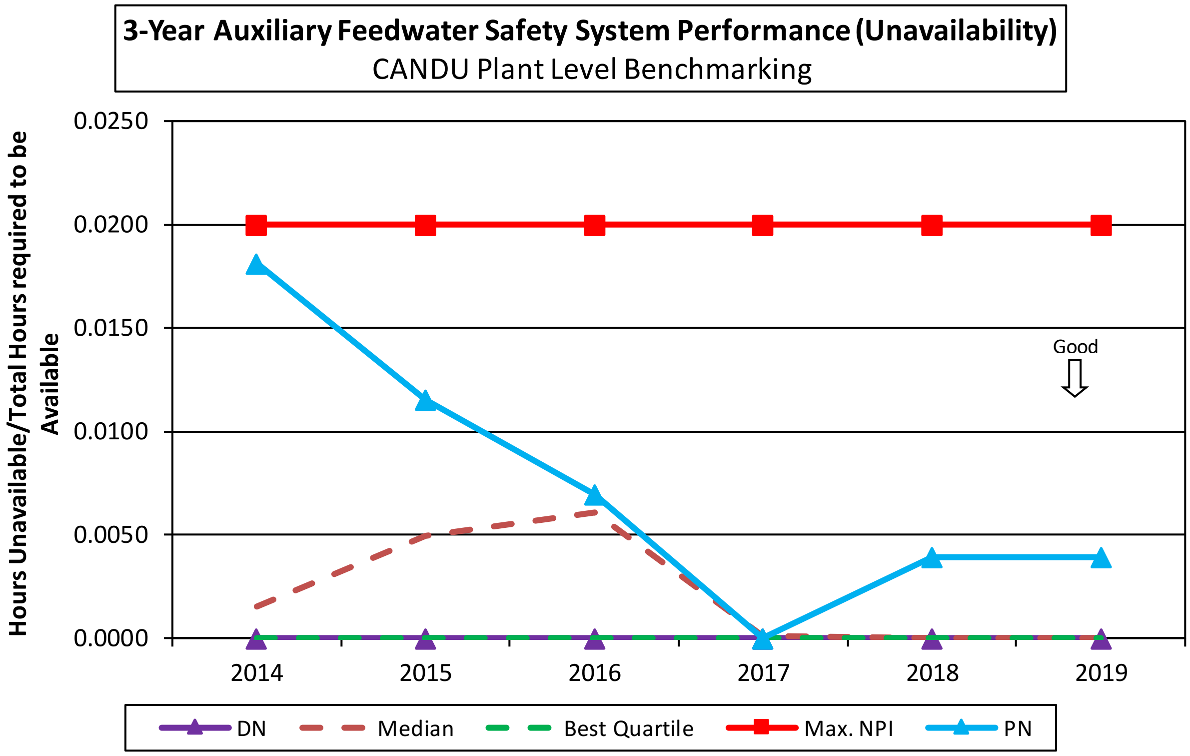
Trend

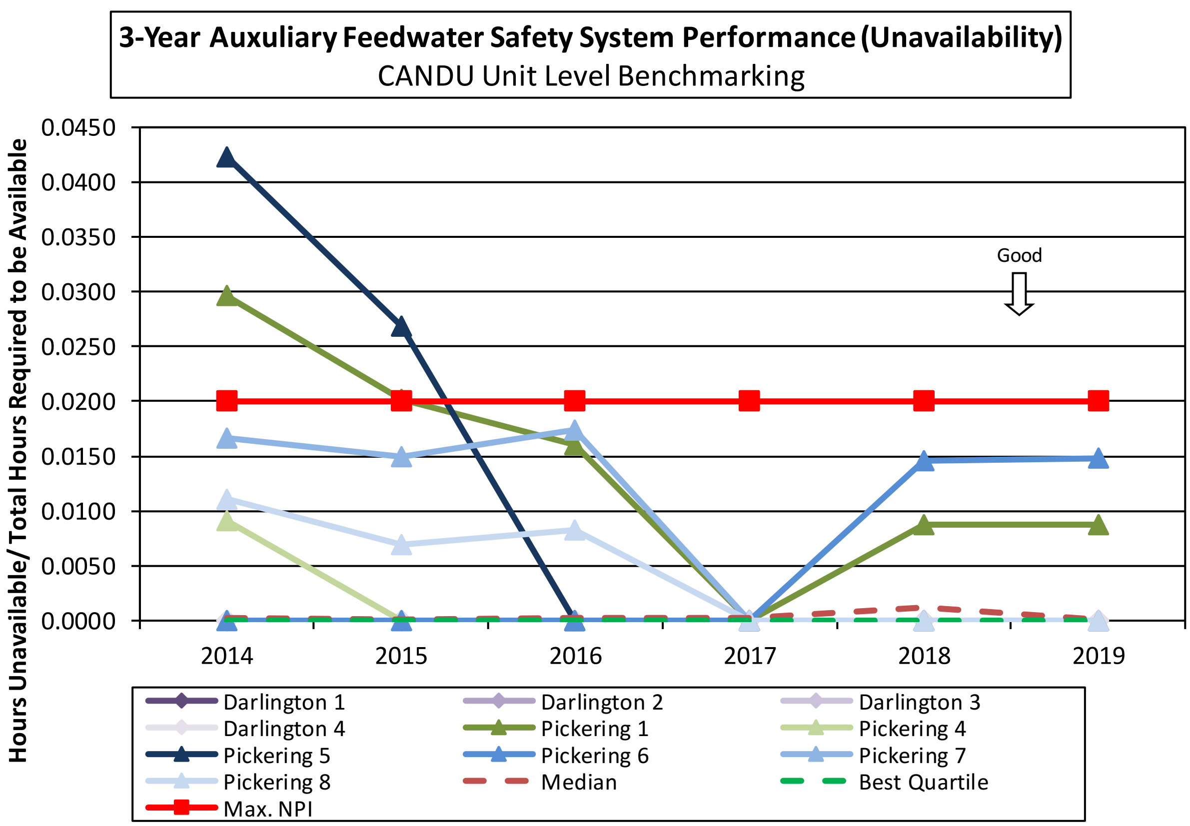
- The unplanned automatic reactor trip best quartile for CANDU plants has been zero throughout the trend period. The median value deteriorated in 2016 and 2017 from 2015. In 2018 and 2019 the median value improved to zero.
- At the plant level, PNGS performance declined in 2016 to 2018, and improved in 2019 for an overall improvement over the trend period.
- At the plant level, DNGS peaked in 2017, improved in 2018, and achieved the industry best quartile result of a zero trip rate in 2019.

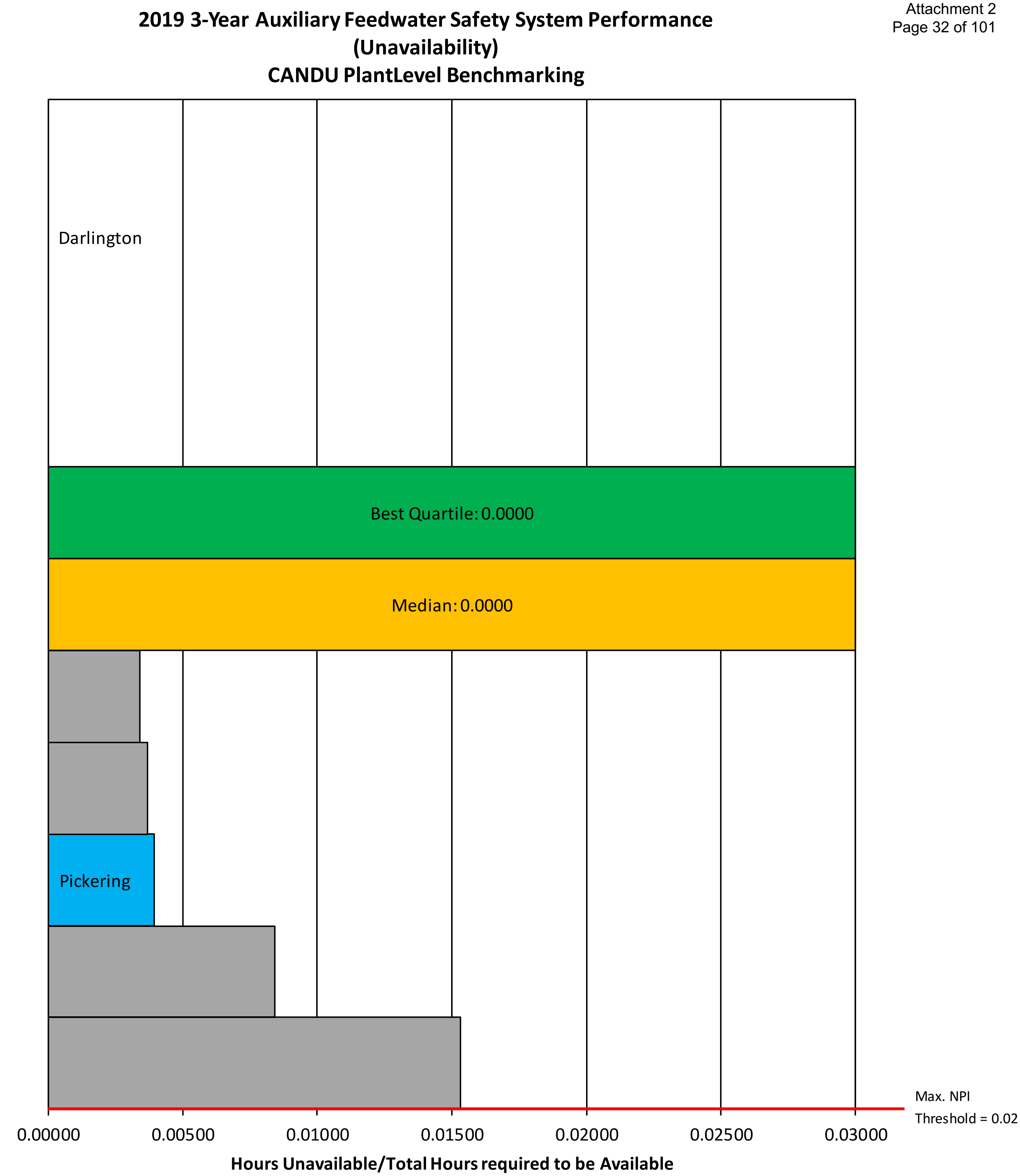
Factors Contributing to Performance

- Key performance drivers for this metric include: general equipment reliability, material condition, and human performance.
- On-going due diligence by Station Operations, Engineering, and Maintenance organizations. Operating Experience (OPEX) from each event has been shared at Pickering, Darlington and at external summits.
- Training material and technical procedures have been revised based on OPEX.
- Like-for-like parts replacement has taken place to improve equipment reliability. System health teams are involved in obsolescence issues.

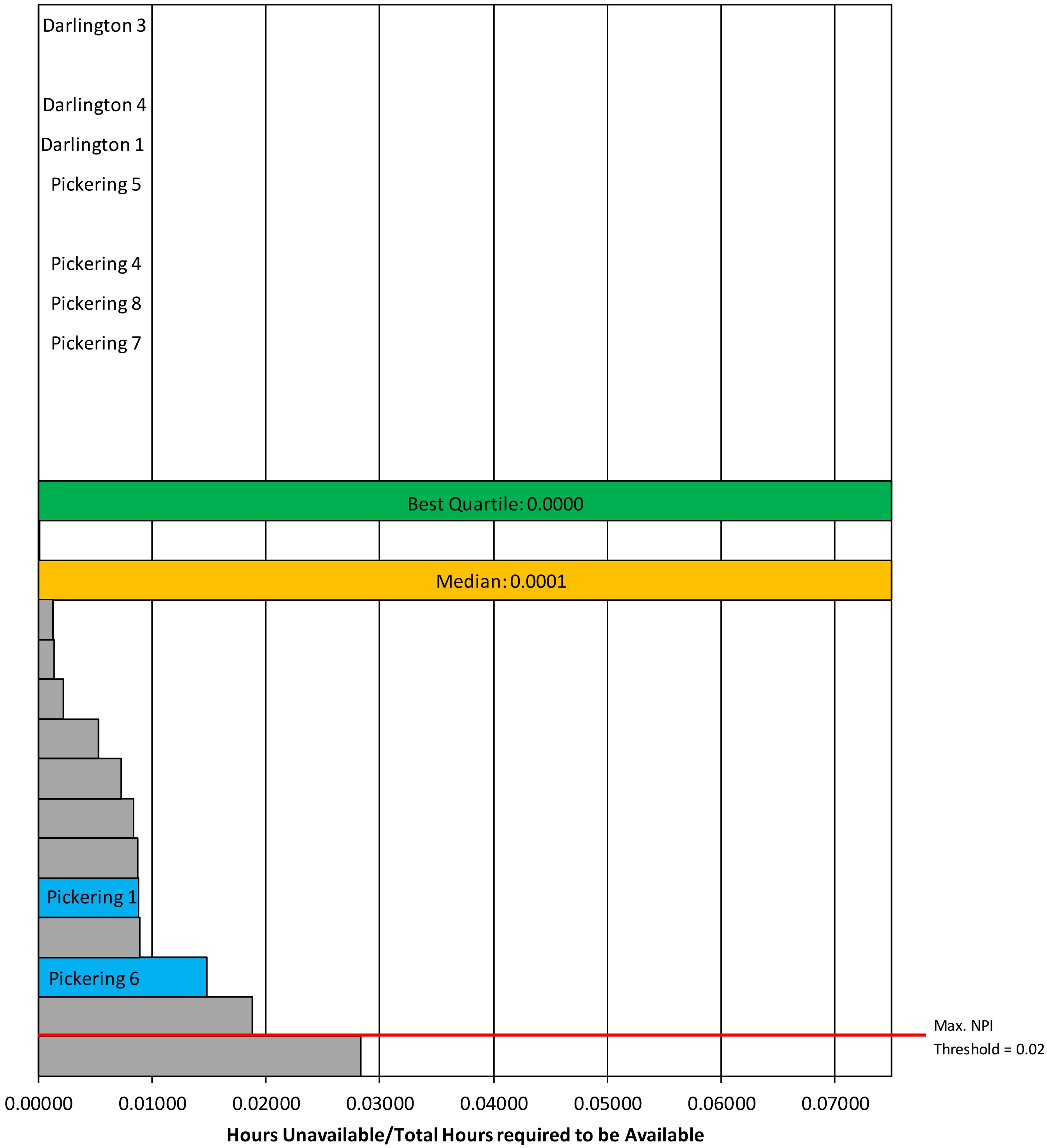
3-Year Auxiliary Feedwater Safety System Unavailability






2019 3-Year Auxiliary Feedwater Safety System Performance (Unavailability)
CANDU PlantLevel Benchmarking
Darlington
Best Quartile: 0.0000
Median: 0.0000
Pickering
Max. NPI
Threshold = 0.02
0.00000
0.00500
0.01000
0.01500
0.02000
0.02500
0.03000
Hours Unavailable/Total Hours required to be Available

2019 3-Year Auxiliary Feedwater Safety System Performance (Unavailability)
CANDU Unit Level Benchmarking



Observations – 3-Year Auxiliary Feedwater System Unavailability (CANDU)

2019 (3-Year Rolling Average)

- Auxiliary feedwater (AFW) safety system performance at best quartile for CANDU plants was zero with a median value of 0.0000.
- At the plant level, PNGS AFS unavailability of 0.0039 achieved maximum NPI points.
- DNGS achieved best quartile performance of zero unavailability for both the station and unit levels in 2019. Darlington Unit 2 began a long-term refurbishment outage on October 15, 2016 and has been excluded from benchmarking results.

Trend

- The 3-Year AFW unavailability best quartile performance of CANDU plants maintained zero unavailability from 2014 to 2019.
- The plant level industry median value has fluctuated over the review period but has remained below the NPI maximum threshold.
- Pickering station performance fluctuated over the trend period and had an overall improvement.
- Darlington station performance has been at zero unavailability over the entire trend period.

Factors Contributing to Performance

- Key performance drivers for this metric include: general equipment reliability, material condition, and human performance.
- 2019 - Quarter 1, Pickering - Unit 6 Auxiliary Boiler Feedwater Pump (ABFP) was declared unavailable due to loss of cooling flow to non drive end (NDE) bearing. Per operating procedure, an impairment of ABF System was declared, and the unit was placed on a 72 hr shutdown clock. Following the silt/blockage removal of the inlet and discharge lines of the NDE bearing, and cleaning of the manual isolation valve, the pump was successfully tested and returned to service.

  To improve the system performance at PNGS the following actions will be taken:
  - Remove debris from the pipework.
  - Investigate failure of the instrumentation and control to indicate the cooling flow to NDE bearing and repair or replace the failed equipment.

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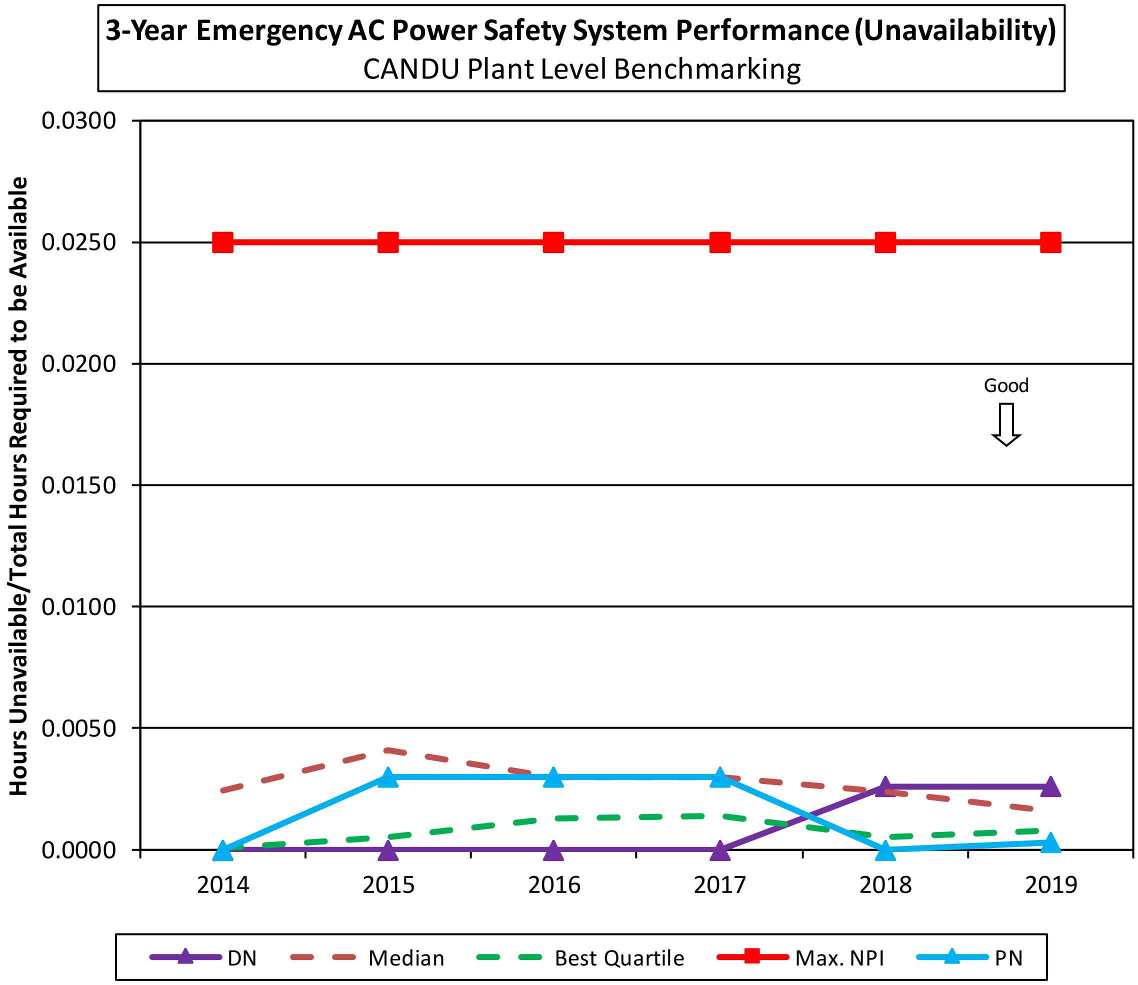
3-Year Emergency AC Power Safety Unavailability



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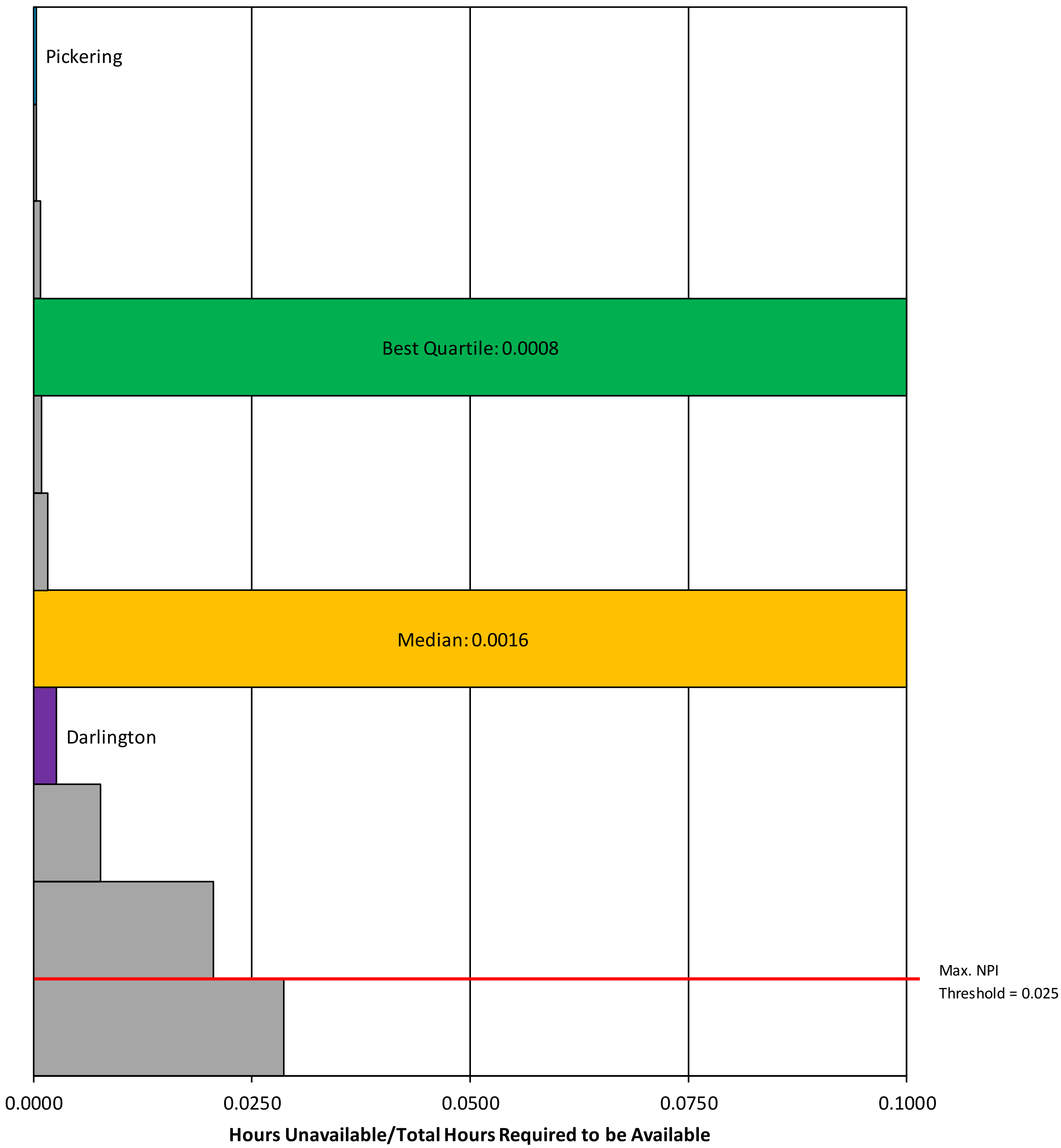
2019 3-Year Emergency AC Power Safety System Performance (Unavailability)
CANDU Plant Level Benchmarking



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Observations – 3-Year Emergency AC Power Safety System (CANDU)

2019 (3-Year Rolling Average)

- 3-Year Emergency AC Power Safety System performance at best quartile for CANDU plants was 0.0008. The industry median value was 0.0016.
- At the plant level, PNGS is one of the best performing stations in the CANDU peer group, achieving an unavailability of 0.0003.
- DNGS had an unavailability of 0.0026, and achieved the maximum NPI points.

Trend

- The 3-year Emergency AC Power Safety System unavailability industry best quartile for CANDU plants declined each year from 2015 to 2017, improved in 2018 and deteriorated in 2019 again. The industry median value improved in 2016 from 2015 and remained unchanged in 2017 with further improvement in 2018 and 2019.
- PNGS performance remained below the NPI maximum threshold throughout the trend period and the unavailability was close to zero in 2019.
- DNGS performance remained below the NPI maximum threshold throughout the trend period and remained unchanged in 2019 compared to 2018.

Factors Contributing to Performance

- Key performance drivers for this metric include: general equipment reliability, material condition, and human performance.
- 2019 Quarter 3, Pickering – During the execution of the start reliability test (Class III Standby Generators - Black Start of Standby Generator (SG)), a standby generator, SG1, tripped due to a failure of its AC motor driven fuel pump. When SG1 tripped, another standby generator, SG3, was in a planned outage, which resulted in reduction of SG redundancy.
- To improve the system performance at PNGS the following actions will be taken:
    - Perform design changes to modify the steam generators with electrical driven fuel pumps to shaft driven pumps, matching the configuration of SG2 and SG3, which do not exhibit machine breaker closure trips.
    - Replacement of the relay control logic and annunciator under the Standby Generator Reliability improvement modification Project. This project will resolve an obsolescence concern.
    - Upgrades of vibration monitoring system on SGs.
- At DNGS, an event occurred in 2018 which resulted in only one SG available out of a total of four, impacting the AC Power Safety System unavailability. As this metric is based on a 3-year rolling average, this value will carry over until Q2-2021 if no additional events occur.

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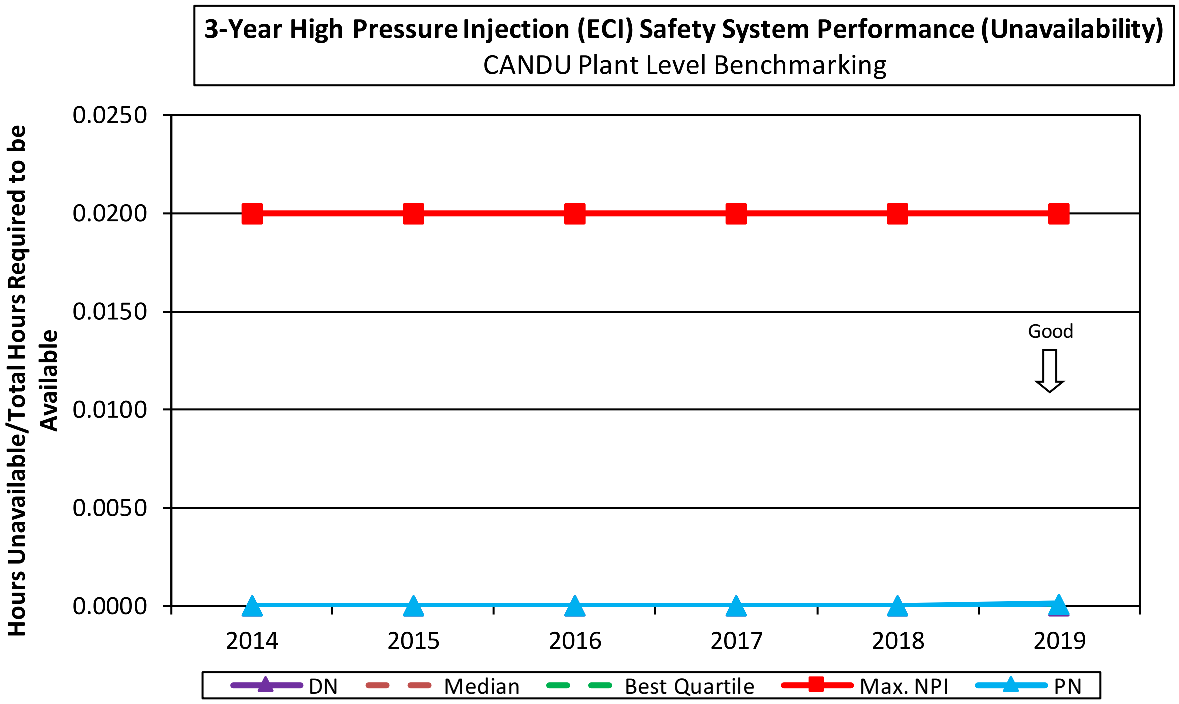
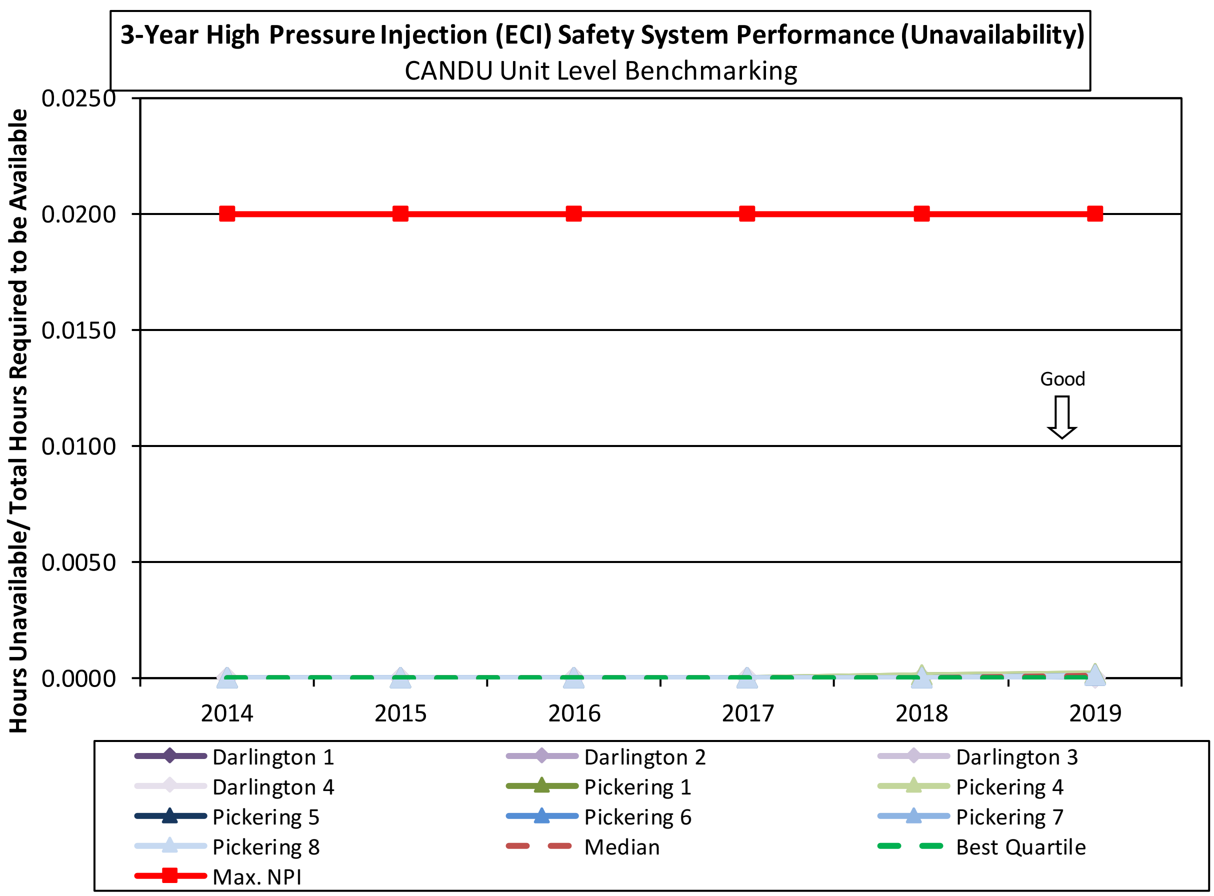
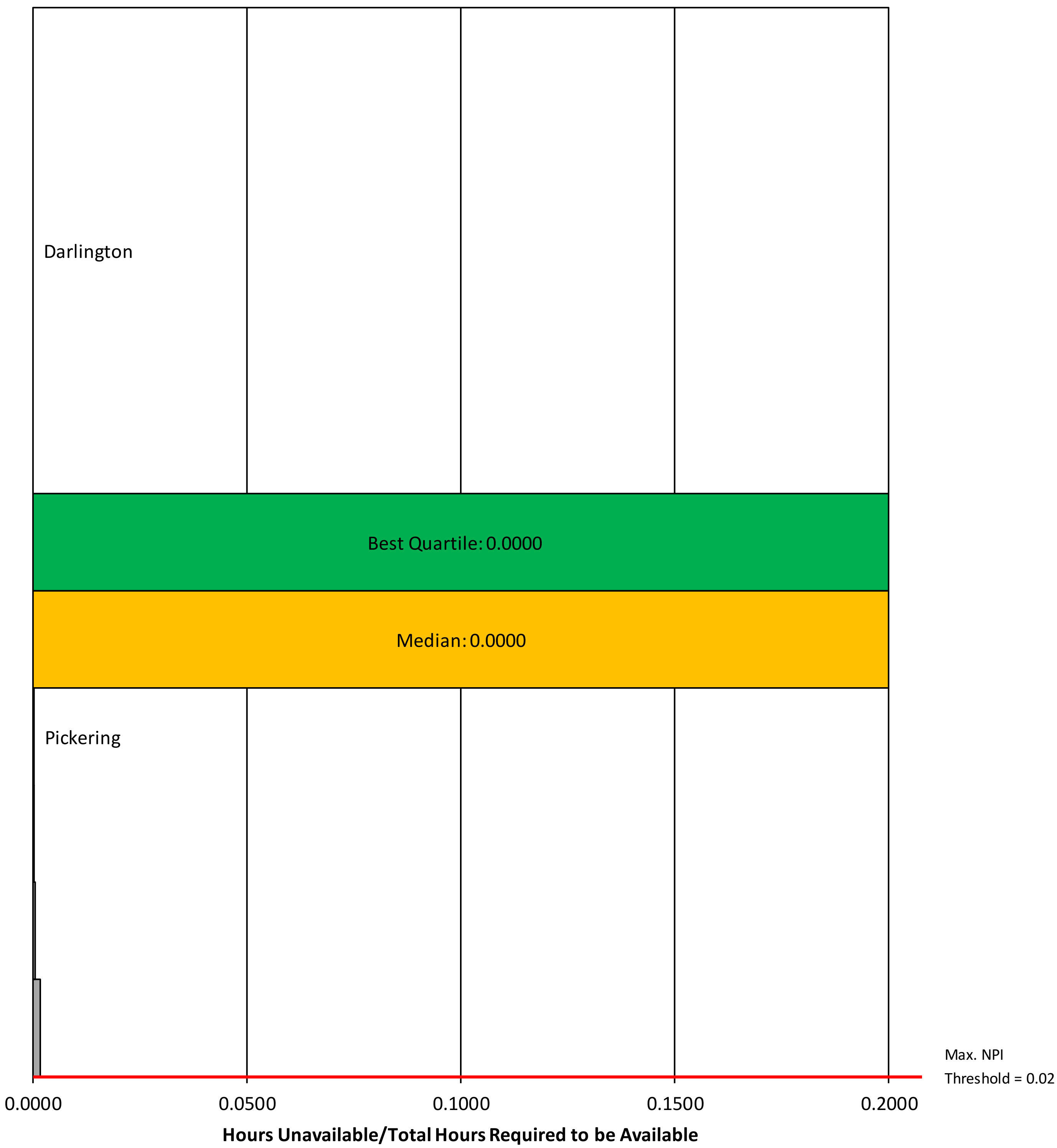
3-Year High Pressure Safety Injection





2019 3-Year High Pressure Injection (ECI) Safety System Performance (Unavailability)
CANDU Plant Level Benchmarking



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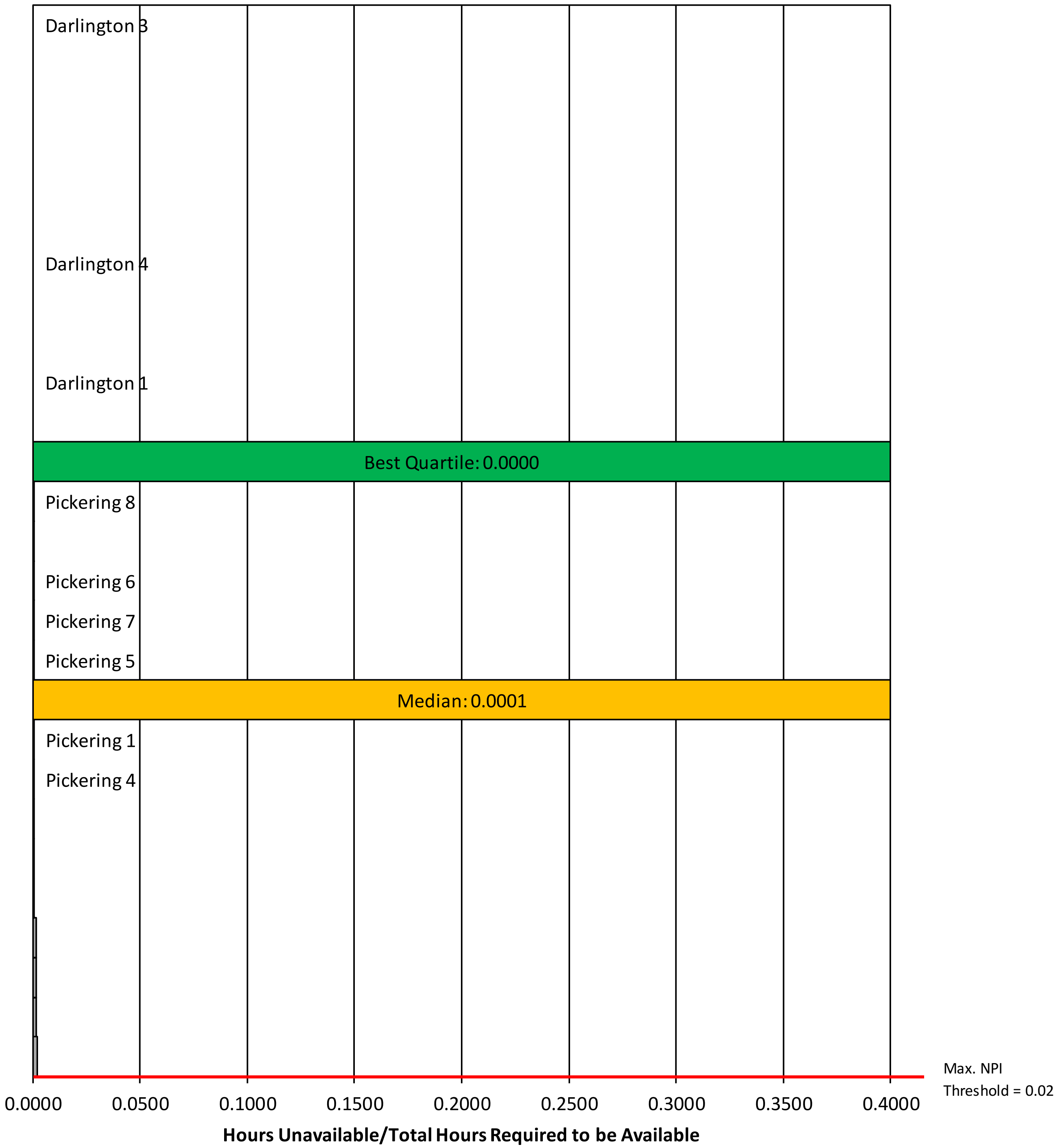
2019 3-Year High Pressure Injection (ECI) Safety System Performance (Unavailability)
CANDU Unit Level Benchmarking



Observations – 3-Year High Pressure Safety Injection Unavailability (CANDU)

2019 (3-Year Rolling Average)

- The best quartile and median values for the 3-Year High Pressure Safety Injection (HPSI) Unavailability performance for CANDU plants were zero.
- At the plant level, PNGS with an HPSI unavailability of 0.0001 achieved maximum NPI points.
- DNGS achieved best quartile performance of zero unavailability in 2019. Darlington Unit 2 began a long-term refurbishment outage on October 15, 2016 and has been excluded from benchmarking results.

Trend

- The 3-Year HPSI unavailability best quartile and median performance of CANDU plants has been zero since 2014.
- At the plant level, PNGS performance achieved maximum NPI points throughout the trend period and was near zero in 2019.
- DNGS achieved best quartile performance of zero HPSI unavailability throughout the trend period.

Factors Contributing to Performance

- Key performance drivers for this metric include: general equipment reliability, material condition, and human performance.
  - 2019 Quarter 1, Pickering ECI Trace Heater - During routine panel monitoring, Emergency Coolant Injection (ECI) heat trace alarm was received. The water temperature in the High Pressure Emergency Coolant Injection (HPECI) piping was detected to be less than 6°C and the outdoor temperature was less than 1°C. This condition constitutes a Level 2 ECI system impairment. To establish flow in the ECI system and also heat the water, an HPECI pump was started at which point the lack of flow concern was resolved.

  - 2019, Quarter 2 – Pickering– During a routine test (Recovery System – Unit Emergency Control Centre (UECC) Tests), when UECC hand switch was selected to open, ECI recovery sump level rose rapidly and ECI storage tank level dropped to 10.8 m, which results in Level 2 ECI system impairment, applicable to Units 1, 4, and 5 to 8. The hand switch was reclosed. ECI storage tank level was restored to above 10.8 m following sump level pump back to the ECI storage tank. Test (ECI Recovery Sump Valve and Recovery Pump Discharge Valve Test) was performed in order to identify the passing check valve. The recovery pump check valve was isolated. Note that Level 2 ECI system impairment lasted for the period of time when the ECI storage tank level was below 10.8 m.
- To improve system performance at PNGS, the following actions will be taken:
  1) Investigate the failure of primary heater.
  2) Replace the degraded check valve.
  3) Align the ECI impairments Abnormal Accident Manuals, ECI Operational Safety Requirements, and test.

3.0 RELIABILITY

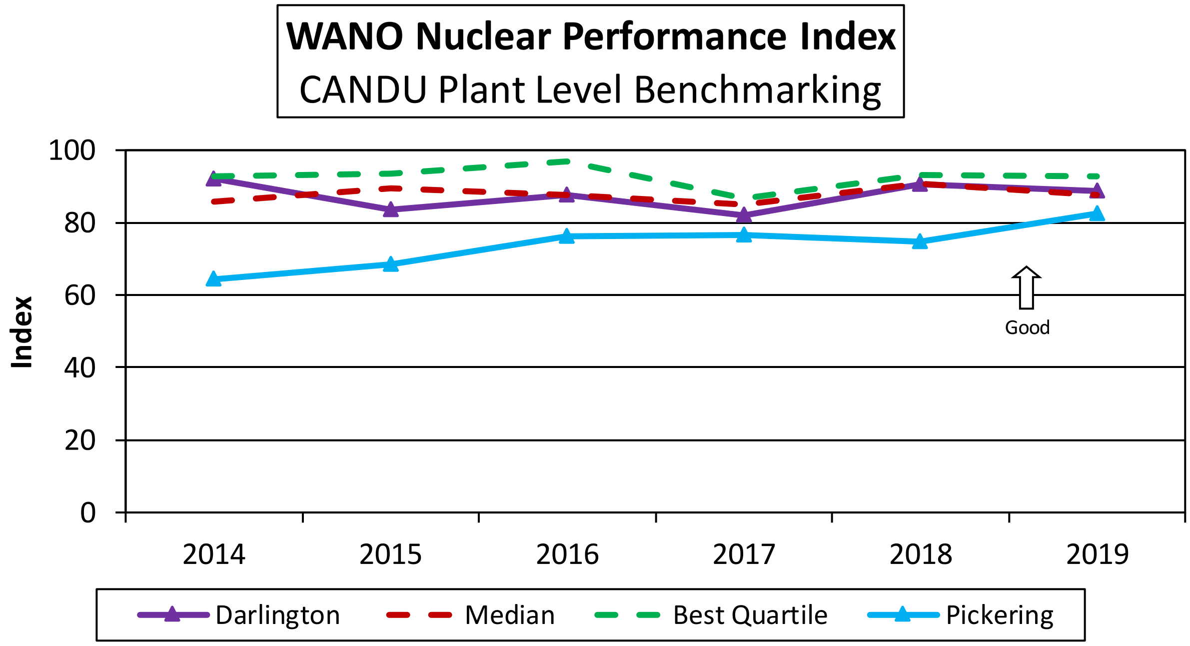
Methodology and Sources of Data

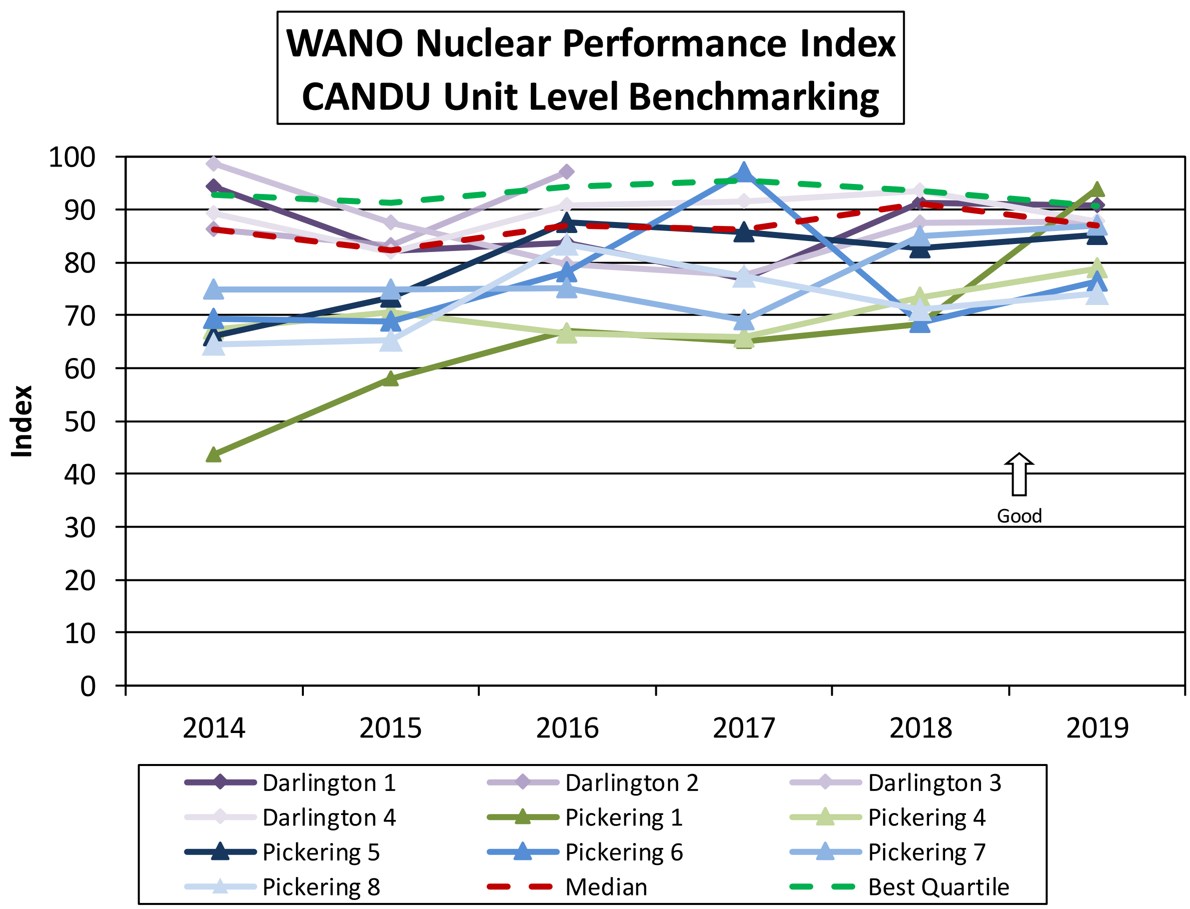
The majority of reliability metrics were calculated using data from WANO. Any data labelled as invalid by WANO was excluded from all calculations. Indicator values of zero are not plotted or included in calculations except in cases where zero is a valid result. Complete data for the review period was obtained and averages are as provided by WANO. The Embalse plant is excluded since it was taken offline since December 31, 2015 for refurbishment.

Backlog metrics, On-line Deficient and Corrective maintenance, are also included within this section and the data comes from an industry sponsored INPO AP-928 subcommittee. Data points benchmarked on backlogs are a single point in time, not a rolling average. All of the data is self-reported.

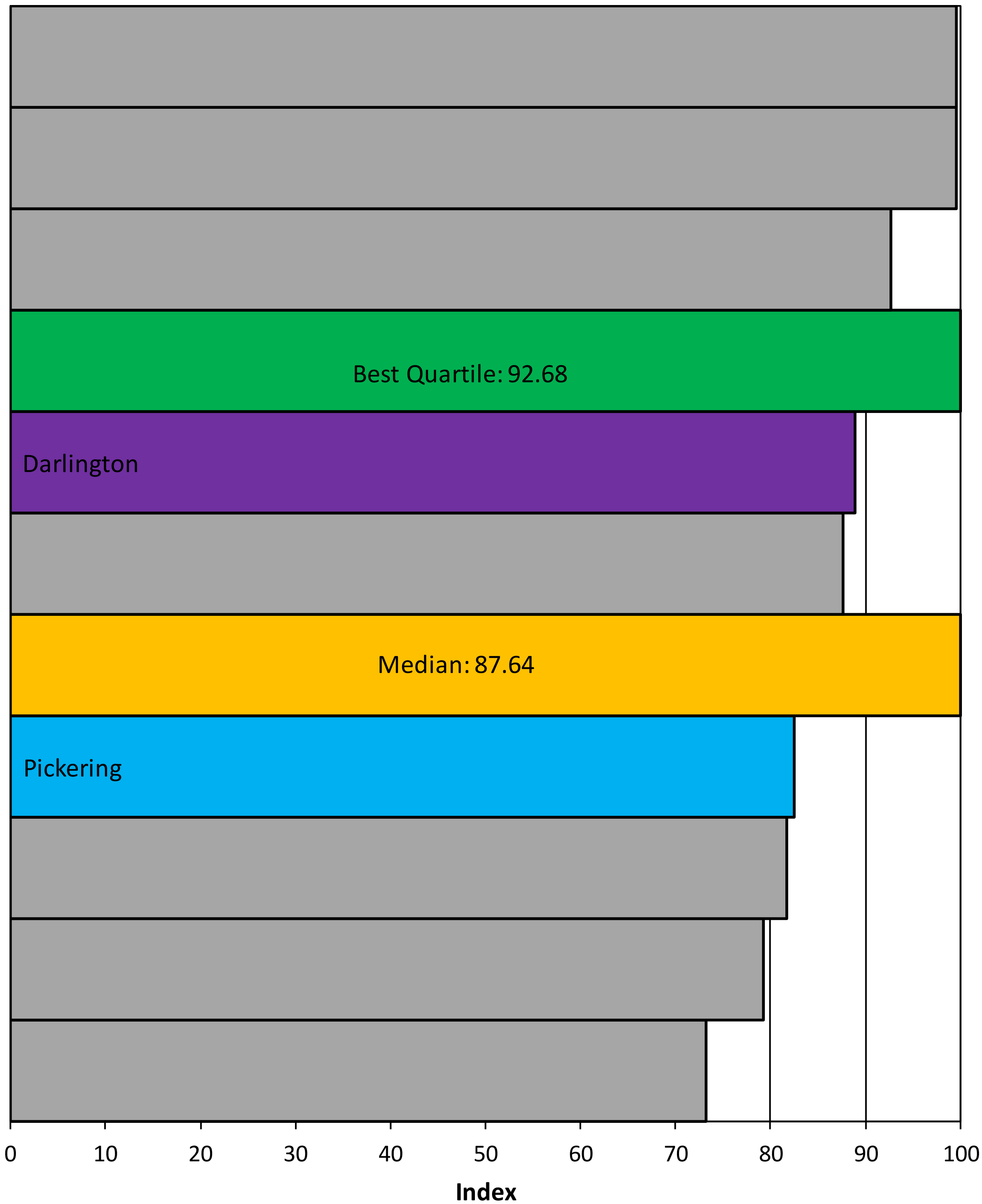
The primary metric within the reliability section is the WANO Nuclear Performance Index (NPI). A maximum score of 100 is possible. The WANO NPI is an operational performance indicator comprised of 10 metrics, three of which are analyzed in this section: Forced Loss Rate, Unit Capability Factor, and Chemistry Performance Indicator. The remainder of the WANO NPI components are analyzed in the safety section (Section 2.0).

WANO Nuclear Performance Index





2019 WANO Nuclear Performance Index
CANDU Plant Level Benchmarking



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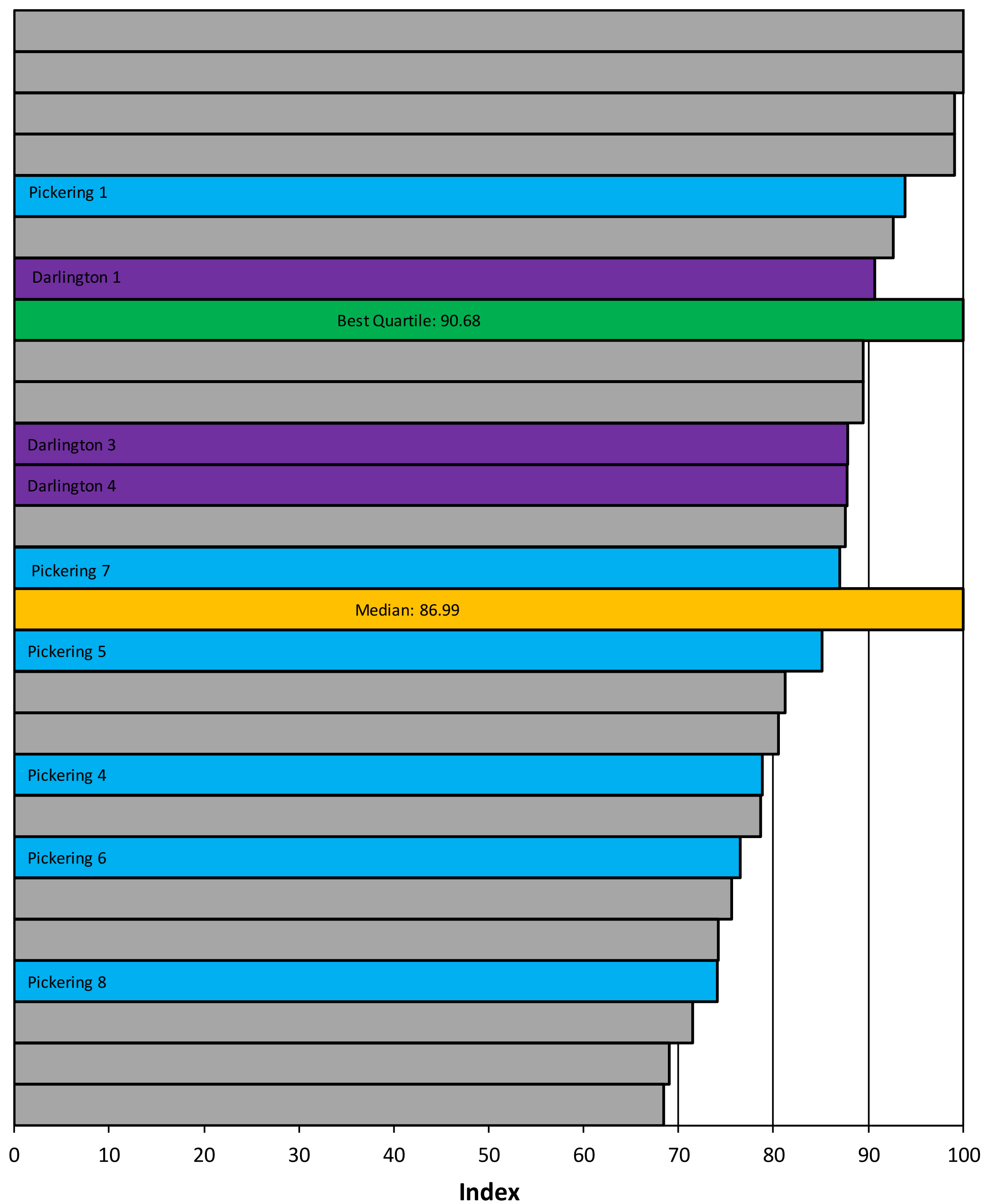
2019 WANO Nuclear Performance Index
CANDU Unit Level Benchmarking



Observations – WANO Nuclear Performance Index (NPI) (CANDU)

2019

- 2019 best quartile of the CANDU plant comparison panel for WANO NPI is 92.68, representing a 0.32 point decrease from 2018.
- 2019 median of the CANDU plant comparison is 87.64, a 3.1 point decrease from 2018.
- PNGS NPI at 82.5, improved by 7.6 points in comparison to 2018, and achieved its best ever NPI score as a combined six-unit station; however, it placed in third quartile.
- In 2019, PNGS improvement was driven by the achievement of maximum WANO NPI results or top quartile performance for all seven NPI sub-metrics under the Safety cornerstone.
- DNGS NPI at 88.9 decreased by 1.8 points in comparison to 2018, and placed in second quartile.
- In 2019, DNGS achieved maximum WANO Nuclear Performance Index (NPI) results or best quartile performance for six of the seven NPI sub-metrics under the Safety cornerstone and UCF.

Trend

- A significant positive trend was seen by PNGS NPI as it increased by 18 points from 2014 to 2019.
- DNGS' performance ranged from 82 to 90 points from 2014-2019.

Factors Contributing to Performance

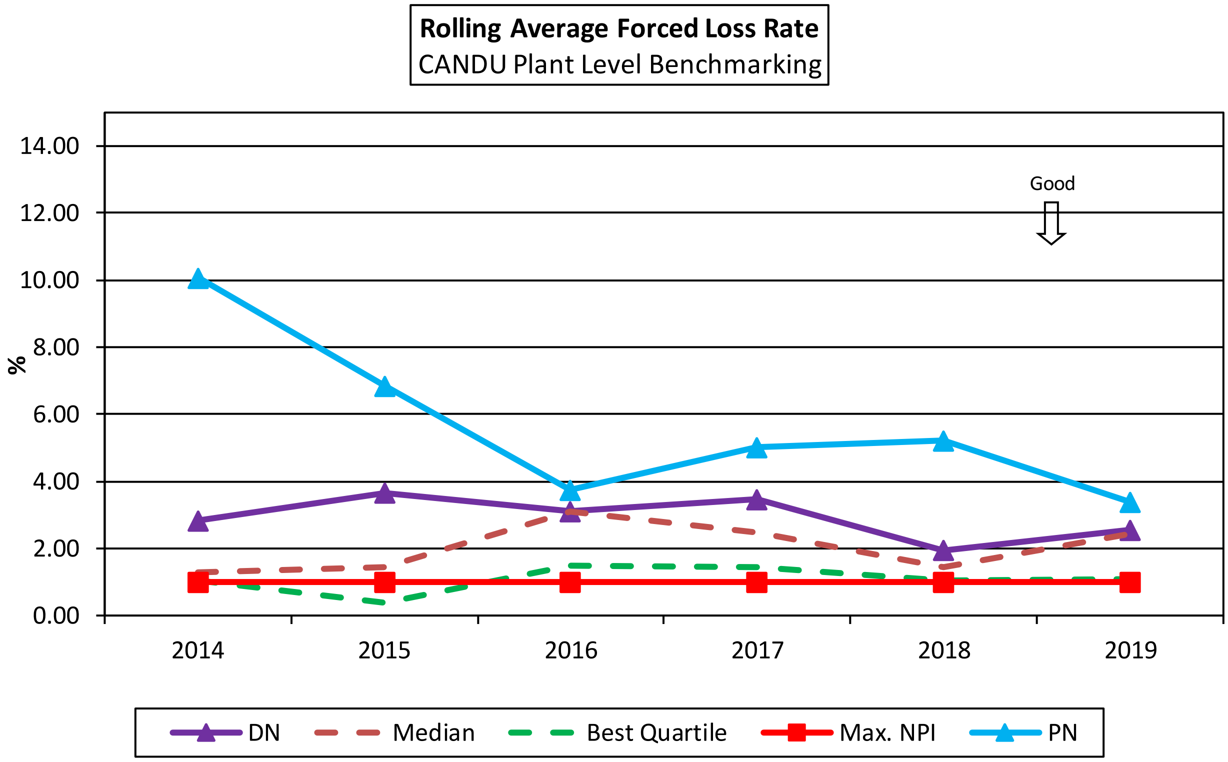
Pickering

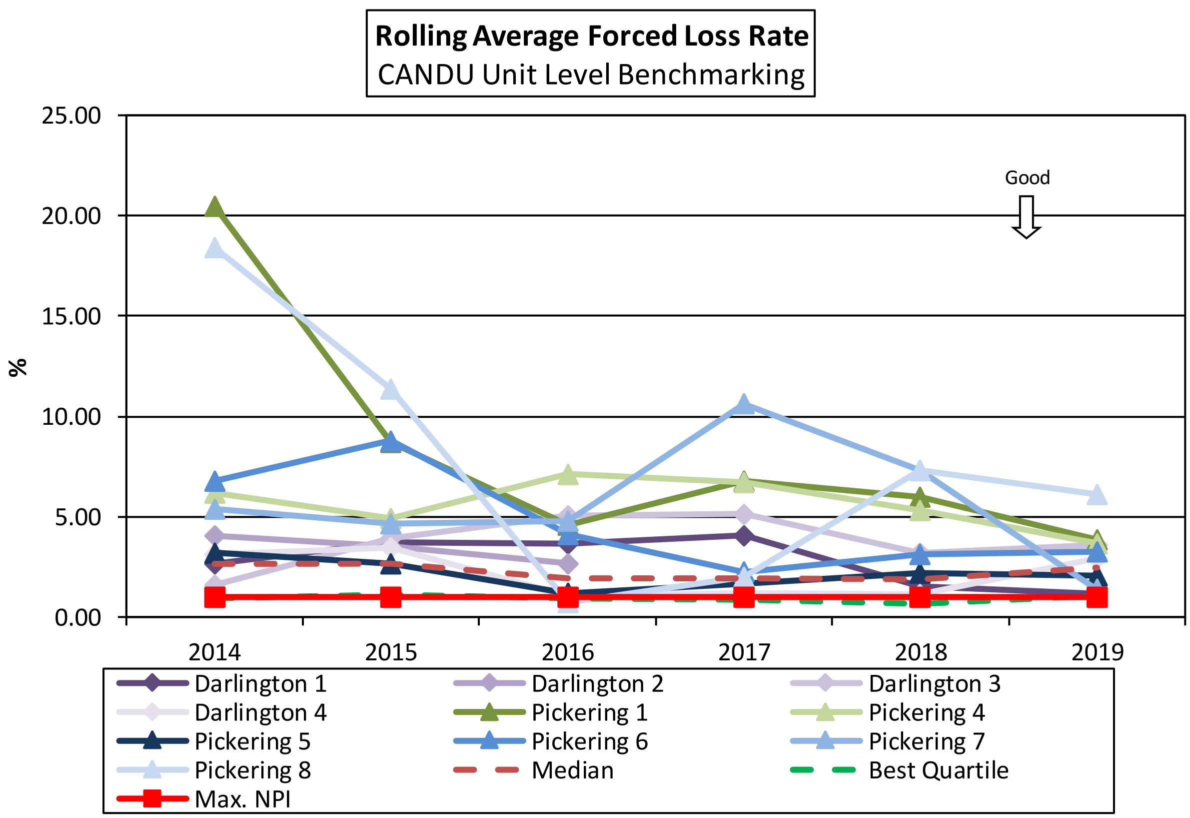
- While the lowest scores were attained for Unit Capability Factor and Forced Loss Rate, the most significant improvements were made for both of these metrics, particularly from 2018. These metrics are weighted the heaviest within the NPI calculation.
- Pickering's NPI performance is impacted by the need for long outages to accommodate fuel channel inspection programs, which impacts Unit Capability Factor and Collective Radiation Exposure metrics.

Darlington

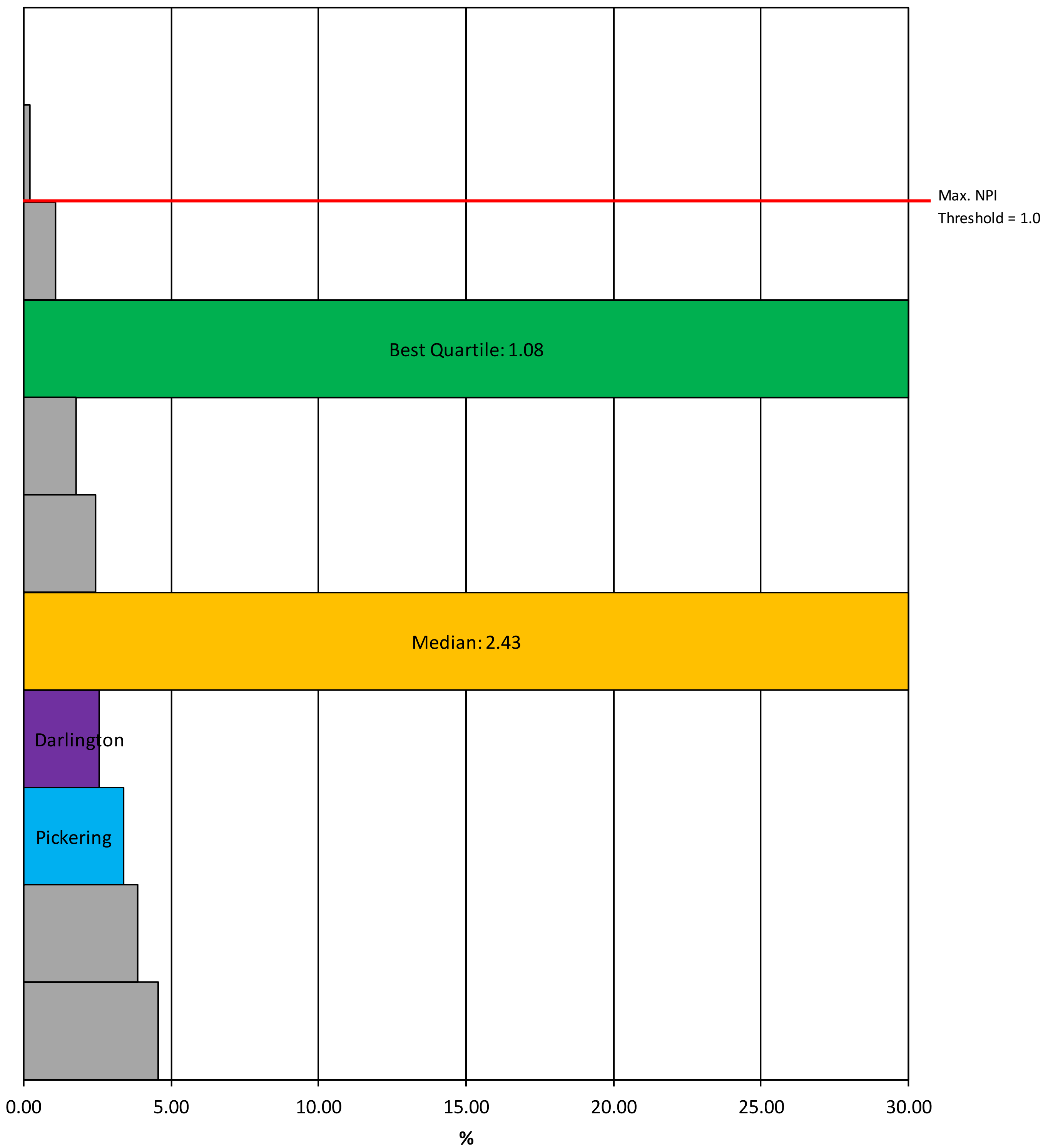
- Fluctuations in DNGS' year-over-year performance are attributed to:
    - 2015 - Vacuum Building Containment outage for planned regulatory maintenance.
    - 2016 Plant reliability improvements positively impacted both the FLR and UCF.
    - 2017 - Unbudgeted outages affecting Unit Capability Factor and FLR.
    - 2018 - Lower number of unbudgeted and forced outages.
    - 2019 – Forced outages caused by the Heat Transport and Secondary side leakages along with Fuel Handling bridge repairs. Actions have been taken to increase scope in future outages for the instrument line visual inspections to minimize heat transport system leaks to containment. A Fuel Handling Life Extension and Reliability plan is being implemented to facilitate commissioning of the most critical fuel handling scope and sustain favourable Forced Loss performance.

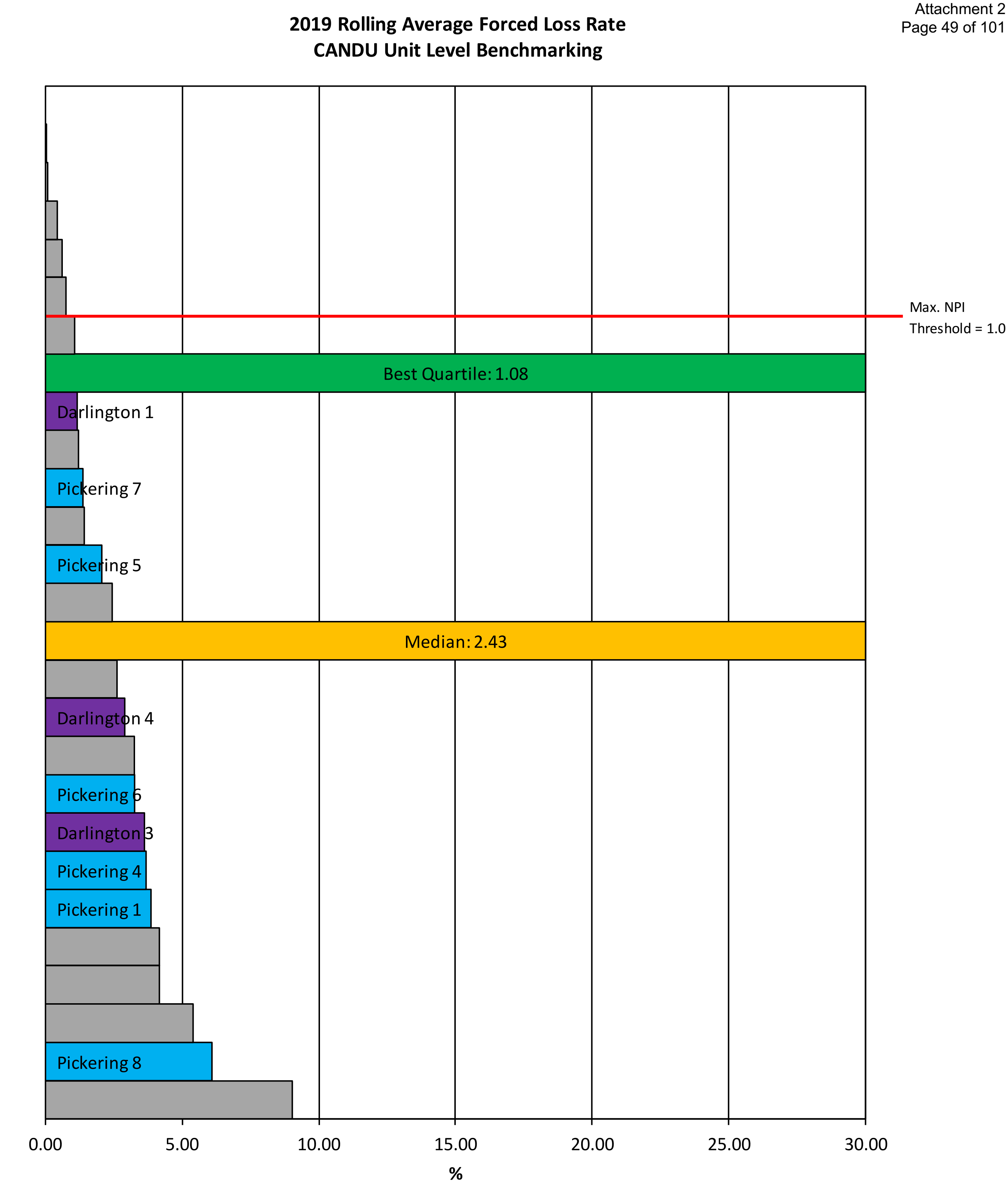
Rolling Average Forced Loss Rate





2019 Rolling Average Forced Loss Rate
CANDU Plant Level Benchmarking




2019 Rolling Average Forced Loss Rate
CANDU Unit Level Benchmarking
Max. NPI Threshold = 1.0
Best Quartile: 1.08
Darlington 1
Pickering 7
Pickering 5
Median: 2.43
Darlington 4
Pickering 6
Darlington 3
Pickering 4
Pickering 1
Pickering 8
0.00
5.00
10.00
15.00
20.00
25.00
30.00
%

Observations – Rolling Average Forced Loss Rate (CANDU)

2019 (Rolling 2 Year Average, Pickering %; Rolling 3 Year Average, Darlington %)

- The industry plant level best quartile was 1.08 and the industry median was 2.43.
- PNGS Forced Loss Rate (FLR) results showed an improvement in performance to third quartile, decreasing from 5.20 in 2018 to 3.39 in 2019, achieving its best ever FLR in the process, as a combined six-unit station.
- DNGS FLR performance went from 1.94 in 2018 to 2.56 in 2019 and maintained third quartile performance. Darlington Unit 2 began a long-term refurbishment outage on October 15, 2016 and has been excluded from benchmarking results.

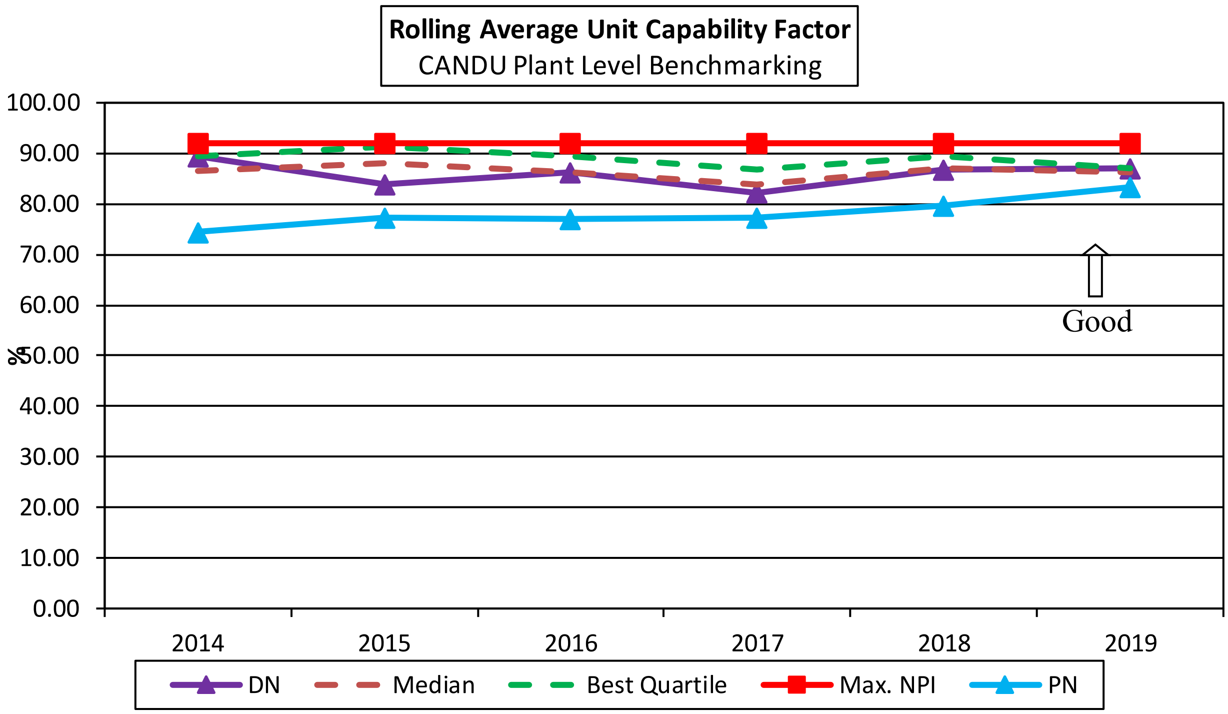
Trend

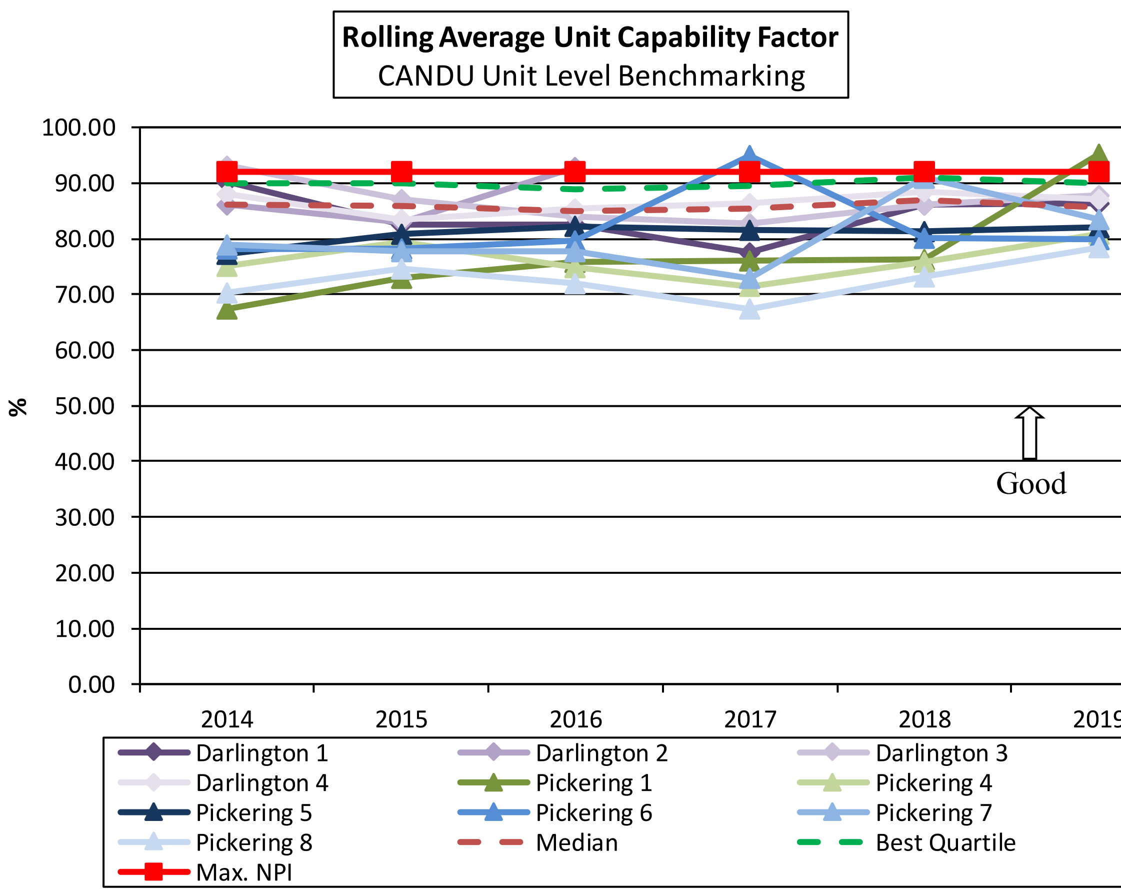
- Industry plant median FLR trend went up and experienced variability over the trend period.
- PNGS overall FLR trend has shown marked improvement year-over-year, from double digit values in 2014 to 3.39 in 2019, which is the lowest FLR for PNGS.
- DNGS overall trend shows an improvement from 2014 when it was 2.85 to 2.56 in 2019.

Factors Contributing to Performance

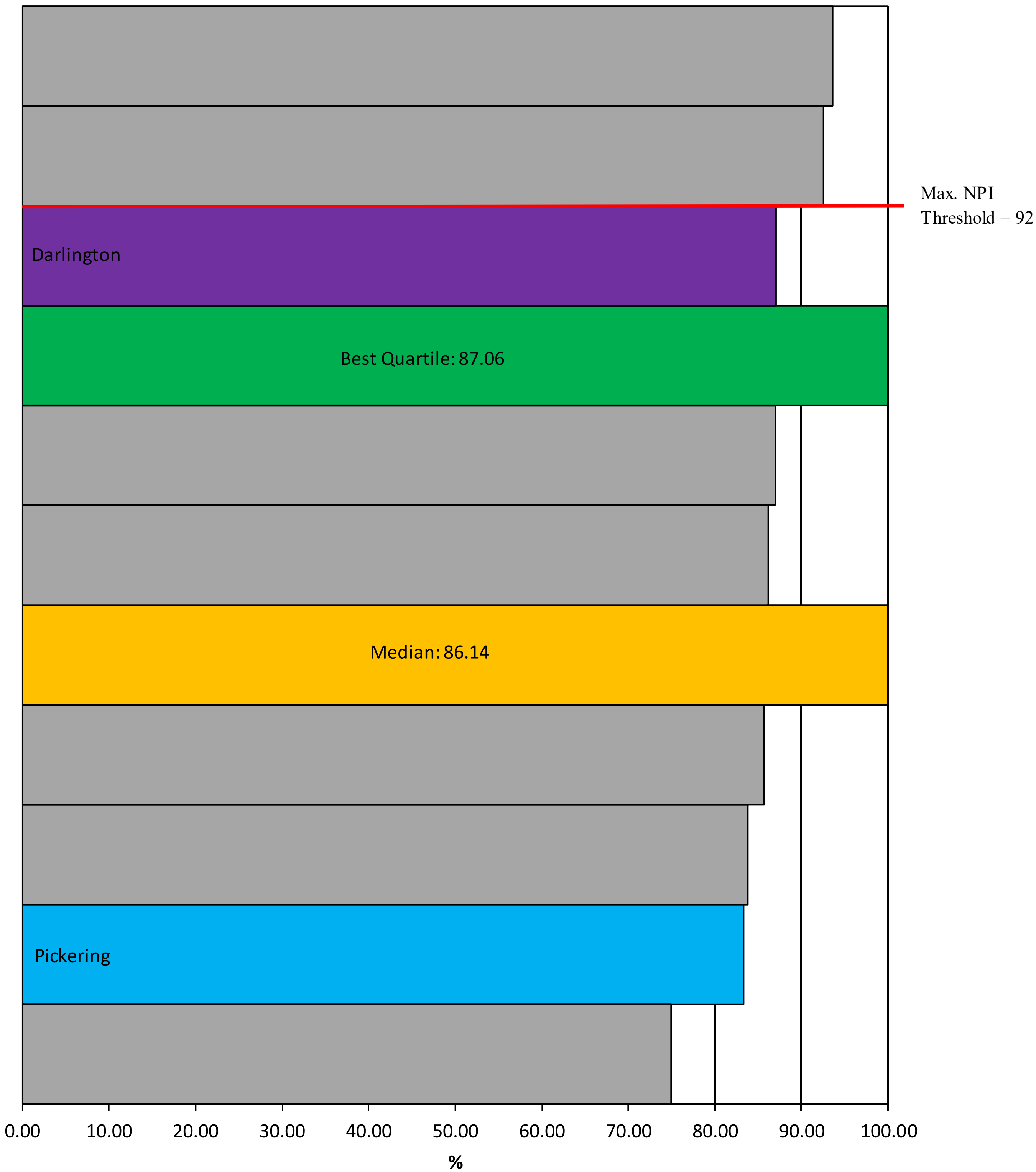
- PNGS and DNGS have seen significant reductions to frequency of forced outages by conducting the Preventative Maintenance program, through the implementation of Value Based Maintenance initiatives, which enables sites to complete the right work at the right time, improving equipment reliability.
- Both PNGS and DNGS continue to drive plant reliability via the system health improvement process and recovery actions. The Plant Reliability List of important work orders are implemented to improve system health.
- At PNGS, the 2019 causes for forced losses were varied, including:
  - Unit 1, dual Reactor Control System failure.
  - Unit 5, turbine trip on boiler high level.
  - Unit 6, spurious closure of all 4 governor valves caused boiler pressure error to initiate Steam Relief Valve opening.
- At DNGS, the 2019 causes for forced losses were varied, including:
  - Unit 3, heat transport system leak
  - Unit 3, cross shaft failure and fueling unavailability
  - Unit 4, leak & auxiliary lube pump.

Rolling Average Unit Capability Factor





2019 Rolling Average Unit Capability Factor
CANDU Plant Level Benchmarking



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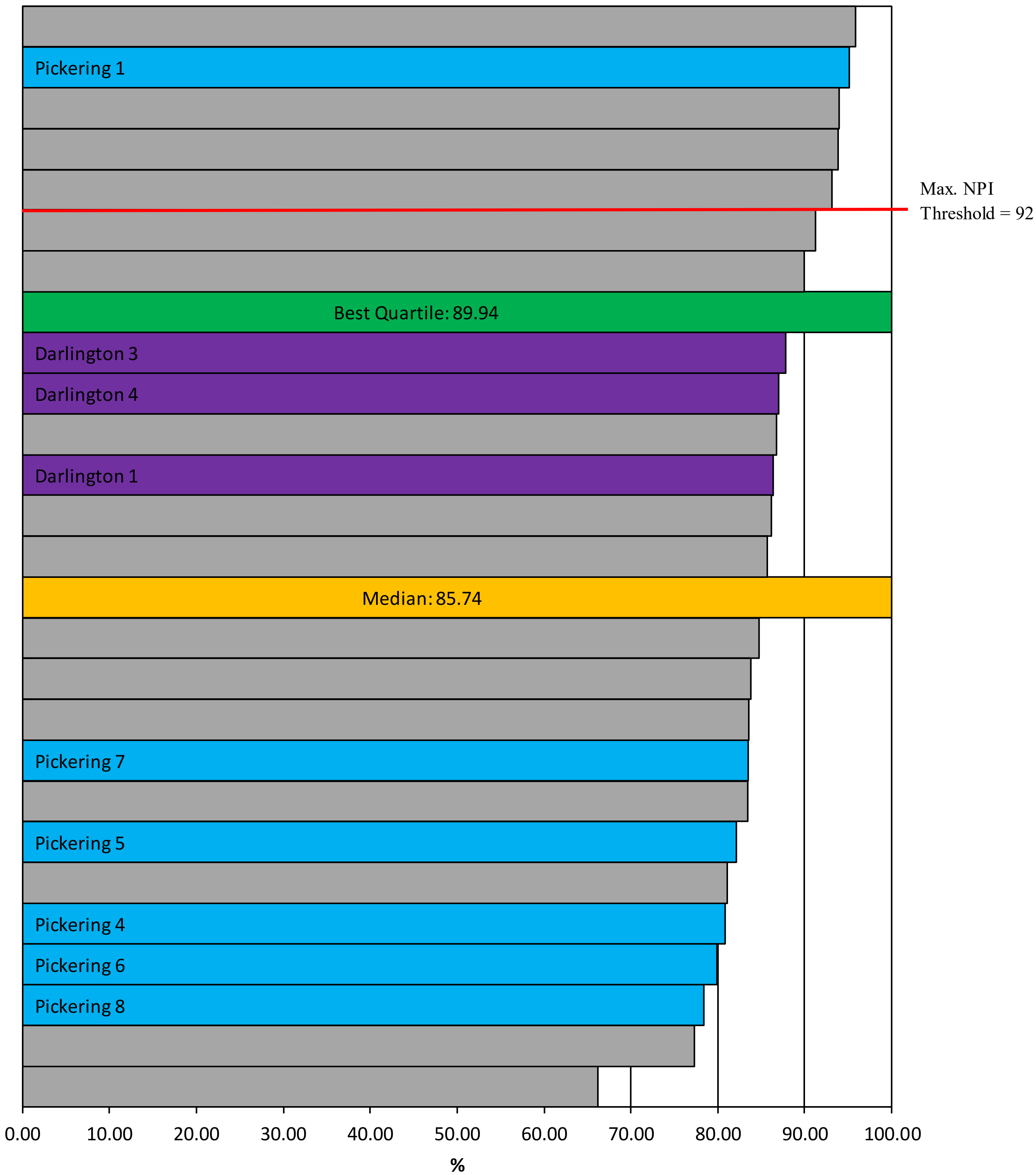
2019 Rolling Average Unit Capability Factor
CANDU Unit Level Benchmarking



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Observations – Rolling Average Unit Capability Factor (UCF) (CANDU)

2019 (Rolling 2 Year Average, Pickering %; Rolling 3 Year Average, Darlington %)

- The industry best quartile was 87.06 and the industry median was 86.14.
- PNGS UCF performance improved from 79.55 in 2018 to 83.31 in 2019, achieving its best ever performance as a combined six-unit station, while remaining in fourth quartile.
- DNGS UCF performance improved from 86.89 to 87.06, and advanced to the best quartile of CANDU plants.
- Darlington Unit 2 began a long-term refurbishment outage on October 15, 2016 and has been excluded from benchmarking results.

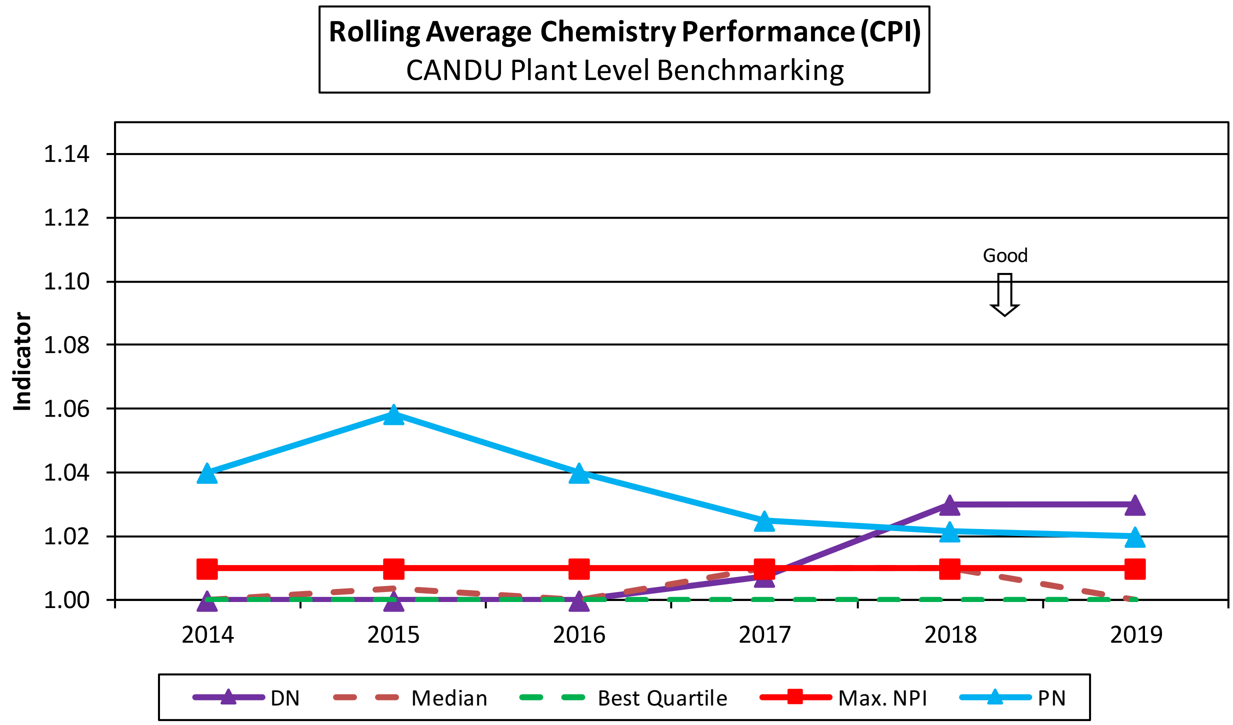
Trend

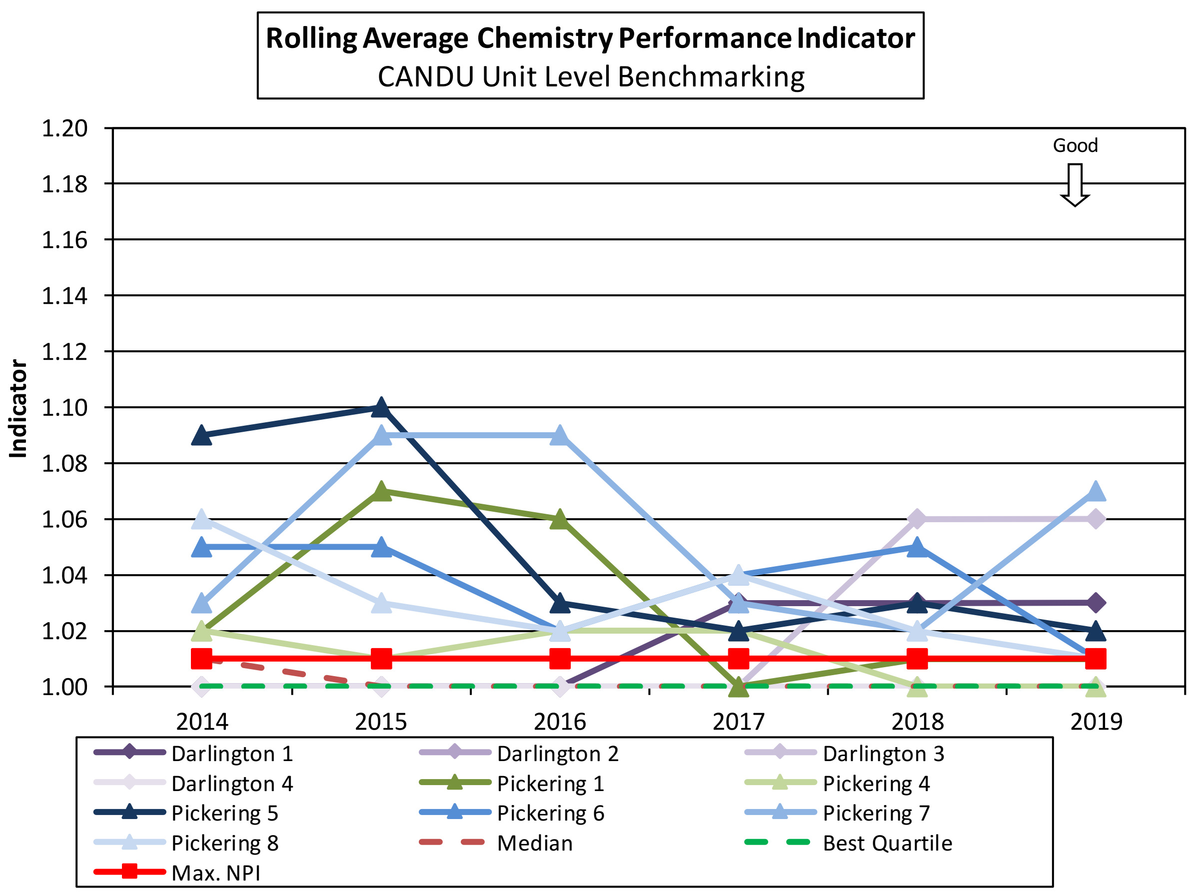
- PNGS UCF trended favourably, increasing year over year for the past 4 years, with 2019 as the highest value. The overall trend of Pickering's UCF demonstrates continuous improvement.
- DNGS overall trend shows variability over the review period, with consistent improvements from 2017 to 2019.
- Plant median and best quartile UCF benchmarks have also shown variability and both decreased in 2019.

Factors Contributing to Performance

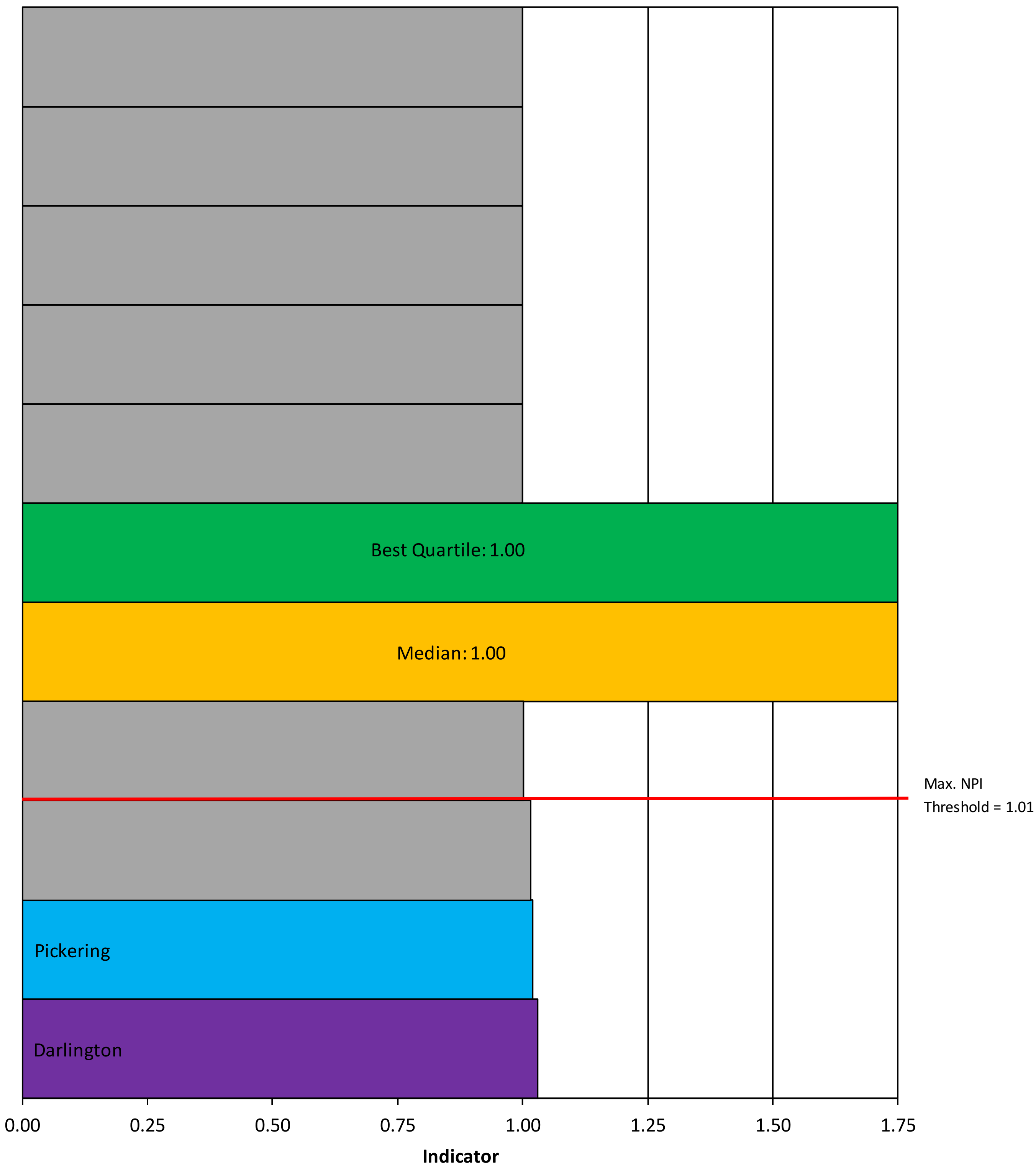
- Higher number of planned outage days contribute to lower UCF values when compared to CANDU peers, even though all 2019 planned outages were completed safely and ahead of schedule.
- The higher UCF at PNGS in 2019 compared to 2018 reflected fewer planned outage days in line with the station's cyclical maintenance schedule, the favourable execution of planned outage work, and fewer unplanned outage days.
- UCF performance at DNGS in 2019 improved compared to 2018, and the increase in the number of unplanned outage days was largely offset by fewer planned outage days due to the favourable execution of planned outage work.
- FLR performance challenges negatively impact UCF.
- Improvements in equipment reliability have correlated with improved FLR and UCF performance.

Rolling Average Chemistry Performance Indicator





2019 Rolling Average Chemistry Performance Indicator
CANDU Plant Level Benchmarking



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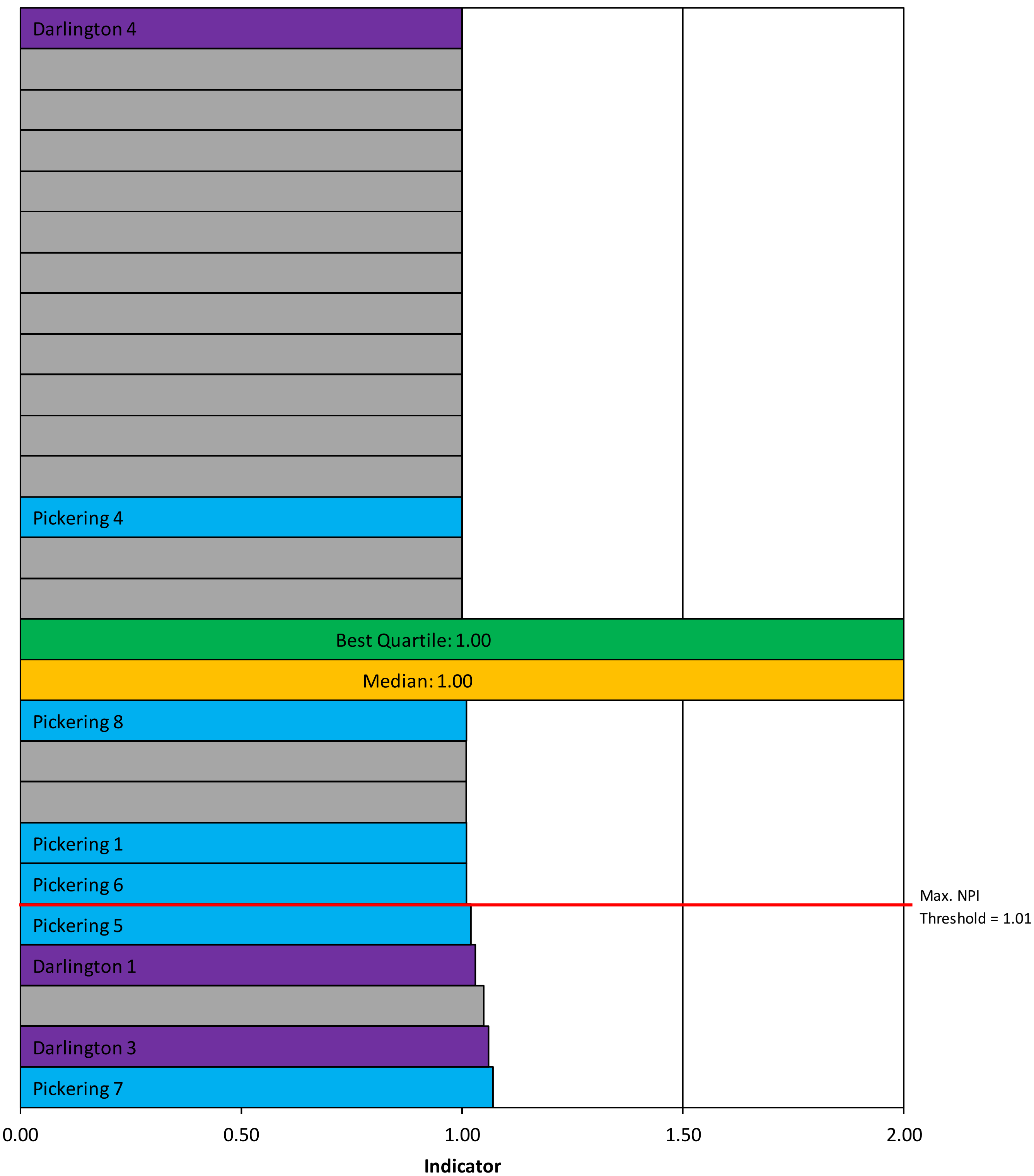
2019 Rolling Average Chemistry Performance Indicator
CANDU Unit Level Benchmarking



Observations – Rolling Average Chemistry Performance Indicator (CANDU)

2019 (Rolling 2 Year Average Pickering, Rolling 3 Year Average Darlington)

- The CANDU plant median and best quartile values are both 1.00.
- PNGS CPI performance has remained unchanged from 2018 at 1.02.
- DNGS CPI performance has remained unchanged from 2018 at 1.03.

Trend

- Overall industry performance has remained stable, with the best quartile holding at 1.00 over the last five years.
- The overall performance trend for PNGS has been positive over the last 5 years, with CPI performance improving year-over-year from 1.06 and to 1.02.
- DNGS has exhibited a declining trend in the last three years, increasing from a CPI of 1.00 to the current CPI value of 1.03.

Factors Contributing to Performance

- In 2019, challenges were experienced with boiler chemistry start-up on Pickering Unit 5.
- In 2019, Pickering experienced high sodium levels following outage start-up on Unit 7 and elevated chloride levels on Units 5 and 8 due to ingress from the Water Treatment Plant.
- The 2019 performance at Darlington can be attributed to Unit 3 condenser tube leaks, which caused an increase in boiler conductivity and feedwater iron levels during start-ups following the unit outages. As the CPI is a 3-year rolling average, the event from 2018 continues to impact 2019 performance.
- Work practices that are being implemented to improve performance include:
    - Development of component cleanliness requirements.
    - Improvements in condenser tube leak detection at Darlington.
    - Chemistry data trending review meetings to share operating experience, lessons learned, and improvement plans.

- **Chemistry initiatives to further improve CPI to best quartile:**
    - Procurement of filtration skid to mitigate corrosions products following restart from Refurbishment.

    - Implementing new innovations for improved chemistry control, reliability and safety, including:
        - Hydrazine-in-air scrubber use / new PPE for hydrazine vapour hazards at Pickering;
        - Hydrazine neutralization agent feasibility assessments at Pickering;
        - Film Forming Amine at Darlington (first successful application on Darlington Unit 3 in March 2020); and
        - EPRI Smart Chemistry online analyzer application at Darlington.

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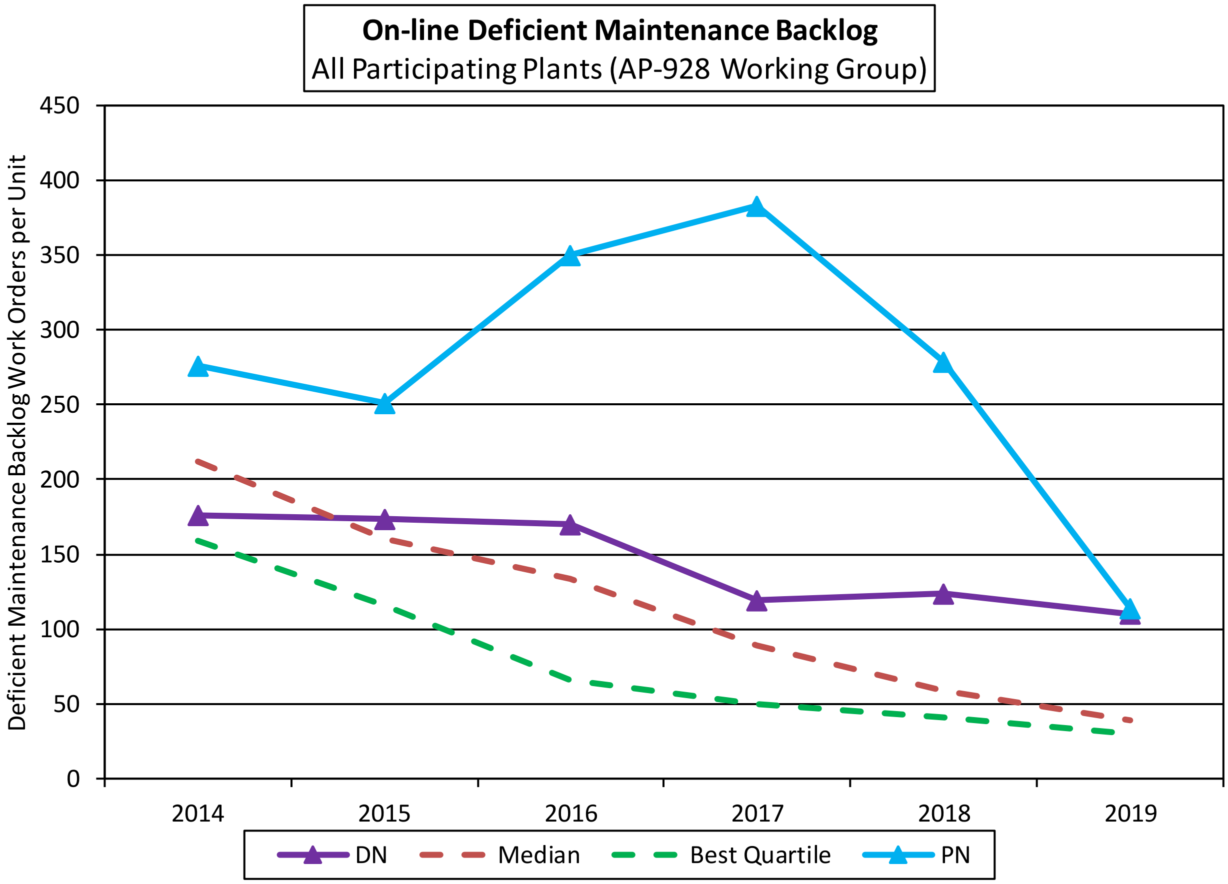
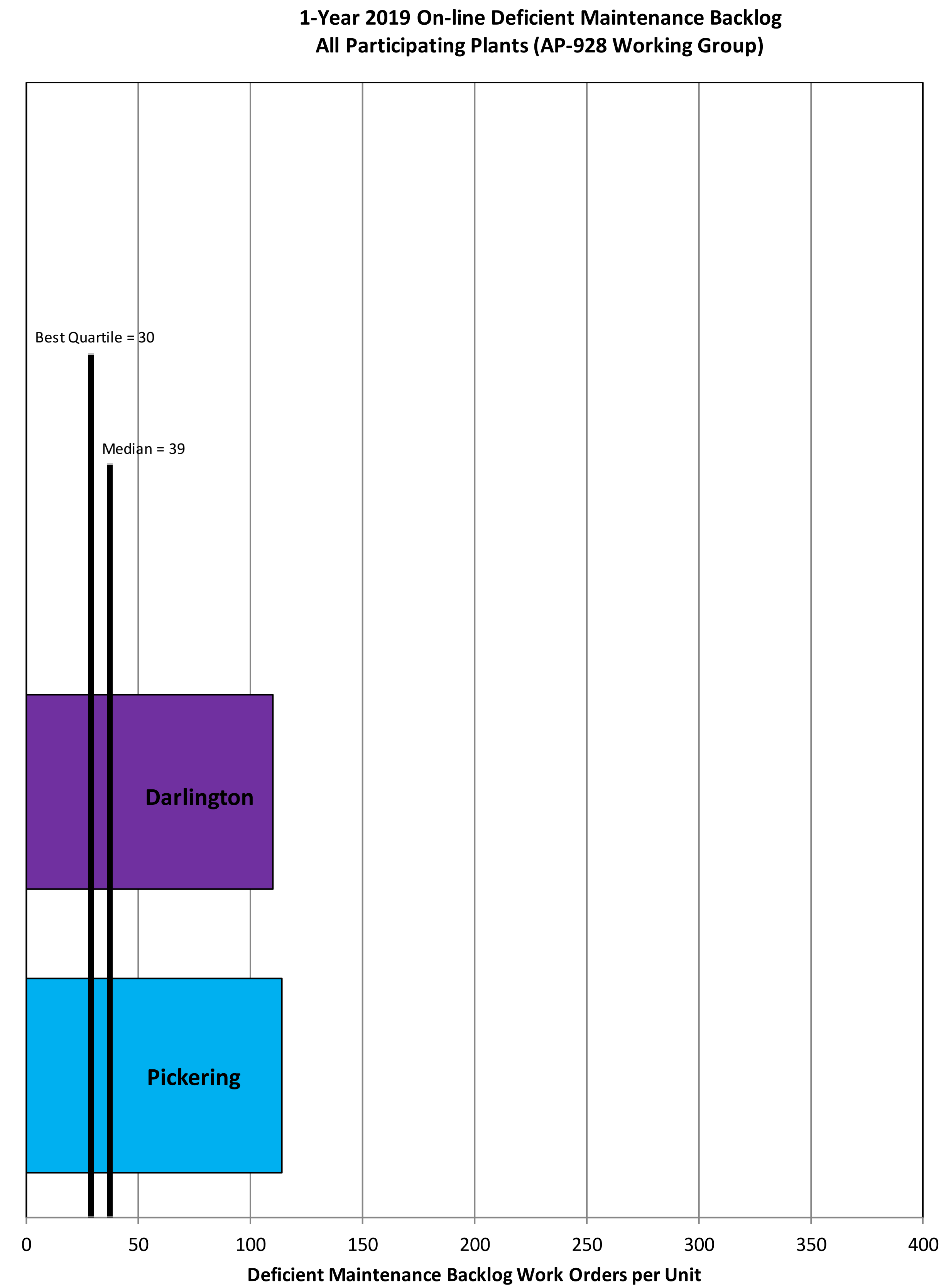
On-Line Deficient Maintenance Backlog




1-Year 2019 On-line Deficient Maintenance Backlog
All Participating Plants (AP-928 Working Group)
Best Quartile = 30
Median = 39
Darlington
Pickering
0
50
100
150
200
250
300
350
400
Deficient Maintenance Backlog Work Orders per Unit

Observations – On-Line Deficient Maintenance Backlog (AP-928 Working Group)

2019 (Annual Value)

- The industry Best Quartile and Median Thresholds were 30 and 39 work orders/unit, respectively for On-Line Deficient Maintenance (DM) backlog.
- Darlington DM backlogs were at 110 work orders/unit and Deficient Critical (DC) backlogs were at 3 work orders/unit.
- Pickering DM backlogs were at 114 work orders/ unit and DC backlogs were at 5 work orders/unit.

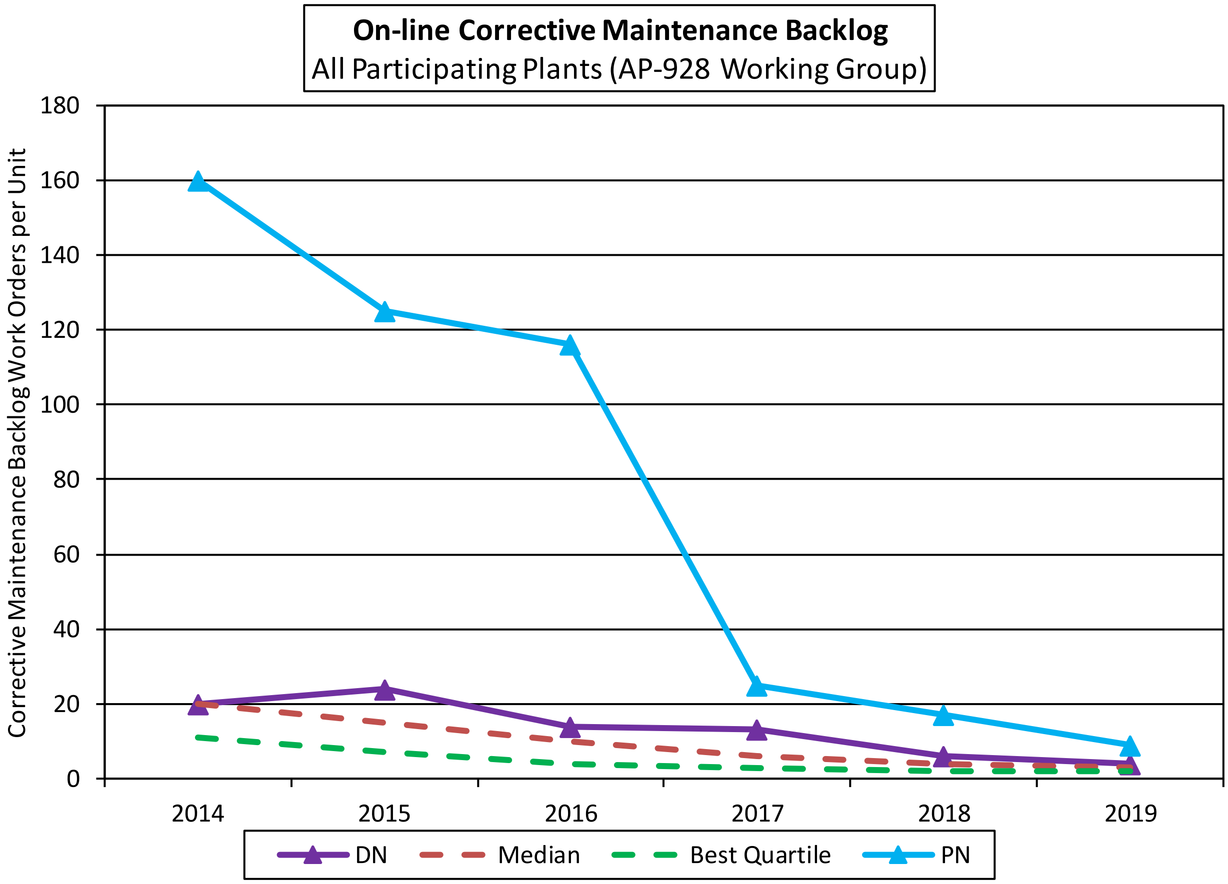
Trend

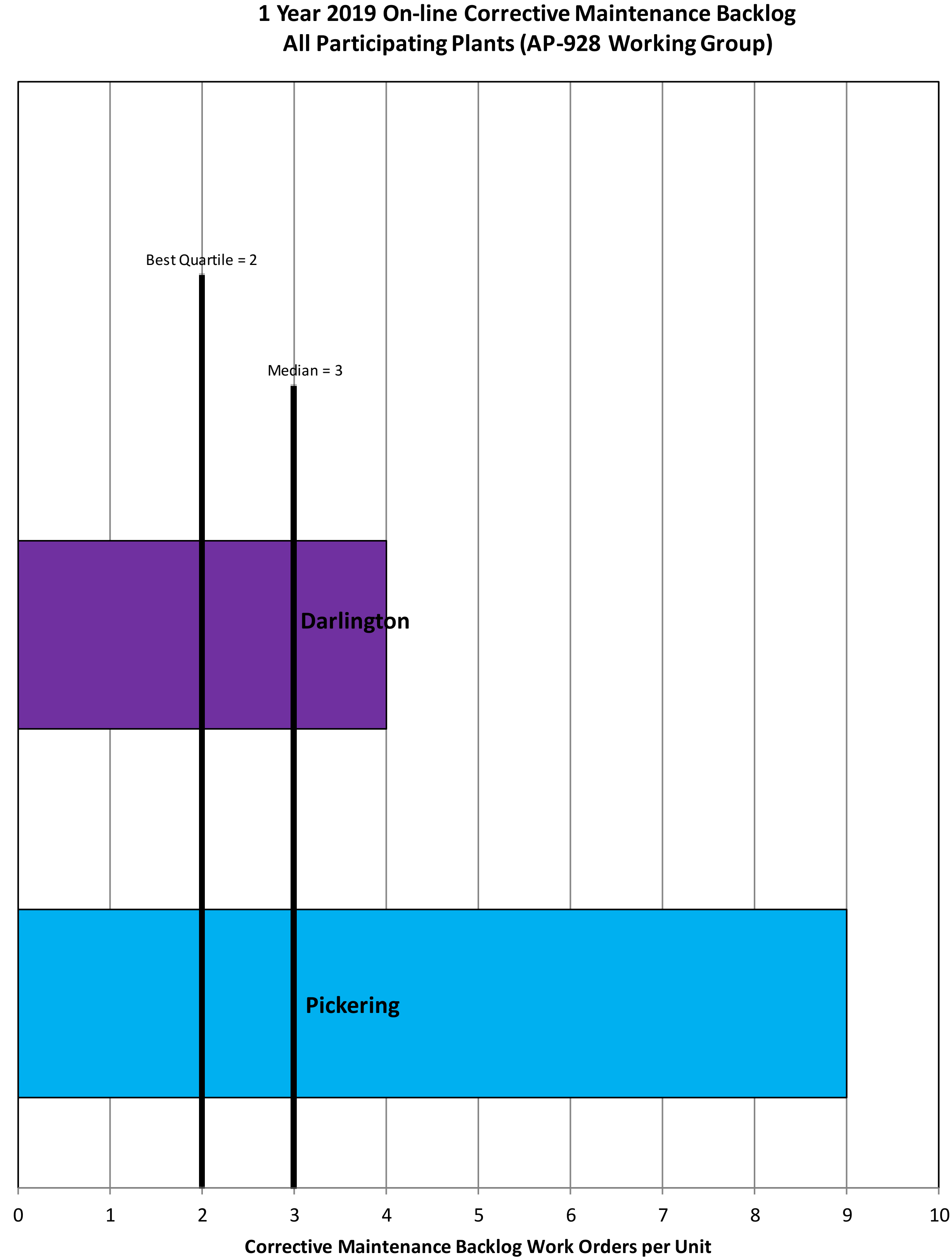
- Both DNGS and PNGS exhibited backlog improvements in the last year and over the trend period.
- In comparison to the 2018 data:
    - Darlington DM performance in 2019 improved from 124 to 110 work orders/unit.
        - Darlington DC performance improved from 9 to 3 work orders/unit.
    - Pickering DM performance in 2019 improved significantly from 279 to 114 work orders/unit and showed significant improvement since 2017.
        - Pickering DC performance improved from 9 to 5 work orders/unit.
    - Median backlog improved from 59 to 39 work orders/unit.

Factors Contributing to Performance

- At PNGS and DNGS, the focus continues on the reduction of on-line deficient critical backlogs, which has resulted in the improvement of critical DC backlogs for both sites.
- To improve performance, initiatives focus on:
    - Efficiencies and Optimizing existing maintenance resources.
    - Value Based Maintenance:
        - Move to a condition based maintenance program versus time based to better leverage resources and increase efficiencies.
        - Leverage technology to support value based and condition based maintenance strategies.

On-Line Corrective Maintenance Backlog




1 Year 2019 On-line Corrective Maintenance Backlog
All Participating Plants (AP-928 Working Group)
Best Quartile = 2
Median = 3
Darlington
Pickering
0
1
2
3
4
5
6
7
8
9
10
Corrective Maintenance Backlog Work Orders per Unit

Observations – On-Line Corrective Maintenance Backlog (AP-928 Working Group)

2019 (Annual Value)

- The industry Best Quartile and Median Thresholds were 2 and 3 work orders/unit respectively for On-Line Corrective Maintenance (CM) backlog.
  - Darlington CM backlogs were at 4 work orders/ unit and corrective critical backlogs were at 0.3 work order/unit.
  - Pickering CM backlogs were at 9 work orders/unit and corrective critical backlogs were at 0.5 work orders/unit.

Trend

- In comparison to the 2018 data:
  - Darlington performance in 2019 has improved from 6 to 4 work orders/unit.
  - Pickering performance in 2019 improved from 17 to 9 work orders/ unit.
  - Median backlog improved from 4 to 3 work orders per unit.

- Darlington has shown backlog improvement from 2014 through 2019.
- Pickering has shown significant backlog improvement in each of the last five years.

Factors Contributing to Performance

- At the end of 2019, PNGS On-line Corrective Critical Backlog declined to fourth quartile due to the standby generator and fuelling machine repair work orders, which were completed in January of 2020. Priority is placed on corrective critical backlogs and equipment is restored as expeditiously as possible.
- To improve performance, initiatives focus on:
  - Efficiencies and Optimizing existing maintenance resources.
  - Value Based Maintenance:
    - Move to a condition based maintenance program versus time based to better leverage resources and increase efficiencies.
    - Leverage technology to support value based and condition based maintenance strategies.

4.0 VALUE FOR MONEY

Methodology and Sources of Data

The Electric Utility Cost Group (EUCG) database is the source for cost benchmarking data. Data was collected for three-year rolling averages for all financial metrics covering the period from 2014-2019. All data submitted to and subsequently extracted from EUCG by OPG is presented in Canadian dollars.

EUCG automatically applies a purchasing power parity (PPP) factor to adjust all values across national borders. The primary function of the PPP value is to adjust for currency exchange rate fluctuations but it also adjusts for additional cross-border factors, which may impact purchasing power of companies in different jurisdictions. As a result, cost variations between plants are limited, as much as possible, to real differences and not due to advantages of utilizing one currency over another.

The benchmarking panel utilized for value for money metrics is made up of all North American plants reporting to EUCG. Bruce Power is the only other CANDU technology plant reporting within that panel. The remaining plants are Boiling Water Reactors or Pressurized Water Reactors. For that reason, some of the gaps in performance are associated with technology differences rather than comparable performance. As a result, beginning with 2017 results, Pickering and Darlington's TGC/MWh and TGC/Unit performance has been normalized for CANDU technology (including outage duration) and age-related impacts.

Darlington's TGC/MWh, TGC/Unit, Non Fuel Operating Costs (NFOC)/MWh and Capital Cost/MW DER performance have also been normalized for refurbishment. The refurbishment normalization methodology allows OPG to adjust the distribution of actual operating and capital costs to reflect Darlington's number of operating units rather than a four-unit site. OPG is performing a mid-life refurbishment at Darlington, which involves bringing units offline for the replacement of certain life-limiting components. It is necessary to normalize these metrics during refurbishment to allow for comparisons to prior site performance and industry peers, given reduced generation and no corresponding decline in fixed costs.

OPG engaged ScottMadden Management Consultants (ScottMadden) to develop the normalization methodologies[4]. The combined normalization allows for a more comparable assessment of performance between peers.

The relationship underlying certain value for money metrics is shown in the illustration below.

Total Generating Cost per MWh is the sum of Non-Fuel Operating Cost (NFOC), Fuel Cost and Capital Cost measured on a per MWh basis for benchmarking purposes.

[4] Two ScottMadden normalization reports provide details on the normalization methodologies: 1) *OPG Nuclear Cost Performance Benchmarking A Study of Factors Impacting TGC/MWh Performance with Normalizing Adjustments to Facilitate Closer Comparison* and 2) *OPG Nuclear Cost Performance Benchmarking Methodology to Adjust for Refurbishment and Validation of Implementation*

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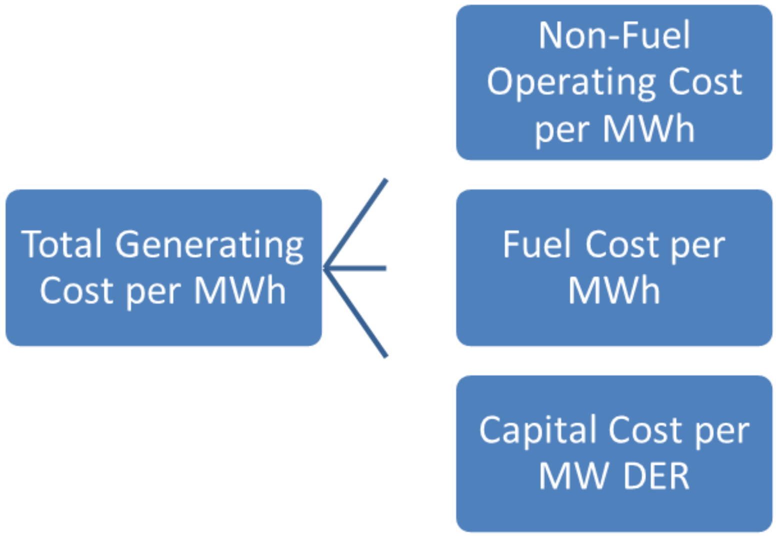
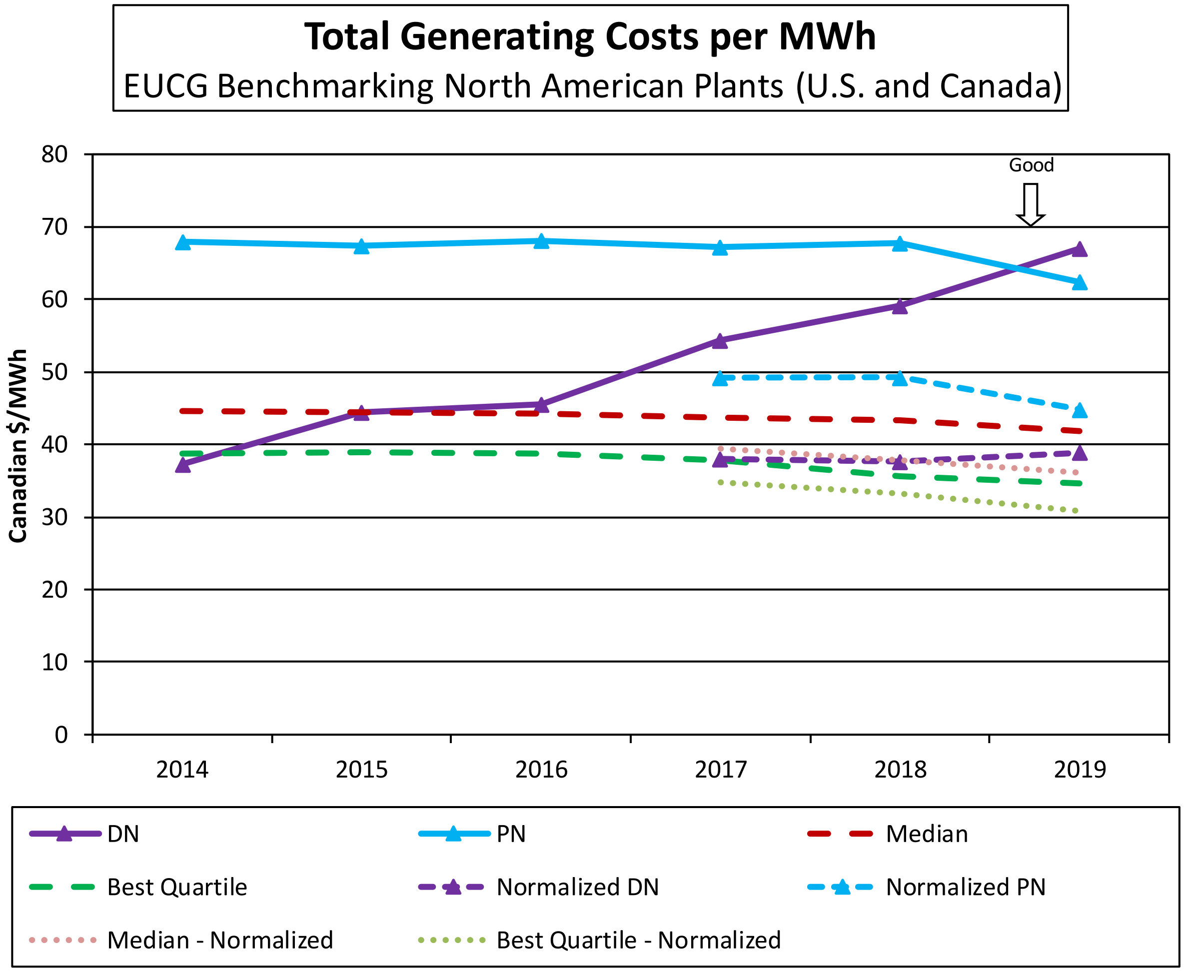
Given the differences between OPG's nuclear generating stations and most North American plants with respect to non-fuel, fuel and capital costs, it is difficult to compare plants by using non-fuel operating cost, fuel cost or capital cost metrics separately.

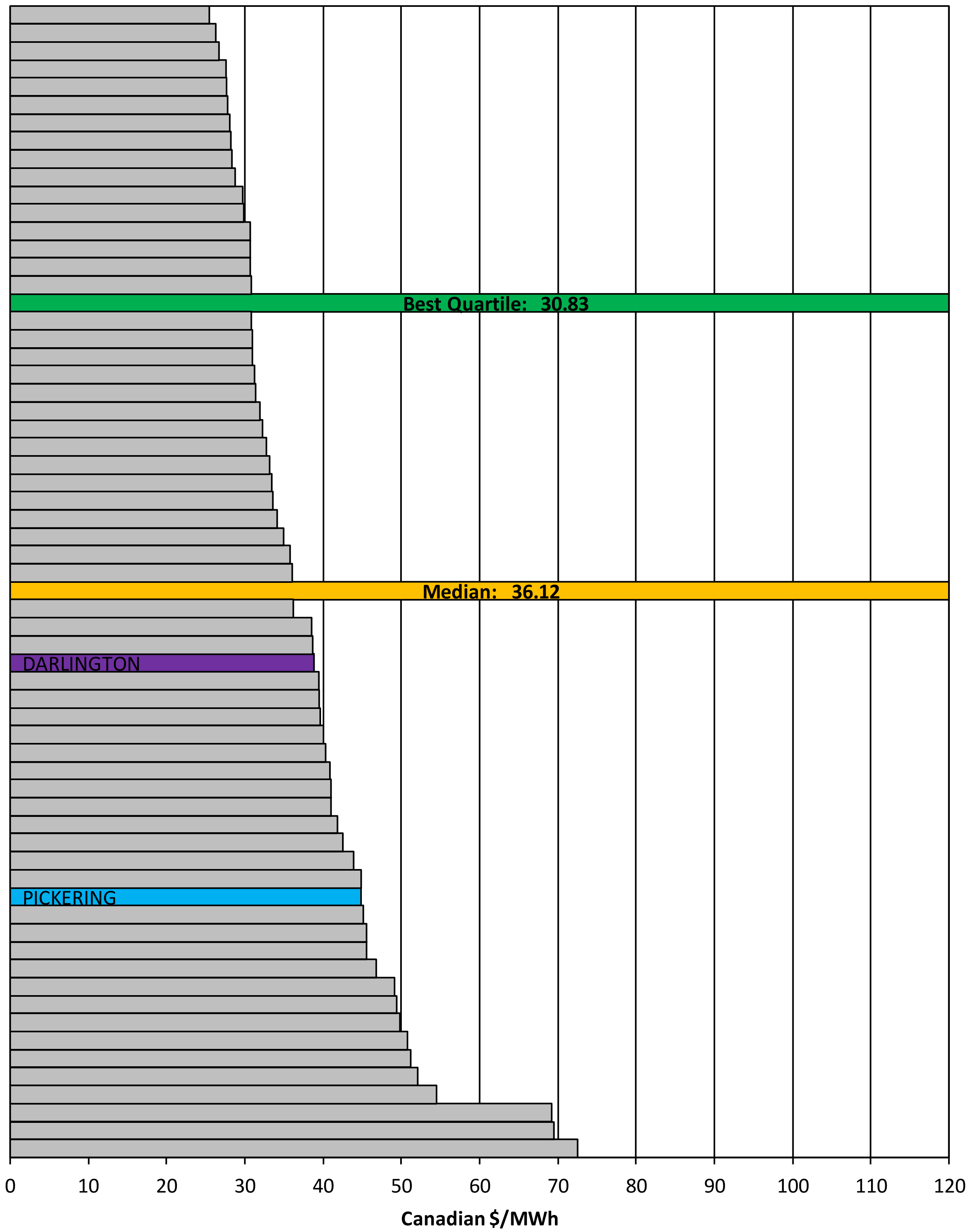
Summary Relationship of Value for Money Metrics



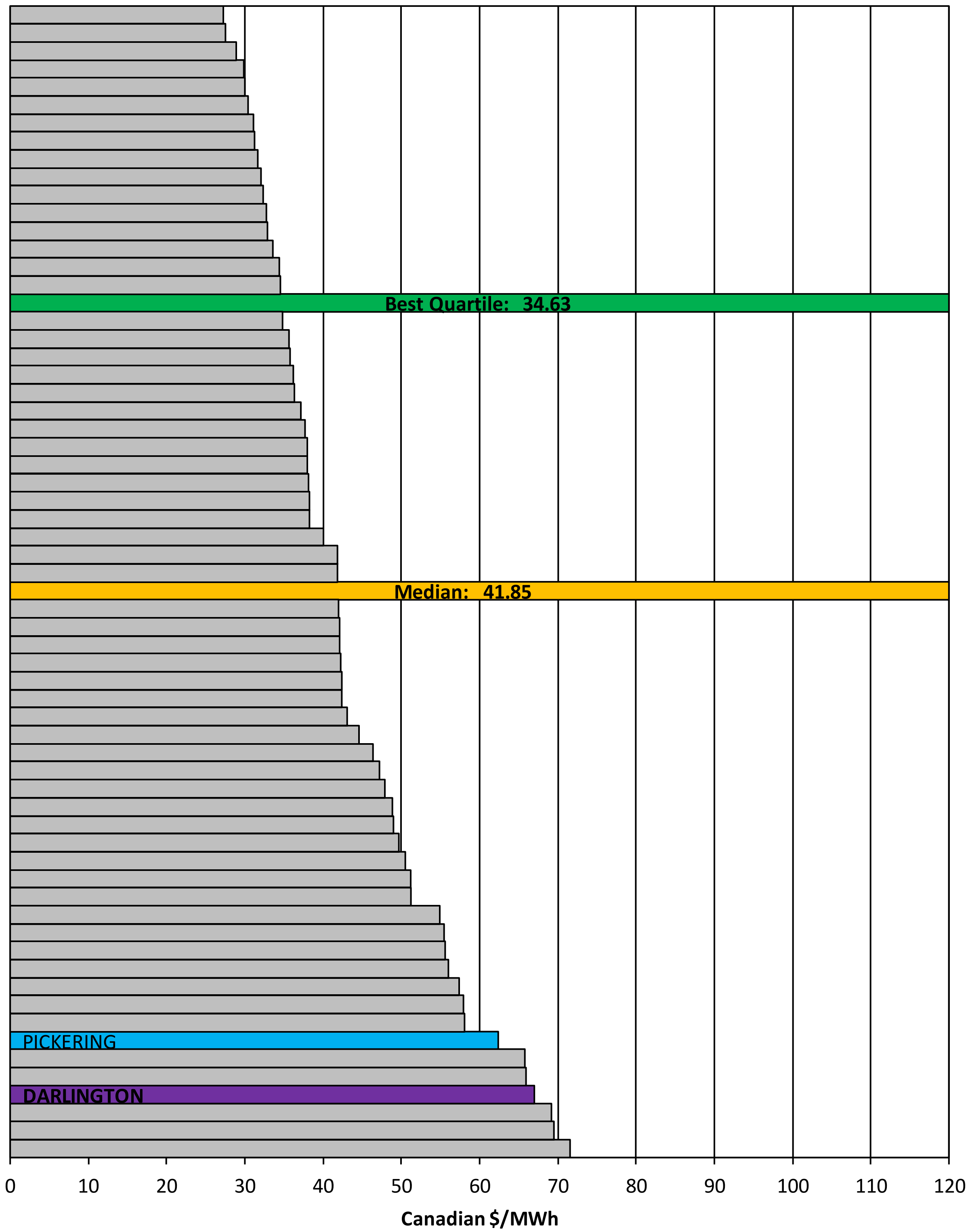
3-Year Total Generating Cost per MWh



2019 Normalized 3-Year Total Generating Costs per MWh
EUCG Benchmarking North American Plants (U.S. and Canada)



2019 Non-Normalized 3-Year Total Generating Costs per MWh
EUCG Benchmarking North American Plants (U.S. and Canada)



Observations – 3-Year Total Generating Cost per MWh (All North American Plants)

2019 (3-Year Rolling Average)

- Best quartile level for normalized Total Generating Cost/MWh (TGC/MWh) was $30.83 (non-normalized $34.63/MWh) while the normalized median level was $36.12 (non-normalized $41.85/MWh).
- DNGS normalized result– achieved 3rd Quartile: $38.84/MWh (non-normalized $67.00/MWh).
- PNGS normalized – achieved 4th Quartile: $44.85/MWh (non-normalized $62.39/MWh).

Trend

- Since 2017, the normalized[1] best quartile cost decreased, reflecting a $3.95/MWh improvement, (non-normalized improved by $3.15/MWh for the same time period and by $4.07/MWh since 2014).
- The normalized median cost also decreased since 2017, showing an improvement of $3.30/MWh (non-normalized improved by $1.81/MWh for the same time period and by $2.76/MWh since 2014).
- DNGS normalized TGC/MWh increased by $0.90/MWh since 2017 (non-normalized increased by $12.60/MWh and by $29.72/MWh since 2014).
- PNGS normalized TGC/MWh performance was essentially the same in 2017 and 2018, with a marked improvement in 2019. Since 2017, the favourable trend shows a reduction of $4.42/MWh (non-normalized improved by $4.83/MWh for the same time period and by $5.61/MWh since 2014).
- Best and median normalized quartile levels had a decreasing Compound Annual Growth Rate (CAGR) of -2.38% and -1.73% respectively. Darlington's normalized CAGR increased over the review period by 0.47% (non-normalized increased by 12.44%). Pickering normalized had a decreasing CAGR over the review period of -1.86% (non-normalized had a decreasing rate of -1.71%).

Factors Contributing to Performance

- DNGS changes from 2019 to 2018 included lower generation due to the refurbishment activities (in 2017-2019 compared to 2016-2018) and increased capital investment from 2016 - 2019 that will serve the station in its life post-refurbishment.

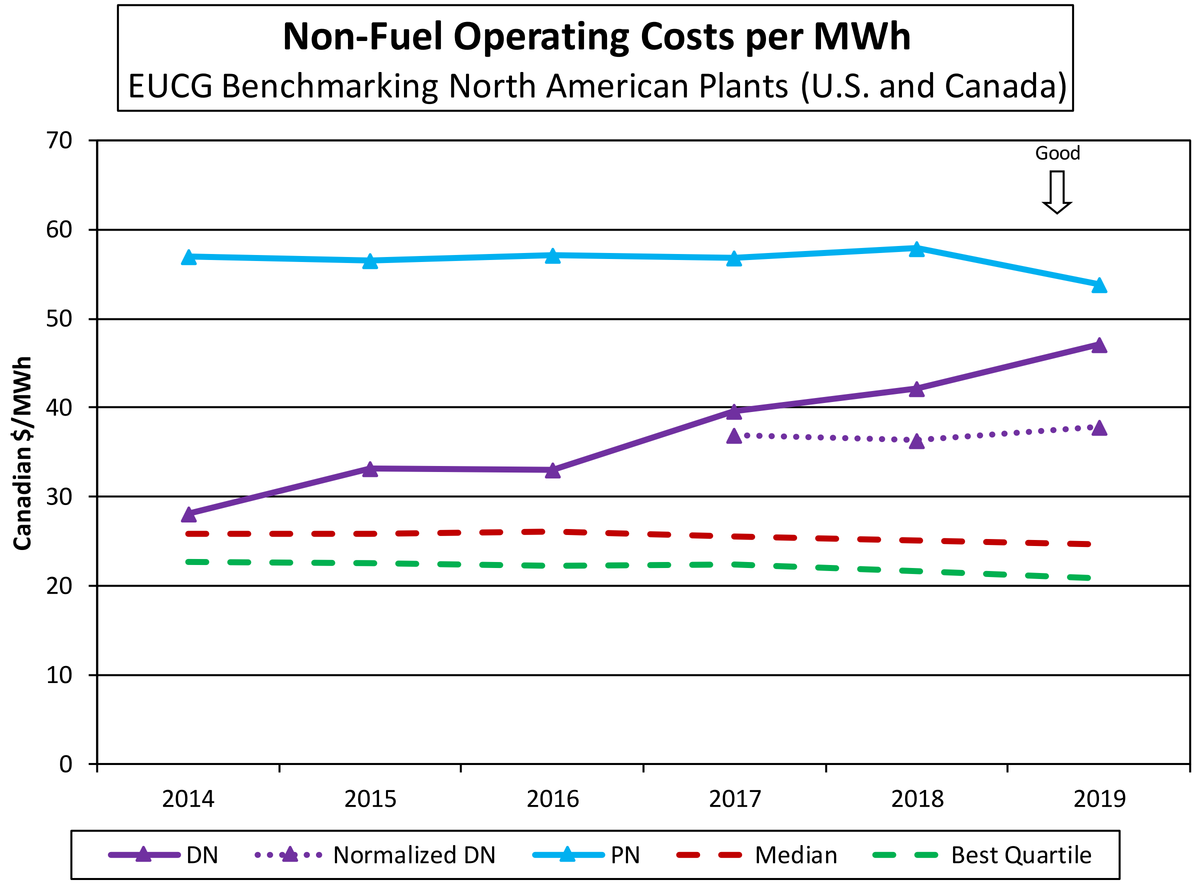
[1] Normalization for Refurbishment and CANDU Technology applied from 2017 onwards in accordance with methodologies provided by ScottMadden.

Pickering

- Pickering's improvement in performance from 2018 includes higher generation and associated outage OM&A cost reduction due to fewer outage days, as well as decreased capital investment, and improved Fuel Costs/MWh.

- Site capacity (reflecting unit size) as well as outage durations required to extend operations continued to contribute to Pickering's TGC/MWh. Pickering units are the smallest in the peer group with total unit capacity of 540 MW compared to the peer group average of 1,026 MW. The majority of the generating units in the peer group fall within the 900 to 1,299 MW range.

3-Year Non-Fuel Operating Cost per MWh



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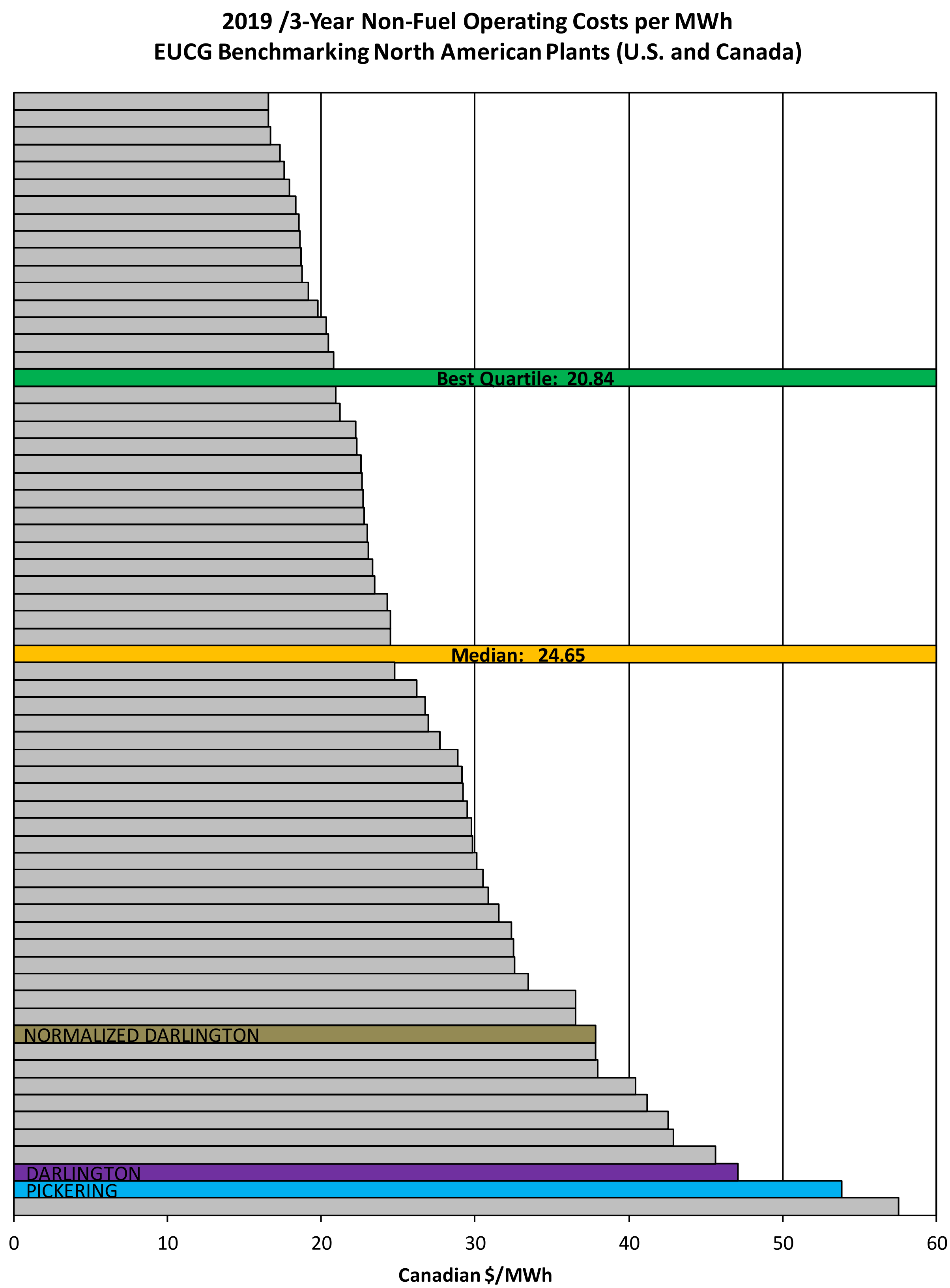

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Observations – 3-Year Non-Fuel Operating Cost per MWh (All North American Plants)

2019 (3-Year Rolling Average)

- Best quartile level Non-Fuel Operating Costs per MWh (NFOC/MWh) was $20.84 while the median level was $24.65/MWh.
- Darlington normalized[1] (for Refurbishment only) – 4th Quartile: $37.85/MWh (non-normalized $47.10/MWh)
- Pickering non-normalized – 4th Quartile: $53.85/MWh

Trend

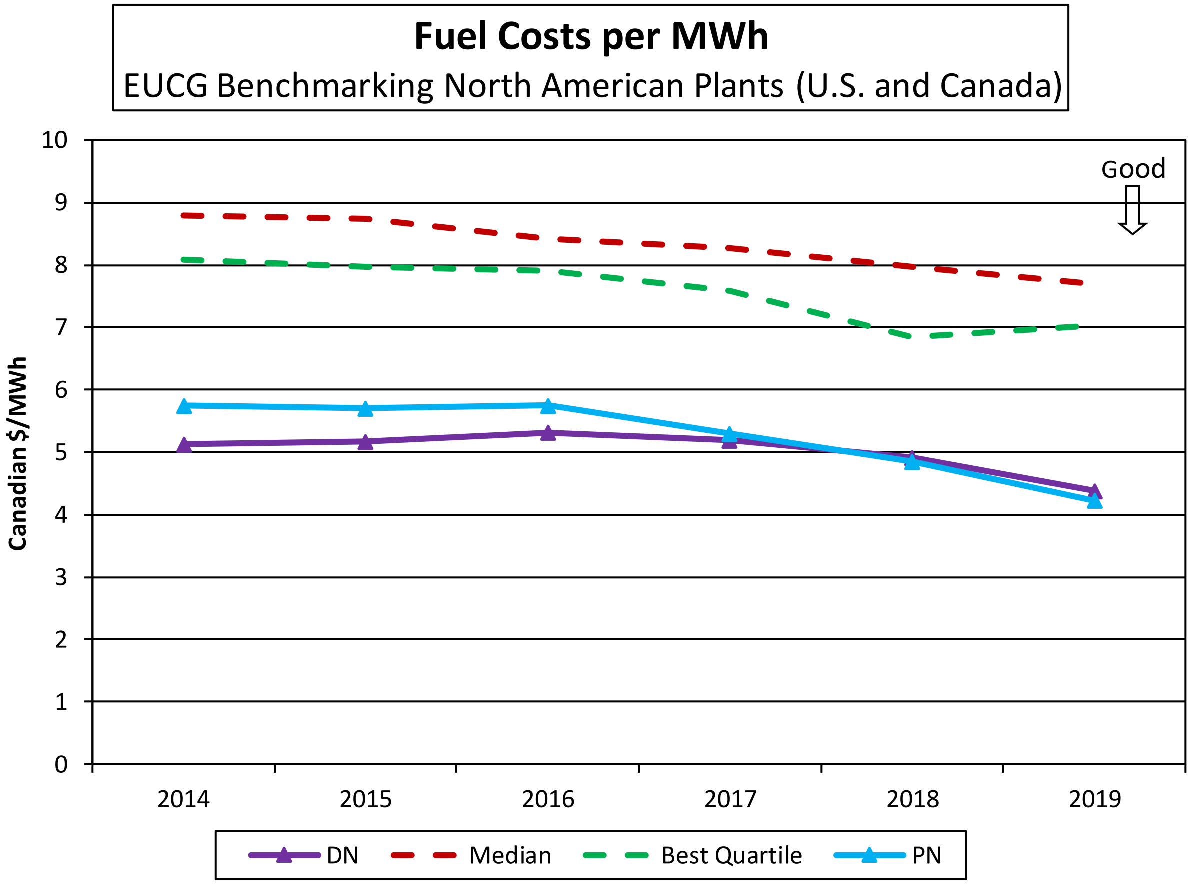
- Best quartile cost has decreased, reflecting a $1.84/MWh improvement over the trend period, and the median cost also declined, improving by $1.18/MWh.
- Darlington normalized (for Refurbishment only) increased by $0.95/MWh since 2017 (non-normalized rose by $19.00/MWh since 2014).
- Pickering non-normalized decreased, improving by $3.16/MWh over the trend period.

Factors Contributing to Performance

- DNGS normalized (for Refurbishment only) 3-Year rolling average increased $1.47/MWh (non-normalized rose by $4.96/MWh) compared to 2018. The primary driver for the change from 2018 and over the trend period was lower generation associated with Darlington Refurbishment in years 2017 to 2019 compared to previous 3-year rolling averages.
- Pickering's non-normalized 3-Year rolling average decreased by $4.07/MWh compared to 2018, mainly as a result of higher generation.

[1] Normalization for Refurbishment applied from 2017 onwards in accordance with the methodology provided by ScottMadden.

3-Year Fuel Cost per MWh



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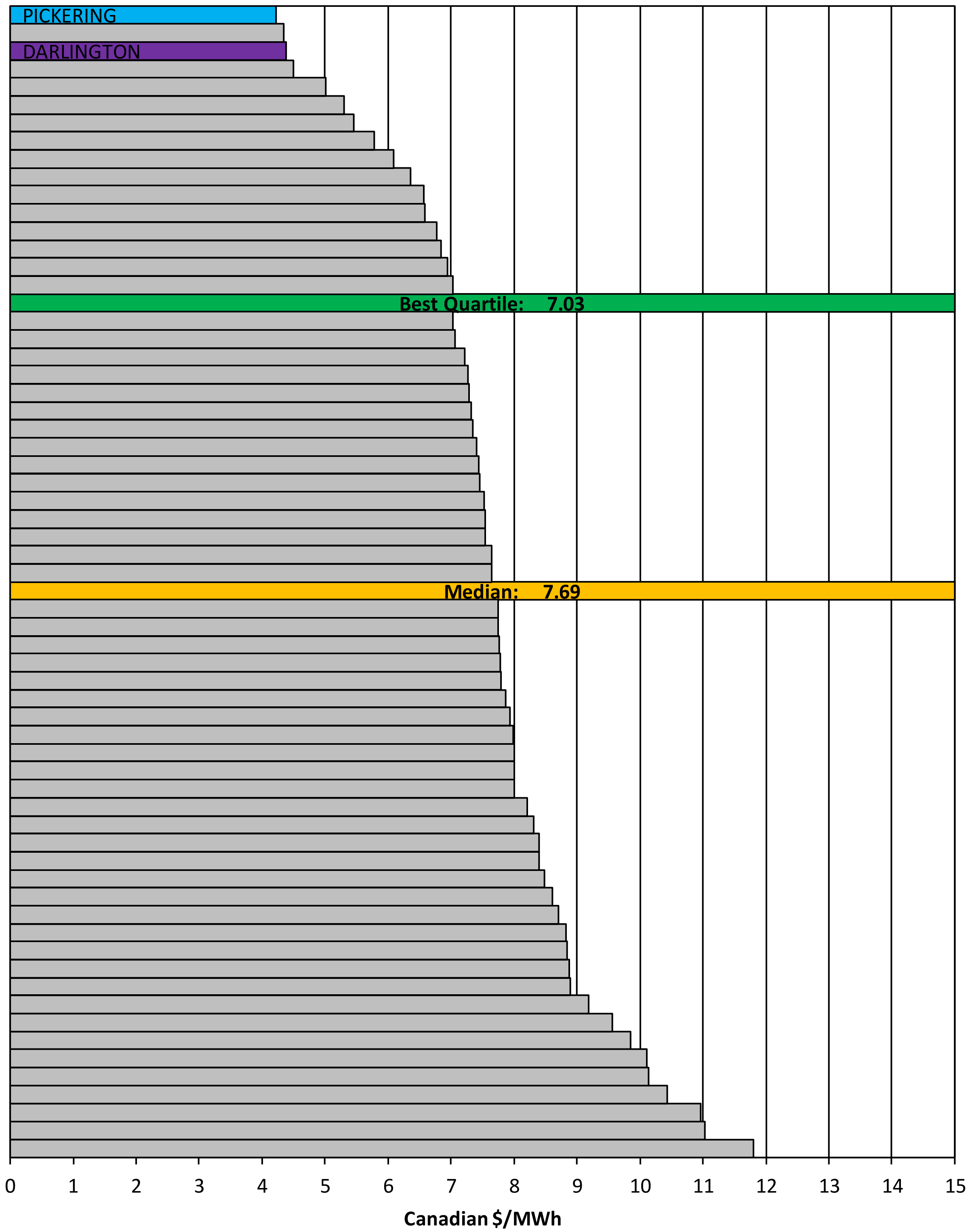
2019 3-Year Fuel Costs per MWh
EUCG Benchmarking North American Plants (U.S. and Canada)



Observations – 3-Year Fuel Cost per MWh (All North American Plants)

2019 (3-Year Rolling Average)

- Best quartile was $7.03/MWh for the panel of North American EUCG plants.
- PNGS ranked at the top for the lowest fuel cost/MWh in the North American panel at $4.22/MWh and DNGS was ranked third at $4.38/MWh.

Trend

- The best quartile Fuel Cost/MWh improved by $1/MWh from 2014 to 2019.
- DNGS and PNGS performed consistently better than the best quartile during the review period.
- Fuel Cost/MWh for all OPG plants improved in 2019, as the improving trend continued since 2016.

Factors Contributing to Performance

- Fuel costs, primarily driven by the technological differences in CANDU technology, are lower for OPG than North American Pressurized Water Reactors or Boiling Water Reactors (PWR/BWR) as CANDUs do not require enriched uranium like BWRs and PWRs. This provides a significant advantage for OPG and other CANDUs in this cost category.
- The downward trend in the Fuel Cost per MWh for both PNGS and DNGS is due to a combination of lower input uranium costs, offset by general escalation in the fuel conversion and fuel fabrication costs.
- OPG's best quartile fuel cost performance is also due to the fact that CANDU is the most efficient of all reactors in using uranium, requiring about 15% less uranium than PWRs for each megawatt hour of electricity.

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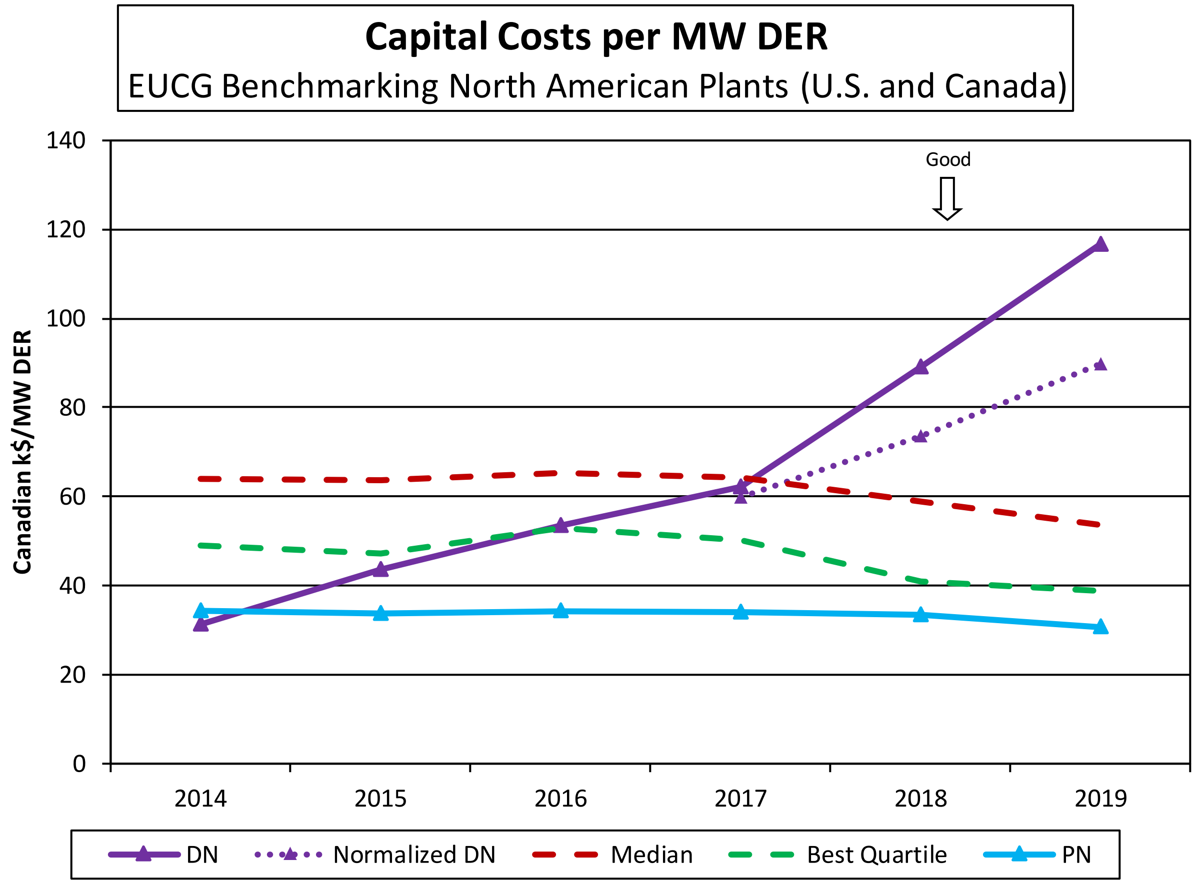
3-Year Capital Cost per MW DER (Design Electrical Rating)



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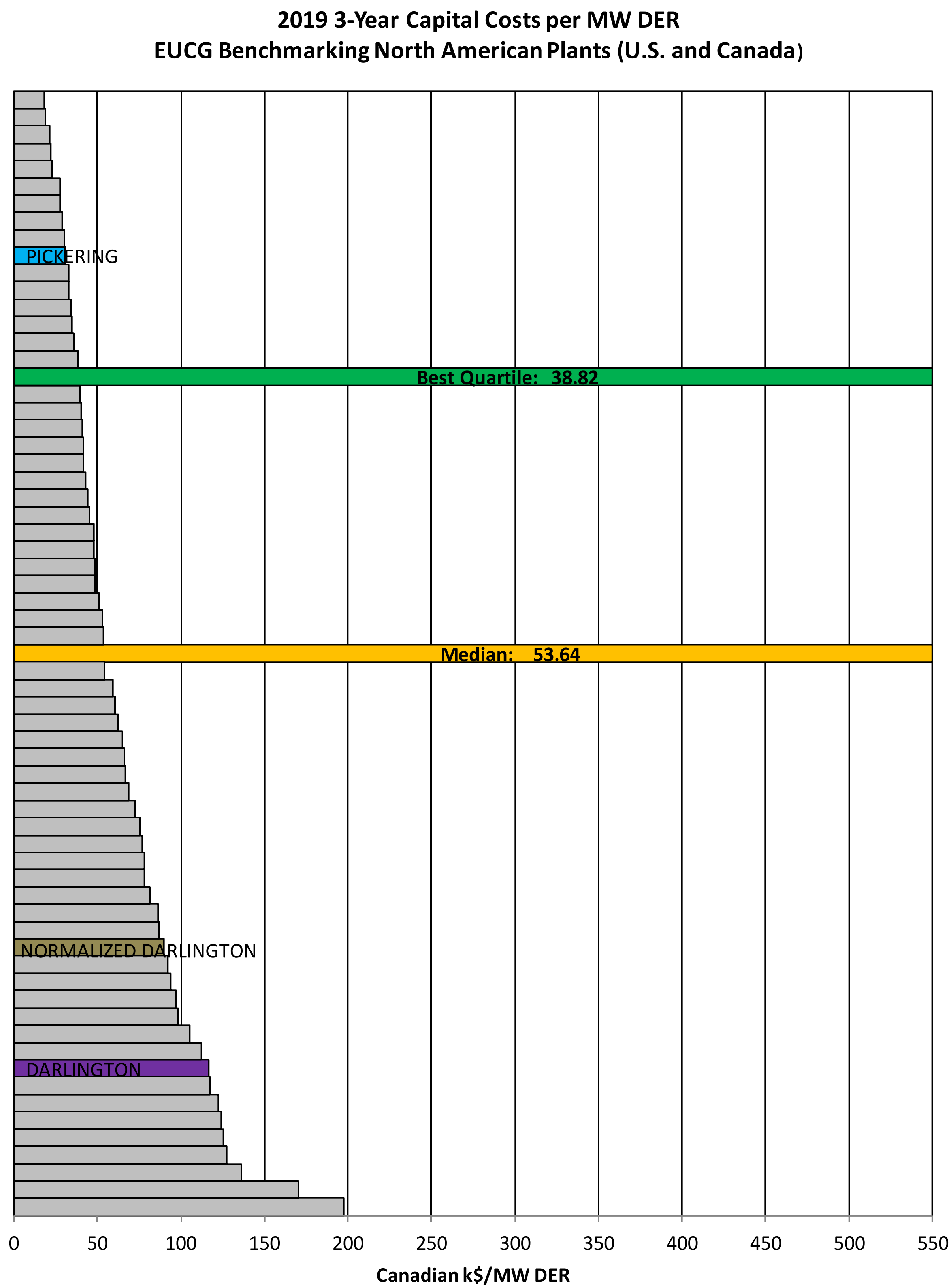

Observations – 3-Year Capital Cost per MW DER (All North American Plants)

2019 (3-Year Rolling Average)

- The best quartile threshold for Capital Cost per MW DER across US and Canadian EUCG peer plants was $38.82 k/MW DER.
- Median cost for the panel was $53.64 k/MW DER.
- PNGS was in the first quartile at $30.66 k/MW DER.
- DNGS was in the fourth quartile at $89.78 k/MW DER normalized and $116.67 k/MW DER non-normalized.

Trend

- Both best and median quartile thresholds decreased in 2019 due primarily to regulatory spending on Fukushima response ending. That reduction was partly offset by increased spending on reliability improvements. Spending on information technology and capital spares increased marginally with other categories being essentially flat over the trend period.
- Pickering's Capital Cost/MW DER improved in 2019 compared to previous years, due to reduced regulatory spending on Fukushima response, as well as reduced capital requirements as Pickering approaches end of commercial operations.
- Darlington's Capital Cost/MW DER rose year-over-year due to increased spending on life extension, performance improvements, sustaining investments, information technology and capital spares. This was partially offset by a reduction in Fukushima response spending.

Factors Contributing to Performance

- PNGS is performing in the first quartile and showed improvement in 2019 by $2.73 k/MW DER. This change from 2018, and over the trend period, reflects reductions in spending while maintaining reliable operations in the period leading up to the end of commercial operations. This is consistent with spending trends observed at other nuclear facilities approaching their end of commercial operations.
- DNGS is performing in the fourth quartile in 2019 and increased by $16.32 k/MW DER on a normalized basis compared to 2018. This change from 2018 and over the trend period reflects increased spending on life extension, sustaining investments, information technology and capital spares to support operations before, during and after refurbishment.
- Historically, Darlington's capital expenditures were better than the industry median. Once the decision to refurbish Darlington and extend end of life was made, OPG began an extensive program to replace obsolete and/or life-expired plant equipment.

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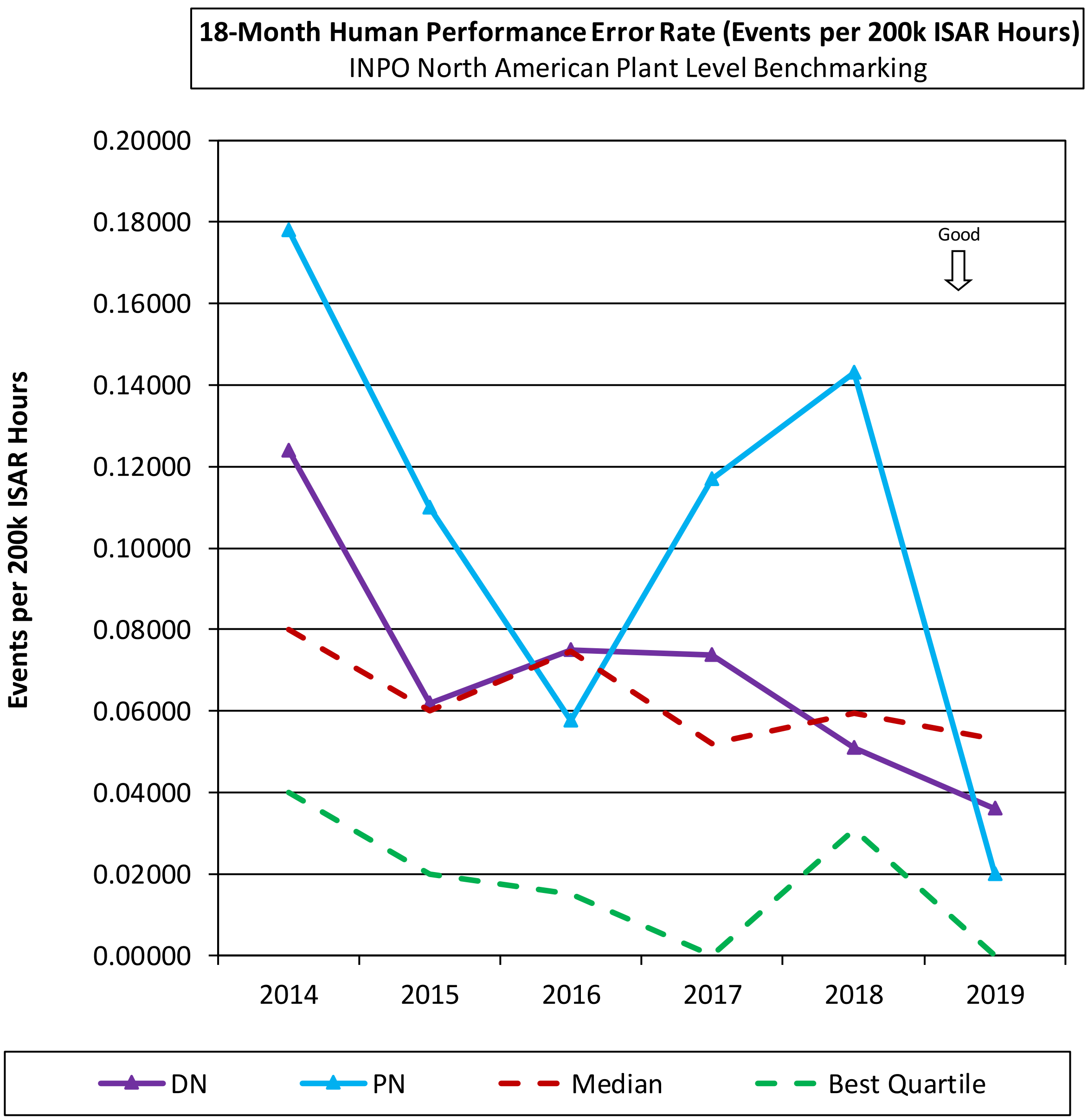
5.0 HUMAN PERFORMANCE

Methodology and Sources of Data

The Human Performance Error Rate metric is used to benchmark the performance of OPG's Nuclear fleet against other INPO utilities in the area of Human Performance. This will ensure a continued focus on improving Human Performance.

18-Month Human Performance Error Rate



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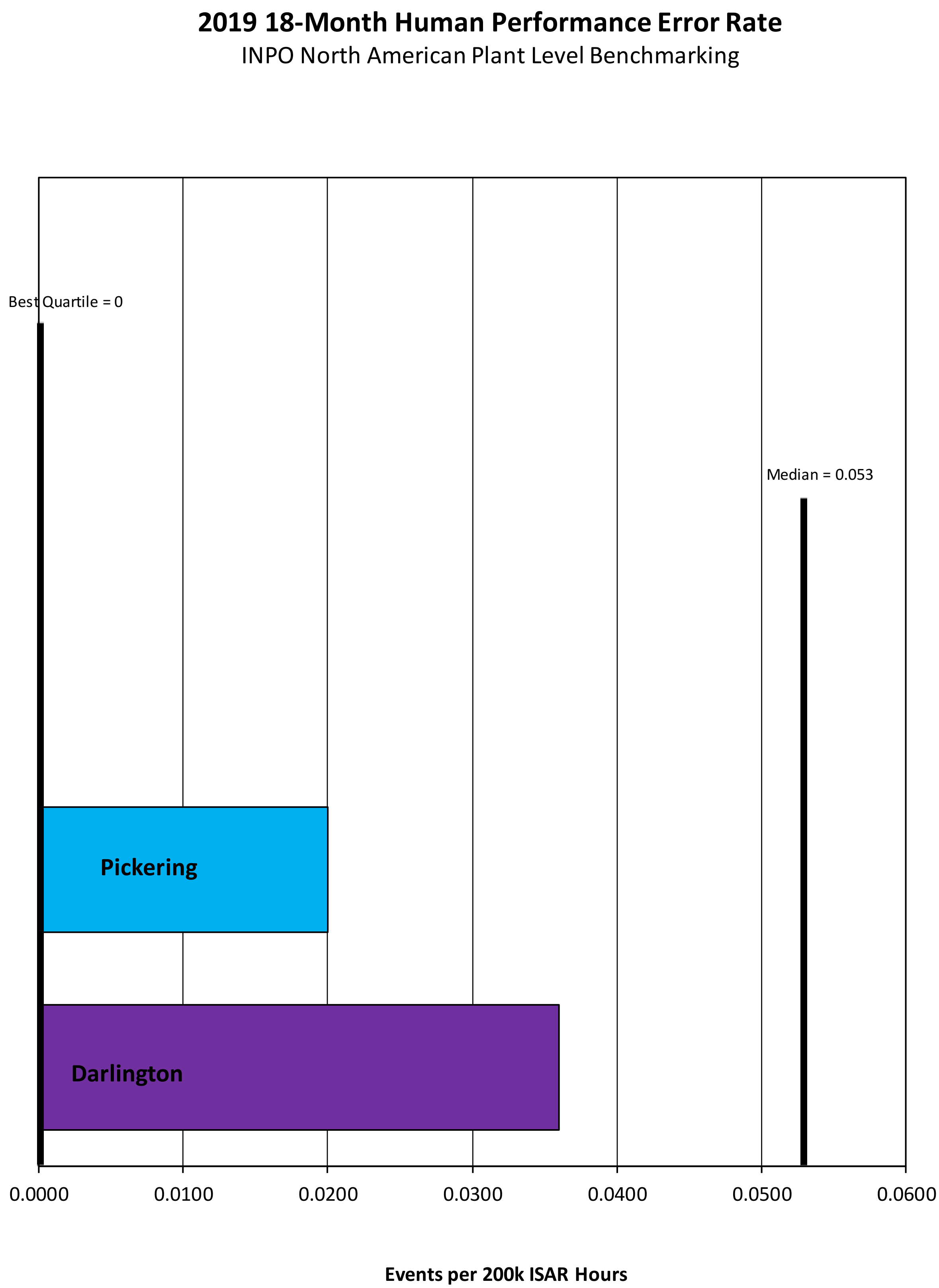


Observations – 18 Month Human Performance Error Rate (INPO North American Plants)

2019 (18 Month Rolling Average)

- The best quartile is 0 for the Human Performance (Hu) error rate for INPO plants. The median is 0.053. These rates reflect industry performance over an 18-month period.
- Pickering Hu Error Rate is 0.02, and Darlington is 0.036, which reflect second quartile performance at both stations. Darlington Unit 2 began a long-term refurbishment outage on October 15, 2016 and has been excluded from benchmarking results.
- Three site event free day resets (S-EFDRs) occurred in the 18-month period ending in 2019, with two at DNGS and one at PNGS.

Trend

- PNGS and DNGS performance has improved significantly over the trend period.
- The overall industry also improved steadily over the review period with best quartile at the end of 2019 being 0.00, improved from 0.04 in 2014.

Factors Contributing to Performance

- There are many successes in Human Performance that have contributed to Pickering and Darlington's low error rates in 2019 and improvement over the trend period. Industry-leading Human Performance practices have been built through innovation including:
  - the "iConnect" Mobile Observation & Coaching Application,
  - analysis tools for early detection of signs of decline in Hu performance,
  - associated Microsoft Power BI Dashboards to support data analytics and reporting, and
  - specialized training with the use of a simulator to teach Hu concepts and behaviours.

6.0 MAJOR OPERATOR SUMMARY

Purpose

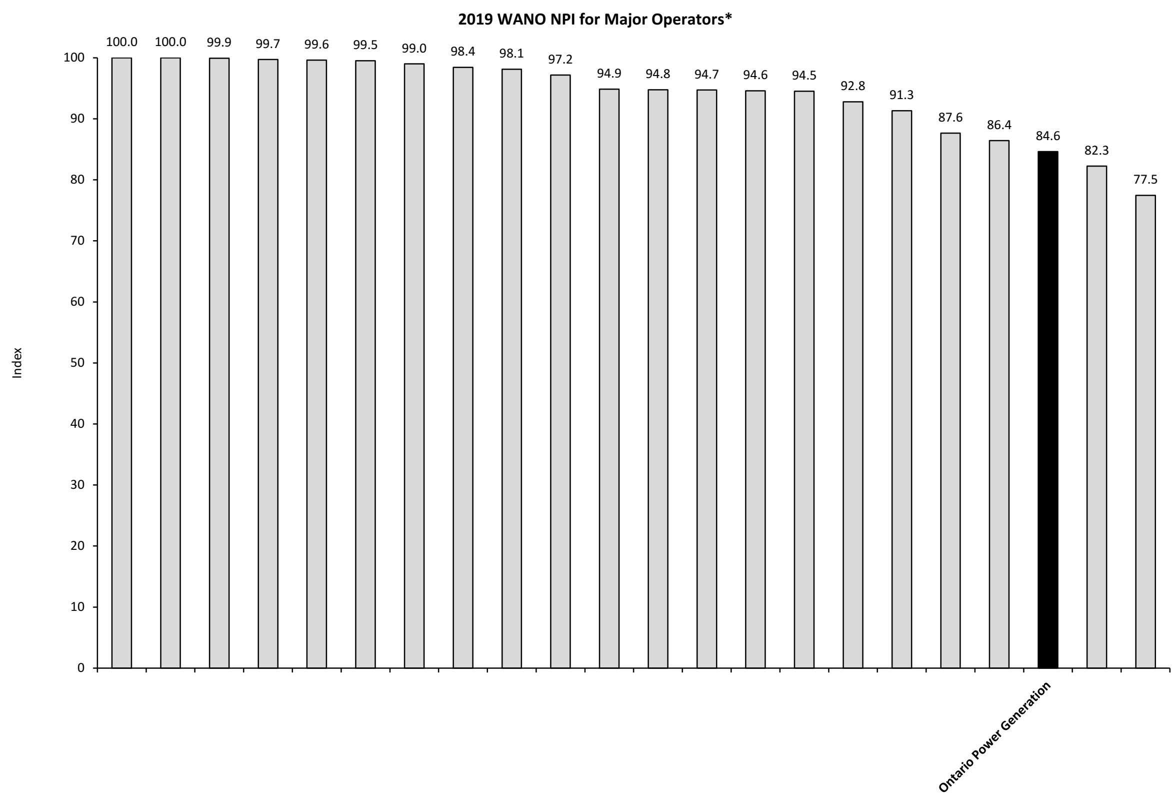
This section provides a more detailed comparison of the major operators of nuclear plants for three key metrics: WANO Nuclear Performance Index (NPI), Unit Capability Factor (UCF), and Total Generating Cost (TGC) per MWh.

Operator level summary results are the average (mean) of the results across all plants managed by the given operator. These comparisons provide additional context, but the detailed data in the previous sections provide a more complete picture of plant by plant performance. This view is consistent with ScottMadden's Evaluation of 2019 OPG Nuclear Benchmarking, in which ScottMadden recommended that OPG focus on site-level comparisons of performance for Pickering and Darlington rather than operator-level comparisons.

The WANO NPI and UCF are calculated as the mean of all unit performance for a specific operator. The TGC per MWh is the mean of plant level data.

WANO Nuclear Performance Index Analysis

The WANO NPI results for the operators in 2019 are illustrated in the graph below. OPG Nuclear performance ranking improved from 2018 by three rankings as shown in Table 2.



*See Table 7 in the Appendix for listing of operators and plants.

**OPG Nuclear unit values averaging to a WANO NPI of 84.6 in 2019 are shown below:

Unit	2019 WANO NPI
Pickering 1	93.9
Pickering 4	78.2
Pickering 5	85.1
Pickering 6	76.5
Pickering 7	87.0
Pickering 8	74.1
Darlington 1	90.8
Darlington 2	N/A
Darlington 3	87.8
Darlington 4	87.9

OPG ranked 20th, with an NPI of 84.6. OPG's NPI performance increased by 4.5 compared to the 2018 ranking.

The NPI rankings of the major operators from 2014 to 2019 are listed in Table 2. The list and ranking of operators has been updated to reflect any applicable industry developments.

Table 2: Average WANO NPI Rankings

Operator	2014	2015	2016	2017	2018	2019
	2	4	13	2	2	1
	18	21	15	6	3	2
	5	5	3	1	1	3
	13	9	9	9	6	4
	8	3	1	16	18	5
	7	10	7	5	5	6
	19	7	11	14	7	7
	10	8	10	8	8	8
	20	20	12	10	12	9
	4	6	6	7	4	10
	12	16	14	3	9	11
	9	2	2	4	10	12
	17	19	22	22	14	13
	6	17	17	11	15	14
	16	1	8	13	13	15
	15	12	4	15	16	16
	3	15	16	12	11	17
	24	24	23	18	17	18
	1	14	18	21	20	19
Ontario Power Generation	22	23	21	23	23	20
	11	11	20	17	21	21
	21	22	19	19	19	22
	14	13	5	20	22	NA
	23	18	NA	NA	NA	NA

Note: The following operators are no longer ranked in 2019 (reason for 24 ranked operators in 2014 vs. 22 in 2019):

- Omaha Public Power District was removed from the WANO data set as of October 2016 (Fort Calhoun no longer in service).
- South Carolina Electric & Gas Co. is now a subsidiary of Dominion Generation since 2019.
- All 2014-2018 rankings are carried over from previous Benchmarking reports.

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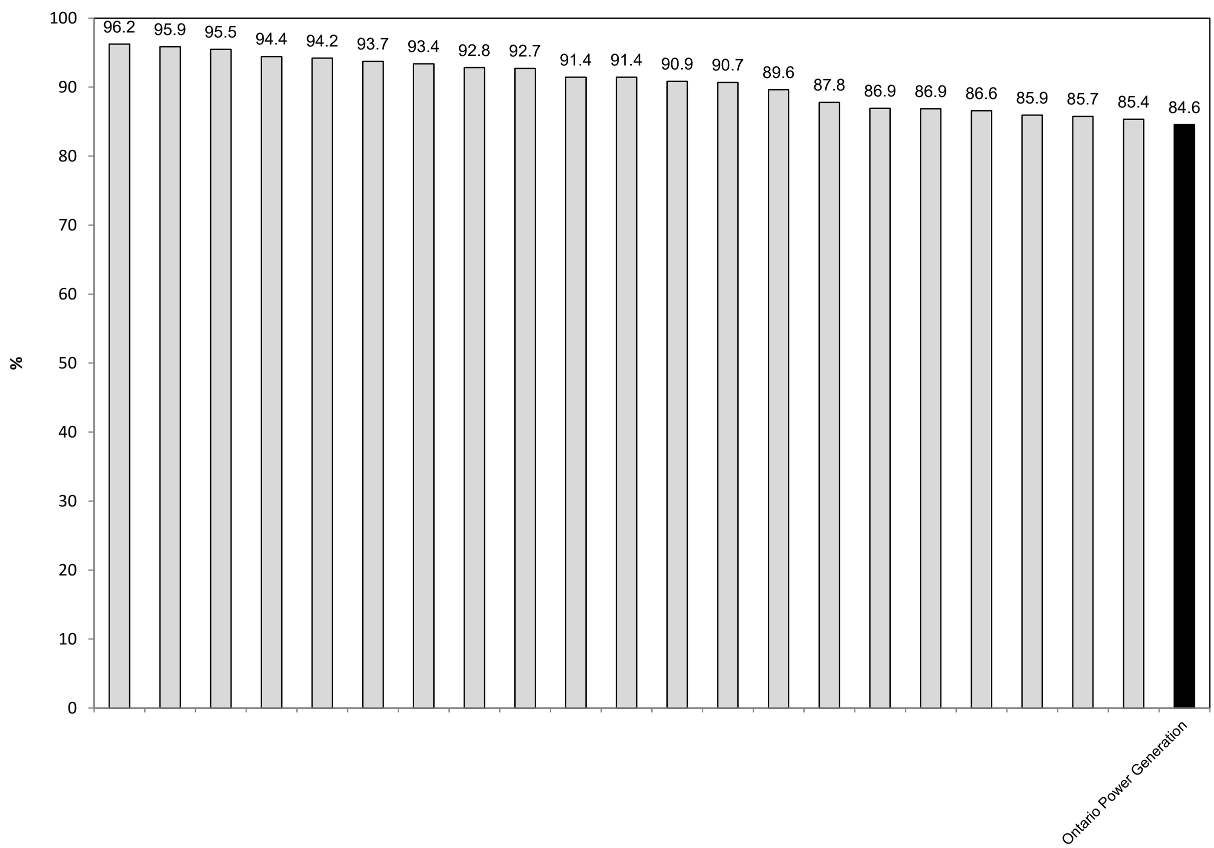
Unit Capability Factor Analysis

A comparison of UCF values for major nuclear operators is presented in the graph below. The list and ranking of operators has been updated to reflect any applicable industry developments.

UCF is expressed as a two-year average for all operators except for OPG Nuclear, which includes a three-year average for the Darlington station and a two-year average for Pickering to reflect each plant's respective historical outage cycle. OPG Nuclear experienced a rolling average UCF of 84.6% and ranked 22 out of 22 operators in the WANO data set.

2019 Rolling Average Unit Capability Factor Ranking for Major Operators*



* See Table 7 in the Appendix for listing of operators and plants.
**OPG unit values averaging to a rolling average UCF of 84.6% in 2019 are shown below:

Unit	2019 Rolling Average UCF
Pickering 1	95.1
Pickering 4	80.8
Pickering 5	82.1
Pickering 6	79.9
Pickering 7	83.5
Pickering 8	78.4

Unit	2019 Rolling Average UCF
Darlington 1	86.4
Darlington 2	N/A
Darlington 3	87.8
Darlington 4	87.0

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Rankings for the major operators for UCF over the past six years are provided in Table 3 below.

Table 3: Rolling Average Unit Capability Factor Rankings

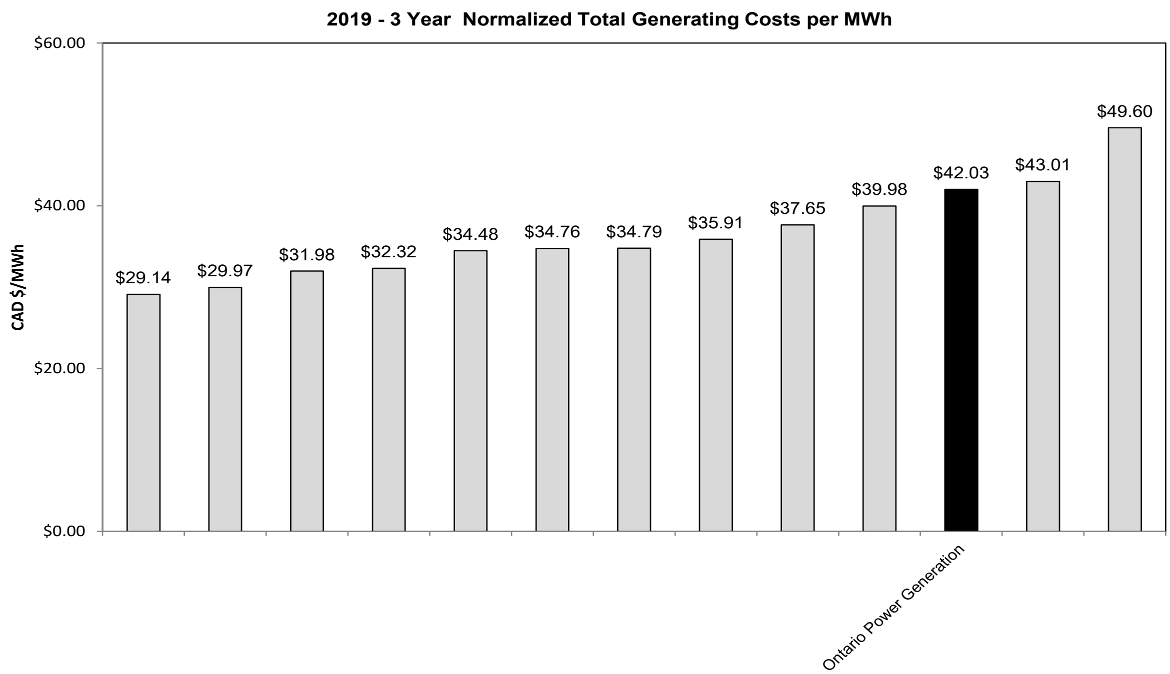
Operator	2014	2015	2016	2017	2018	2019
	1	1	1	1	1	1
	2	7	2	3	5	2
	18	20	20	13	4	3
	10	14	10	7	3	4
	5	10	3	14	17	5
	6	5	8	5	2	6
	8	6	5	2	7	7
	20	17	14	4	10	8
	19	4	6	20	15	9
	4	9	11	6	8	10
	14	19	19	21	13	11
	16	15	13	10	11	12
	7	2	7	9	12	13
	3	13	16	23	21	14
	13	12	4	8	9	15
	11	11	15	16	20	16
	17	3	12	18	19	17
	23	22	21	12	6	18
	9	8	18	15	14	19
	22	24	23	19	18	20
	15	18	17	17	16	21
Ontario Power Generation	21	23	22	22	23	22
	12	21	9	11	22	NA
	24	16	NA	NA	NA	NA

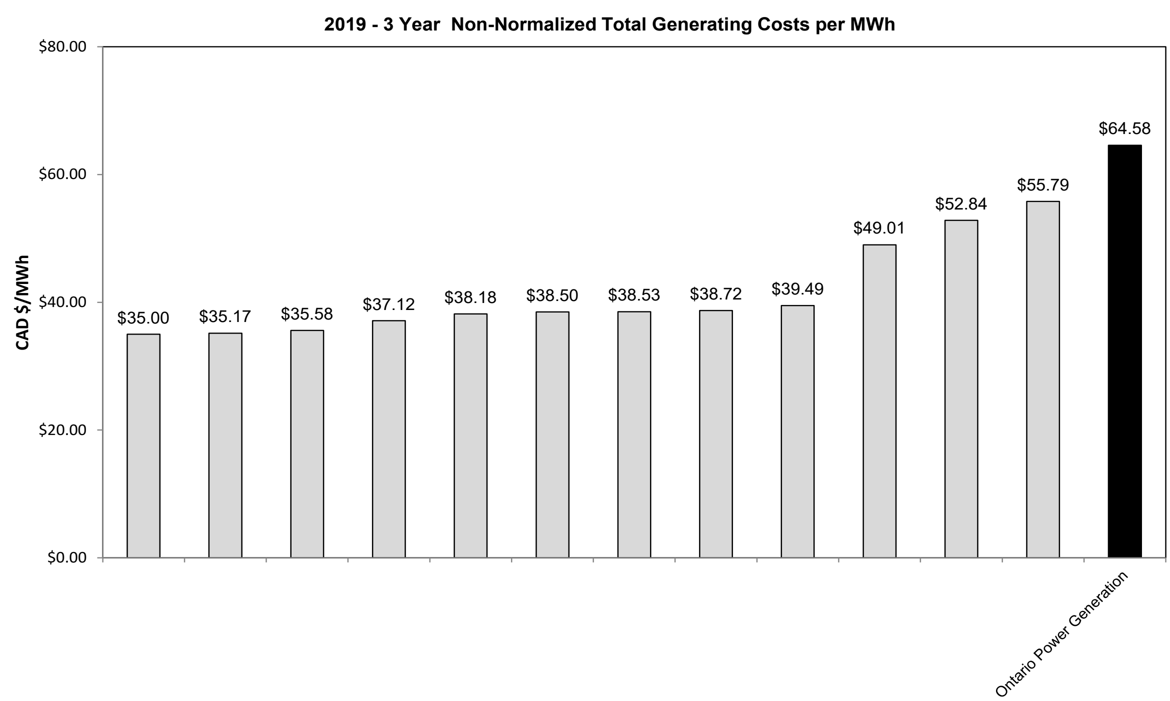
Note: The following operators are no longer ranked in 2019 (reason for 24 ranked operators in 2014 vs. 22 in 2019):

- Omaha Public Power District was removed from the WANO data set as of October 2016 (Fort Calhoun no longer in service).
- South Carolina Electric & Gas Co. is now a subsidiary of Dominion Generation since 2019.
- All 2014-2018 rankings are carried over from previous Benchmarking reports.

Total Generating Cost/MWh Analysis

The 3-year average Total Generating Cost (TGC)/MWh results for the major operators in 2019 are displayed in the graphs below. On a normalized basis, OPG Nuclear ranked 11th, with a 3-year Total Generation Cost of $42.03 per MWh (non-normalized, ranked 13th with $64.58/MWh).





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OPG plant values of 3-year rolling average TGC per MWh are shown below:

	2019 3-Year TGC/MWh	
Station	Normalized	Non-Normalized
Darlington	$38.84/MWh	$67.00/MWh
Pickering	$44.85/MWh	$62.39/MWh

Table 4: Three Year TGC/MWh Rankings

	2014	2015	2016	2017	2018	2019
	11	11	9	3	1	1
	4	2	1	2	2	2
	7	7	6	6	6	3
	12	8	7	8	5	4
	8	9	10	9	9	5
	5	3	3	5	8	6
	3	5	4	7	7	7
	2	4	5	4	4	8
	1	1	2	1	3	9
	6	6	8	10	10	10
	13	13	13	13	12	11
	9	10	11	11	11	12
Ontario Power Generation	10	12	12	12	13	13
Ontario Power Generation - Normalized	-	-	-	11	11	11

Table 5 shows the relative contribution of Non-Fuel Operating Costs, Fuel Costs and Capital Costs to Total Generating Cost/MWh and compares OPG's non-normalized costs to those of all EUCG operators.

Table 5: EUCG Indicator Results Summary (Operator Level)

EUCG Indicator Results Summary	OPG Average	EUCG Major Operators*		Unit of Measure
		Median	Best Quartile	
Value for Money Performance				
3-Yr. Non-Fuel Operating Costs per MWh (non-normalized)	$50.65	$23.43	$22.48	CAD $/MWh
3-Yr. Fuel Costs per MWh (non-normalized)	$4.30	$7.73	$7.17	CAD $/MWh
3-Yr. Capital Costs per MWh (non-normalized)	$9.63	$9.02	$6.16	CAD $/MWh
3-Yr. Total Generating Costs per MWh (non-normalized)	$64.58	$38.53	$37.12	CAD $/MWh
3-Yr. Total Generating Costs per MWh - Normalized	$42.03	$34.79	$32.32	CAD $/MWh

**See Table 8 in the appendix for list of operators included.*

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7.0 APPENDIX

Acronyms

Acronym	Meaning
ALARA	As Low As Reasonably Achievable
BWR	Boiling Water Reactor
CANDU	CANada Deuterium Uranium (type of PHWR)
CEA	Canadian Electricity Association
COG	CANDU Owners Group
DER	Design Electrical Rating
EPRI	Electric Power Research Institute
EUCG	Electric Utility Cost Group
INPO	Institute of Nuclear Power Operators
OPG	Ontario Power Generation
PHWR	Pressurized Heavy Water Reactor
PWR	Pressurized Water Reactor
WANO	World Association of Nuclear Operators

Safety and Reliability Definitions

The following definitions are summaries extracted from industry peer group databases.

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.

Industrial Safety Accident Rate is defined as the number of accidents for all utility personnel (permanently or temporarily) assigned to the station, that result in one or more days away from work (excluding the day of the accident) or one or more days of restricted work (excluding the day of the accident), or fatalities, per 200,000 man-hours worked. The selection of 200,000 man-hours worked or 1,000,000 man-hours worked for the indicator will be made by the country collecting the data, and international data will be displayed using both scales. Contractor personnel are not included for this indicator.

Collective Radiation Exposure, for purposes of this indicator, is the total external and internal whole body exposure determined by primary dosimeter (thermoluminescent dosimeter (TLD) or film badge), and internal exposure calculations. All measured exposure should be reported for station personnel, contractors, and those personnel visiting the site or station on official utility business.

Visitors, for purposes of this indicator, include only those monitored visitors who are visiting the site or station on official utility business.

Airborne Tritium Emissions per Unit: Tritium emissions to air.

Fuel Reliability Index is inferred from fission product activities present in the reactor coolant. Due to design differences, this indicator is calculated differently for different reactor types. For PHWR's, the indicator is defined as the steady-state primary coolant iodine-131 activity (Becquerels/gram or Microcuries/gram), corrected for the tramp uranium contribution and power level, and normalized to a common purification rate.

Unplanned automatic reactor trips (SCRAMS) is defined as the number of unplanned automatic reactor trips (reactor protection system logic actuations) that occur per 7,000 hours of critical operation. The indicator is further defined as follows:

- Unplanned means that the trip was not an anticipated part of a planned test.
- Trip means the automatic shutdown of the reactor by a rapid insertion of negative reactivity (e.g., by control rods, liquid injection shutdown system, etc.) that is caused by actuation of the reactor protection system. The trip signal may have resulted from exceeding a set point or may have been spurious.
- Automatic means that the initial signal that caused actuation of the reactor protection system logic was provided from one of the sensors' monitoring plant parameters and conditions, rather than the manual trip switches or, in certain cases described in the clarifying notes, manual turbine trip switches (or pushbuttons) provided in the main control room.
- Critical means that, during the steady-state condition of the reactor prior to the trip, the effective multiplication factor (k_{eff}) was essentially equal to one.
- The value of 7,000 hours is representative of the critical hours of operation during a year for most plants, and provides an indicator value that typically approximates the actual number of scrams occurring during the year.

The **safety system performance indicators** include the following:

- Auxiliary boiler feedwater system
- Emergency AC power
- High pressure emergency coolant injection system

These systems were selected for the safety system performance indicator based on their importance in preventing reactor core damage or extended plant outage. They include the principal systems needed for maintaining reactor coolant inventory following a loss of coolant, for decay heat removal following a reactor trip or loss of main feedwater, and for providing emergency AC power following a loss of plant off-site power. (Gas cooled reactors have an additional decay heat removal system instead of the coolant inventory maintenance system).

The **Nuclear Performance Index** Method 4 is an INPO sponsored performance measure, and is a weighted composite of ten WANO Performance Indicators related to safety and production performance reliability.

The **Forced Loss Rate (FLR)** is defined as the ratio of all unplanned forced energy losses during a given period of time to the reference energy generation minus energy generation losses corresponding to planned outages and any unplanned outage extensions of planned outages, during the same period, expressed as a percentage.

Unplanned energy losses are either unplanned forced energy losses (unplanned energy generation losses not resulting from an outage extension) or unplanned outage extension of planned outage energy losses.

Unplanned forced energy loss is energy that was not produced because of unplanned shutdowns or unplanned load reductions due to causes under plant management control when the unit is considered to be at the disposal of the grid dispatcher. Causes of forced energy losses are considered to be unplanned if they are not scheduled at least four weeks in advance. Causes considered to be under plant management control are further defined in the clarifying notes.

Unplanned outage extension energy loss is energy that was not produced because of an extension of a planned outage beyond the original planned end date due to originally scheduled work not being completed, or because newly scheduled work was added (planned and scheduled) to the outage less than four weeks before the scheduled end of the planned outage.

Planned energy losses are those corresponding to outages or power reductions which were planned and scheduled at least four weeks in advance (see clarifying notes for exceptions).

Reference energy generation is the energy that could be produced if the unit were operated continuously at full power under reference ambient conditions throughout the given period. Reference ambient conditions are environmental conditions representative of the annual mean (or typical) ambient conditions for the unit.

Unit Capability Factor is defined as the ratio of the available energy generation over a given time period to the reference energy generation over the same time period, expressed as a percentage. Both of these energy generation terms are determined relative to reference ambient conditions.

Available energy generation is the energy that could have been produced under reference ambient conditions considering only limitations within control of plant management, i.e., plant equipment and personnel performance, and work control.

Reference energy generation is the energy that could be produced if the unit were operated continuously at full power under reference ambient conditions.

Reference ambient conditions are environmental conditions representative of the annual mean (or typical) ambient conditions for the unit.

The **Chemistry Performance Indicator** compares the concentration of selected impurities and corrosion products to corresponding limiting values. Each parameter is divided by its limiting value, and the sum of these ratios is normalized to 1.0. If an impurity concentration is equal to or better than the limiting value, the limiting value is used as the concentration. This prevents increased concentrations of one parameter from being masked by better performance in another.

As a result, if a plant is at or below the limiting value for all parameters, its indicator value would be 1.0, the lowest chemistry indicator value attainable under the indicator definition. The following is used to determine each unit's chemistry indicator value for PHWRs:

- *Inconel-600 or Monel tubes
  - Steam generator blowdown chloride
  - Steam generator blowdown sulfate
  - Steam generator blowdown sodium
  - Final feedwater iron
  - Final feedwater copper
  - Final feedwater dissolved oxygen
- Incoloy-800 tubes
  - Steam generator blowdown chloride
  - Steam generator blowdown sulfate
  - Steam generator blowdown sodium
  - Final feedwater iron
  - Final feedwater dissolved oxygen

Online Deficient Maintenance Backlog is the average number of active on-line maintenance work orders per operating unit classified as Deficient Critical (DC) or Deficient Non-Critical (DN) that can be worked on without requiring the unit shutdown. This metric identifies deficiencies or degradation of plant equipment components that need to be remedied, but which do not represent a loss of functionality of the component or system.

Online Corrective Maintenance Backlog is the average number of active on-line maintenance work orders per operating unit classified as Corrective Critical (CC) or Corrective Non-Critical (CN) that can be worked on without requiring the unit shutdown. This metric identifies deficiencies or degradation of components that need to be remedied, and represents a loss of functionality of a major component or system.

On-line maintenance is maintenance that will be performed with the main generator connected to the grid.

Value for Money Definitions

The following definition summaries are taken from the *January 2020 EUCG Nuclear Committee Nuclear Database Instructions*.

Capital Costs ($)
All costs associated with improvements and modifications made during the reporting year. These costs should include design and installation costs in addition to equipment costs. Other miscellaneous capital additions such as facilities, computer equipment, moveable equipment, and vehicles should also be included. These costs should be fully burdened with indirect costs, but exclude AFUDC (interest and depreciation).

Fuel ($)
The total cost associated with a load of fuel in the reactor which is burned up in a given year.

Net Generation (Gigawatt Hours)
The gross electrical output of the unit measured at the output terminals of the turbine-generator minus the normal station service loads during the hours of the reporting period, expressed in Gigawatt hours (GWh). Negative quantities should not be used.

Design Electrical Rating (DER)
The nominal net electrical output of a unit, specified by the utility and used for plant design (DER net expressed in MWe). Design Electrical Rating should be the value that the unit was certified/designed to produce when constructed. The value would change if a power uprate was completed. After a power uprate, the value should be the certified or design value resulting from the uprate.

Operating Costs ($)
All relevant costs to operate and maintain nuclear operations. It includes the cost of labour, materials, purchased services and other costs, including administration and general.

Total Generating Costs ($)
The sum of operating costs, fuel costs and capital costs.

Note: Total Generating Costs are divided by net generation to obtain per MWh results. Capital costs are also divided by MW DER to obtain per MW results.

Human Performance Definitions

The following definition summary is taken from the Institute of Nuclear Power Operations (INPO) database.

Human Performance Error Rate (# per ISAR and Contractor Hours)
The Human Performance Error Rate metric represents the number of site level human performance events in an 18-month period per 200,000 ISAR hours worked (including on site supplemental personnel). The formula used is:

{(# of S-EFDRs) / (Total ISAR Hours + Total Contractor Hours)} x 200,000 Hours (Calculated as an 18-month rolling average)

INPO guidelines define non-utility personnel to include contractor, supplemental personnel assigned to perform work activities on site or at other buildings that directly support station operation. This includes personnel who deliver and receive equipment, deliver fuel oil, remove trash and radioactive waste, and provide building and grounds maintenance within the owner-controlled areas or facilities that support the station.

INPO defines an event to occur as a result of the following:
An initiating action (error) by an individual or group of individuals (event resulting from an active error) or an initiating action (not an error) by an individual or group of individuals during an activity conducted as planned (event resulting from a flawed defense or latent organizational weakness). They may be related to Nuclear Safety, Radiological Safety, Industrial Safety, Facility Operations or considered to be a Regulatory Event reportable to a regulator or governing agency. OPG Nuclear's criteria for defining station event free day resets have been developed based on INPO guidelines.

Table 6: Industry Peer Groups

	WANO/COG CANDUs	All North American PWR and PHWRs (WANO)	INPO AP-928 Workgroup	INPO	CEA	EUCG North American Plants (US and Canada)
Safety						
Total Recordable Injury Frequency					X	
Rolling Average Industrial Safety Accident Rate*		X				
Rolling Average Collective Radiation Exposure*	X					
Airborne Tritium Emissions per Unit	X					
Fuel Reliability Index*	X					
2-Year Reactor Trip Rate*	X					
3-Year Auxiliary Feedwater System Unavailability*	X					
3-Year Emergency AC Power Unavailability*	X					
3-Year High Pressure Safety Injection Unavailability*	X					
Reliability						
WANO NPI	X					
Rolling Average Forced Loss Rate*	X					
Rolling Average Unit Capability Factor*	X					
Rolling Average Chemistry Performance Indicator*	X					
1-Year On-line Deficient Maintenance Backlog			X			
1-Year On-line Corrective Maintenance Backlog			X			
Value for Money						
3-Year Total Generating Costs / MWh						X
3-Year Non-Fuel Operating Costs (OM&A) / MWh						X
3-Year Fuel Costs / MWh						X
3-Year Capital Costs / MW DER						X
Human Performance						
Human Performance Error Rate				X		

* Sub-indicator of WANO NPI

Data provided by the World Association of Nuclear Operators (WANO) is the primary source of benchmarking data for operational performance (Safety and Reliability) indicators. Eleven out of the twenty benchmarking metrics have been compared to the WANO/COG CANDU panel. All WANO performance indicators are presented at the unit and plant levels except the Industrial Safety Accident Rate and Emergency AC Power Unavailability which are only measured at the plant level.

Different peer groups were used for a few of the specialized operating metrics which are not tracked through WANO. For maintenance work order backlogs, the peer group consisted of all plants participating in the Institute of Nuclear Power Operations (INPO) AP-928 working group. For human performance comparisons, data was obtained from INPO. For the Total Recordable Injury Frequency metric, the Canadian Electricity Association (CEA) panel was used.

For financial performance comparisons, data compiled by the Electric Utility Cost Group (EUCG) was used. EUCG is a nuclear industry operating group and the recognized source for cost benchmark information. EUCG cost indicators are presented at the plant level and compared on a net megawatt hour generated basis and on a per megawatt (MW) design electrical rating (DER) basis. The only CANDU operators reporting data to EUCG were OPG Nuclear and Bruce Power which is not a sufficiently large panel to provide a basis for comparison; hence, the data sets were not limited to a CANDU specific panel. Should more CANDU operators choose to join EUCG in the future, comparisons to a CANDU specific panel will be reconsidered.

All data provided by the peer groups (WANO, INPO, CEA, and EUCG) is confidential. A redacted version of this report, which removes individual plant and unit names, is available from Nuclear Business Planning and Benchmarking should there be a requirement to publicly release this report.

Panels

Table 7: WANO Panel

Operator	Plant
Ameren Missouri	Callaway
American Electric Power Co.	Cook
Arizona Public Service Co.	Palo Verde
Bruce Power	Bruce A Bruce B
Dominion Generation	Millstone North Anna Surry V.C. Summer
Duke Energy	Catawba Harris Mcguire Oconee Robinson
Entergy Nuclear	Arkansas Nuclear One Indian Point Palisades Waterford
Exelon Generation Co.	Braidwood Byron Three Mile Island Calvert Cliffs Ginna
FirstEnergy Nuclear Operating Co.	Beaver Valley Davis-Besse
Florida Power & Light Co.	St. Lucie Turkey Point
International CANDU	Cernavoda Embalse Qinshan 3 Wolsong A Wolsong B
Luminant Generation	Comanche Peak
New Brunswick Power	Point Lepreau
NextEra Energy Resources	Point Beach Seabrook
Northern States Power Company	Prairie Island
Ontario Power Generation	Darlington Pickering
Pacific Gas & Electric Co.	Diablo Canyon
Public Service Enterprise Group Nuclear	Salem
Southern Nuclear Operating Co.	Farley Vogtle
STP Nuclear Operating Co.	South Texas
Tennessee Valley Authority	Sequoyah Watts Bar
Wolf Creek Nuclear Operating Corp.	Wolf Creek

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Table 8: EUCG Panel

Major Operator	Plant	Major Operator	Plant
Bruce Power	Bruce A Bruce B	Florida Power & Light Co.	St Lucie Turkey Point
Dominion Generation	Millstone North Anna Surry V.C. Summer	NextEra Energy Resources	Duane Arnold Point Beach Seabrook
		Northern States Power Company	Monticello Prairie Island
Duke Energy	Brunswick Catawba Harris Mcguire Oconee Robinson	Ontario Power Generation	Darlington Pickering
Entergy Nuclear	Arkansas Nuclear One Grand Gulf Indian Point Palisades Pilgrim River Bend Waterford	Public Service Enterprise Group Nuclear	Hope Creek Salem
		Southern Nuclear Operating Co.	Farley Hatch Vogtle
Exelon Generation Co.	Braidwood Byron Calvert Cliffs Clinton Dresden Fitzpatrick Lasalle Limerick Nine Mile Oyster Creek Peach Bottom Quad Cities Ginna Three Mile Island	Tennessee Valley Authority	Browns Ferry Sequoyah Watts Bar
FirstEnergy Nuclear Operating Co.	Beaver Valley David-Besse Perry		

Remaining EUCG Members

Operator	Plant	Operator	Plant
AmerenUE	Callaway	Nebraska Public Power District	Cooper
American Electric Power Co. Inc.	Cook	Pacific Gas & Co.	Diablo Canyon
Arizona Public Service Co.	Palo Verde	Talen Energy	Susquehanna
DTE Energy	Fermi	STP Nuclear Operating Co.	South Texas
Energy Northwest	Columbia	Wolf Creek Nuclear Operations Corp.	Wolf Creek
Luminant Generation	Comanche Peak		

Table 9: COG CANDUs

Operator	Plant
Bruce Power	Bruce A Bruce B
China (CNNP)	Qinshan 3
NASA	Embalse
Korea (KHNP)	Wolsong A Wolsong B
New Brunswick Power	Point Lepreau
OPG	Darlington Pickering
Romania	Cernavoda

Table 10: CEA Members

Companies
Alectra Inc.
Algonquin Power & Utilities Corp.
AltaLink
ATCO Electric
ATCO Power
BC Hydro and Power Smart
Brookfield Renewable Energy Group
Capital Power Corporation
City of Medicine Hat, Electric Utility
City of Red Deer
Elexicon Energy
Emera Power
ENMAX
EPCOR
Evolugen
FortisAlberta Inc.
FortisBC Inc.
FortisOntario
Heartland Generation
Hydro One
Hydro Ottawa
Hydro Quebec

Companies
Hydro Quebec
IESO
London Hydro
Manitoba Hydro
Maritime Electric Company
Nalcor Energy
New Brunswick Power
Newfoundland Power
Northwest Territories Power Corp.
OEC
Ontario Power Generation
Qulliq Energy Corporation
Rio Tinto
Saint John Energy
Saskatoon Light & Power
SaskPower
TC Energy
Toronto Hydro Corp.
TransAlta
Utilities Kingston
Yukon Energy Corp.

Table 11: INPO Members for Human Performance Error Rate

Plant	
Arkansas Nuclear One (ANO)	Monticello
Beaver Valley	Nine Mile Point
Braidwood	North Anna
Browns Ferry	Oconee
Brunswick	Oyster Creek
Byron	Palisades
Callaway	Palo Verde
Calvert Cliffs	Peach Bottom
Catawba	Perry
Clinton	Pilgrim
Columbia Gen	Point Beach
Comanche Peak	Prairie Island
Cook	Quad Cities
Cooper	River Bend
Davis-Besse	Robinson
Diablo Canyon	Salem
Dresden	Seabrook
Duane Arnold	Sequoyah
Farley	South Texas
Fermi 2	St. Lucie
Fitzpatrick	Summer
Ginna	Surry
Grand Gulf	Susquehanna
Harris	Three Mile Island
Hatch	Turkey Point
Hope Creek	Vermont Yankee
Indian Point	Vogtle
LaSalle	Waterford
Limerick	Watts Bar
McGuire	Wolf Creek
Millstone	

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Table 12: INPO Members for On-Line Maintenance Backlogs

Plant	
Arkansas Nuclear One (ANO)	McGuire
Beaver Valley	Millstone
Braidwood	Monticello
Browns Ferry	Nine Mile Point
Brunswick	North Anna
Byron	Oconee
Callaway	Palisades
Calvert Cliffs	Palo Verde
Catawba	Peach Bottom
Clinton	Perry
Columbia Gen	Point Beach
Comanche Peak	Prairie Island
Cook	Quad Cities
Cooper	River Bend
Davis-Besse	Robinson
Diablo Canyon	Salem
Dresden	Seabrook
Farley	Sequoyah
Fermi 2	South Texas
Fitzpatrick	St. Lucie
Ginna	Summer
Grand Gulf	Surry
Harris	Susquehanna
Hatch	Turkey Point
Hope Creek	Vogtle
Indian Point	Waterford
LaSalle	Watts Bar
Limerick	Wolf Creek

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Table 13: NPI Plant Level Performance Summary (North American Panel)

	2019 Actuals				
Indicator	**NPI Max**	**Best Quartile**	**Median**	**Pickering**	**Darlington**
Rolling Average Industrial Safety Accident Rate (#/200k hours worked)	0.20	0.00	0.01	0.02	0.04
Rolling Average Collective Radiation Exposure (person-rem per unit)	80.00	23.40	32.00	70.32	83.23
Fuel Reliability Index (microcuries per gram)	0.000500	0.000001	0.000005	0.000187	0.000295
2-Year Reactor Trip Rate (# per 7,000 hours)	0.50	0.00	0.00	0.24	0.00
3-Year Auxiliary Feedwater System Unavailability (#)	0.0200	0.0020	0.0036	0.0039	0.0000
3-Year Emergency AC Power Unavailability (#)	0.0250	0.0076	0.0122	0.0003	0.0026
3-Year High Pressure Safety Injection Unavailability (#)	0.0200	0.0017	0.0024	0.0001	0.0000
Rolling Average Forced Loss Rate (%)	1.00	0.31	0.98	3.39	2.56
Rolling Average Unit Capability Factor (%)	92.00	95.10	91.43	83.31	87.06
Rolling Average Chemistry Performance Indicator (Index)	1.01	1.00	1.00	1.02	1.03
WANO NPI (Index)	Not Applicable	100.0	98.1	82.5	88.9

ScottMadden Evaluation of 2019 OPG Nuclear Benchmarking

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1. EXECUTIVE SUMMARY

ScottMadden's review found that OPG's current benchmarking methods align with previous guidance and current leading practices in the industry. Our evaluation found no material issues with benchmarking report calculations or presentations of data. OPG's suite of benchmarked metrics provides a robust view of the Company's nuclear performance, and its choice of companies for comparison appropriately reflects its industry peers. However, ScottMadden recommends that OPG focus on site-level comparisons of performance for Pickering and Darlington rather than operator-level comparisons in the future. ScottMadden's 2015 review recommended minor modifications to the report and its supporting materials. We have found that OPG sufficiently implemented those recommendations. Lastly, ScottMadden's review of OPG's Nuclear Business Planning Procedure found that this governance remains consistent with industry leading practice.

Changes in Comparative Peer Panels

There have been no substantive changes to the peer panels for comparison in the benchmarking report since ScottMadden's evaluation in 2015, and these panels remain valid industry comparisons for OPG. There have been no additional CANDU interconnections worldwide and only one non-CANDU interconnection in North America, which has been included in the data.

OPG's choice of companies for comparison appropriately reflects its industry peers. However, ScottMadden recommends that OPG focus on site-level comparisons of performance for Pickering and Darlington rather than operator-level comparisons in the future. This represents an evolution in ScottMadden's guidance from 2009. Operator-level comparisons include companies of significantly different scales, particularly given consolidation in the industry over the last decade, and comprise many fewer data points. Variance in scale from one site to the next, while still significant, is less prominent than from one operator to the next. Site-to-site comparisons provide a larger data set resulting in a more robust and accurate view of OPG performance relative to the industry, which better informs the target-setting process.

Changes in Comparative Benchmark Metrics

We compared the metrics currently used by OPG to those used by OPG in the 2014 report. We also compared the metrics currently used by OPG to those currently used by other nuclear operators to benchmark their operational and financial performance.

Our review identified one primary difference between the 2014 and 2019 benchmarking reports, which was the replacement of All Injury Rate (AIR or AIF) with Total Recordable Injury Frequency (TRIF). We reviewed and are comfortable with the rationale for this change. The 2019 report contains additional detail regarding backlog metrics, which we support. ScottMadden also supports the inclusion of normalizing adjustments to some value for money metrics, which are presented in conjunction with unadjusted (i.e., not normalized) versions of those cost metrics. Additionally, in ScottMadden's 2015 review, we recommended that OPG note where metrics use different rolling averages for different stations, which has been implemented by OPG.

It is our opinion that OPG's suite of benchmarked metrics provides a sufficiently robust view of the Company's nuclear performance.

Validation of Data Calculations and Reporting

We conducted a data validation exercise to ensure benchmarking data contained in the 2019 report was assessed, calculated, and reported accurately. Our evaluation found no material issues with OPG's assessments, calculations, or presentations of data in the benchmarking report. We provide additional context below for OPG's reporting of NPI, which differs from that reported by WANO but is nonetheless accurate and appropriate. In ScottMadden's 2015 review, we also recommended changes to the underlying data files, all of which have been implemented by OPG.

Use of Benchmarks in the Business Planning Process

ScottMadden reviewed OPG's Nuclear Business Planning Procedure. We found that this governance remains aligned with industry leading practice and ScottMadden's previous guidance.

ScottMadden is comfortable with the OPG plan to, beginning in 2020, set targets for three-year rolling averages for value for money metrics. We do not expect that the change from one-year targets to three-year targets will have any negative impact on the understanding of performance and associated goalsetting. We are also comfortable with OPG similarly setting targets for normalized value for money metrics, as long as these normalized targets are always presented and pursued in conjunction with unadjusted (i.e., not normalized) targets.

Changes in Report Format and Presentation

We compared the 2014 and 2019 benchmarking reports for consistency in report format and presentation. It is ScottMadden's view that any changes from 2014 to 2019 were appropriate or immaterial to the overall purpose of the benchmarking analysis.

2. BACKGROUND

In 2009, OPG retained ScottMadden to assist in formally benchmarking its nuclear financial and non-financial performance with industry peers. This initiative was undertaken consistent with shareholder mandate and pursuant to direction from the Ontario Energy Board (OEB). Since this time, nuclear benchmarking has been a standard part of OPG's annual business planning process. OPG has continued to publish annual benchmarking results, comparing OPG to the nuclear industry in terms of financial and non-financial performance metrics. Results are then used to inform target setting for business planning purposes.

OPG previously retained ScottMadden for a similar review of its benchmarking methods. That review, submitted in April 2015 ("ScottMadden's 2015 review"), determined that OPG's benchmarking and target setting processes were responsive to the direction from the OEB. The 2015 review did not find any material errors in the content of the report. The review did recommend minor modifications to the report and its supporting materials.

Since ScottMadden's 2015 review, the OEB has issued an order regarding OPG's nuclear benchmarking methodologies. Issued on December 28, 2017, OEB Decision and Order EB-2016-0152, "Application for payment amounts for the period from January 1, 2017 to December 31, 2021" (Order), states that the OEB expects OPG to file a review by ScottMadden regarding OPG's nuclear benchmarking methodologies with its next cost-based application for the period 2022-2026.

In an effort to ensure OPG's benchmarking and target setting processes are still responsive to the direction from the Ontario Energy Board (OEB), OPG retained ScottMadden, as an independent evaluator, to examine the current methods used by OPG to benchmark the Company's operational and financial performance against its peer companies in the industry.

3. OBJECTIVES AND SCOPE

Objectives

The purpose of the current evaluation is to confirm that the Company's benchmarking methods and approach are still responsive to the original direction from the OEB.

Scope

The benchmarking methods evaluated were those recently performed by OPG in support of its 2020-2026 planning cycle. The scope of our review includes the following:

- Identification of key performance metrics used for comparison
- Selection of companies to be included in the peer panels
- Preparation of supporting analyses and displays of data
- Use of benchmarks in the business planning cycle

The scope of the review compared the 2019 OPG Nuclear Benchmarking Report to the 2014 OPG Nuclear Benchmarking Report, which was reviewed by ScottMadden in 2015. The two documents were compared in terms of (1) use of appropriate peer companies for comparison, (2) use of industry standard metrics, (3) accuracy of assessments, calculations, and presentations of data, (4) application of the performance benchmarks to inform and guide management during the Company's business planning process, and (5) consistency in format and presentation.

This evaluation also validated normalization adjustments included by OPG for value for money metrics, which reflected methodologies presented in separate documents prepared by ScottMadden for OPG:

- "OPG Nuclear Cost Performance Benchmarking: A Study of Factors Impacting TGC / MWh Performance with Normalizing Adjustments to Facilitate Closer Comparison"
- "OPG Nuclear Cost Performance Benchmarking: Methodology to Adjust for Refurbishment and Validation of Implementation"[1]

[1] ScottMadden outlined the methodology for Refurbishment normalization for 2017 and subsequently validated the OPG calculations to ensure the methodology was applied correctly. For 2018, ScottMadden validated that the approach of OPG remained consistent with the methodology and assumed that OPG had also continued to accurately perform the calculations, as detailed in the appendix, consistent with OPG's current corporate cost allocation methodology and organizational structure.

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4. CHANGES IN COMPARATIVE PEER PANELS

Approach

To evaluate changes in comparative peer panels, ScottMadden reviewed summary tables as well as individual metrics to determine which peer groups were used for which metrics. This exercise was performed at the plant and unit level.

Key Changes and Justification

There have been no substantive changes to the peer panels for comparison in the benchmarking report since ScottMadden's evaluation in 2015.

ScottMadden's Evaluation

The peer panels for comparison remain valid industry comparisons for OPG. There have been no additional CANDU interconnections worldwide and only one non-CANDU interconnection in North America (Watts Bar 2), which has been included in the data.

OPG's choice of companies for comparison appropriately reflects its industry peers. However, ScottMadden recommends that OPG focus on site-level comparisons of performance for Pickering and Darlington rather than operator-level comparisons in the future. This represents an evolution in ScottMadden's guidance from 2009. Operator-level comparisons include companies of significantly different scales, particularly given consolidation in the industry over the last decade and comprise many fewer data points. Variance in scale from one site to the next, while still significant, is less prominent than from one operator to the next. Site-to-site comparisons provide a larger and more comparable data set resulting in a more robust and accurate view of OPG performance relative to the industry which better informs the target-setting process.

5. CHANGES IN COMPARATIVE BENCHMARK METRICS

Approach

We compared the metrics currently used by OPG to those used by OPG in 2014. We also compared the metrics currently used by OPG to those currently used by other nuclear operators to benchmark their operational and financial performance.

Key Changes and Justification

Our review identified one primary difference between the 2014 and 2019 benchmarking reports, which was the replacement of All Injury Rate (AIR or AIF) with Total Recordable Injury Frequency (TRIF).

The Canadian Electricity Association (CEA), which administers the metric, recommended the change, noting:

> *"The key difference is that AIF covers lost-time, fatalities and medical treatment injuries; while the TRIF is based on the total number of recordable injuries. TRIF will likely capture a larger number of injuries, as some injuries are recordable, but do not result in lost time or medical treatment. This metric was chosen as a better representation of the rate at which employees are being meaningfully injured on the job."*

Our review also identified additional detail provided for 1-Year On-Line Deficient Maintenance Backlog and 1-Year On-Line Corrective Maintenance Backlog. The 2019 report quantifies work orders per operating unit classified as Deficient Critical (DC) and Corrective Critical (CC). The 2014 report contains 1-Year On-Line Deficient Maintenance Backlog and 1-Year On-Line Corrective Maintenance Backlog, but does not quantify DC and CC work orders, as the 2019 report does.

OPG has added Total Generating Cost per Unit (TGC per Unit) and Normalized TGC per Unit to a plant-level performance summary table located in the executive summary of the 2019 benchmarking report. Added to the same table are Normalized Total Generating Cost per Megawatt-Hour (TGC per MWh) and Normalized Non-Fuel Operating Cost per MWh (NFOC per MWh). These latter two measures, along with Normalized Capital Cost per Megawatt Design Electrical Rating (Capital Cost per MW DER), are also included in the graphs and analysis for TGC per MWh, NFOC per MWh, and Capital Cost per MWh, respectively, located in the value for money section of the benchmarking report.

Additionally, in ScottMadden's 2015 review, we recommended that OPG note where metrics use different rolling averages for different stations, which has been implemented by OPG.

ScottMadden's Evaluation

We reviewed and are comfortable with the rationale for the change from AIR/AIF to TRIF. We also support the additional level of detail regarding backlog metrics that OPG now provides.

OPG has significantly increased its analysis of value for money performance since our 2015 review. The below three metrics are consistent with analytical methodologies presented in separate documents that were prepared by ScottMadden for OPG. These are:

- Normalized TGC per MWh, which includes normalization both for Refurbishment costs (impacting TGC) and for factors derived from an in-depth econometric analysis (impacting TGC) and an outage study (impacting MWh)
- Normalized NFOC per MWh and Normalized 3-Year Capital Cost per MW DER, which include normalization for Refurbishment costs (impacting TGC) but not for factors derived from the outage study or the econometric analysis (see explanation below)

OPG calculates Normalized NFOC per MWh and Normalized Capital Cost per MW DER consistent with the ScottMadden Methodology to Adjust for Refurbishment, which excludes costs which can reasonably be attributed to Darlington unit(s) in Refurbishment. As noted above, these two metrics are not adjusted for the outage study or the econometric analysis because the analytical methodology used to quantify the normalizing adjustments was not performed for NFOC or Capital Cost.

OPG also calculates TGC per Unit and Normalized TGC per Unit, which divide cost values by number of units to provide an additional comparative view of costs for OPG and only appear in the plant-level performance summary table. OPG continues to report an unadjusted (i.e., not normalized) version of cost metrics in conjunction with any normalized version, which ScottMadden supports to ensure a complete understanding of performance.

The 2019 Nuclear Benchmarking Report contains performance benchmarks which are similar or identical to five metrics the WANO Governing Board deems as key[2]: Forced Loss Rate, Collective Radiation Exposure, Total Industrial Safety Accident Rate (OPG tracks TRIF and ISAR, which are similar), Safety System Performance Indicator (SSPI) (this is a composite indicator composed of availability metrics which are present in OPG's benchmarking report), and Unplanned Total Scrams per 7,000 Hours (OPG calls this metric Unplanned Automatic Reactor Trips and calculates it as a two-year rolling average).

It is our opinion that OPG's suite of benchmarked metrics provides a sufficiently robust view of the Company's nuclear performance.

6. VALIDATION OF DATA CALCULATIONS AND REPORTING

Approach

We conducted a data validation exercise to ensure benchmarking data contained in the 2019 report was assessed, calculated, and reported accurately. Data capture for the benchmarking report occurs in three principal steps:

- Receipt of the data from the reporting agencies (e.g., WANO, INPO, COG, EUCG, etc.) and posting of this data to OPG-consolidated spreadsheets
- Custom calculations of the data as needed (e.g., development of two- or three-year rolling averages if not directly reported as such)
- Development of tables and charts comparing OPG performance to that of associated peer panels

ScottMadden independently validated steps 2 and 3 for available data. We were unable to directly validate step 1 insofar as ScottMadden is not a member utility and does not have direct access to the underlying reports provided by these organizations. Membership rules restrict distribution to third parties. In validating step 2, OPG data and associated calculations were examined cell-by-cell. Data and calculations for other comparators were examined and validated in aggregate. Aggregate discrepancies could then be followed up by cell-by-cell examination to identify the source of the discrepancy. Where applicable, ScottMadden recreated custom data calculations from scratch.

Normalization Summary

The table below shows a summary of normalizing adjustments applied to TGC per MWh reflecting the application of normalizing adjustments for Refurbishment costs as well as adjustments for reactor type and unit age. A breakdown of Refurbishment normalizing adjustments for 2018 is shown in the Appendix.

[2] WANO Performance Indicators, 2018

Normalization Summary - TGC/MWh		
3-Year (2016-2018)	**Darlington**	**Pickering**
TGC/MWh - Non-Normalized	59.06	67.76
Total Generating Costs [TGC] (C $K)		
Non-Normalized TGC	3,847,416	4,215,170
Refurbishment Adjustment	(512,734)	-
Reactor Type Adjustment	(852,100)	(852,100)
Unit Age Adjustment	93,935	(55,131)
Normalized TGC	2,576,517	3,307,938
Generation (GWh)		
Non-Normalized Generation	65,147	62,210
Outage Adjustment	3,287	4,901
Normalized Generation	68,434	67,111
TGC/MWh - Fully Normalized	37.65	49.29

ScottMadden's Evaluation

Our evaluation found no material issues with OPG's assessments, calculations, or presentations of data in the benchmarking report. We provide additional context below for OPG's reporting of NPI, which differs from that reported by WANO but is nonetheless accurate and appropriate. In ScottMadden's 2015 review, we also recommended changes to the underlying data files, all of which have been implemented by OPG.

WANO NPI

ScottMadden made two observations of differences between OPG-calculated NPI scores and WANO output provided by OPG. We believe the differences are justified, accurate, and appropriate.

- OPG's calculation of DNGS's NPI performance in 2016 is 1.93 points higher than WANO's figure for the same period. This difference relates to Darlington Unit 2 Refurbishment. OPG pro-rated potential generation for the fourth quarter of 2016 to reflect the beginning of Darlington Unit 2 Refurbishment in October. The effect of the generation adjustment resulted in a higher Unit Capability Factor for Darlington Unit 2, and an increase in overall NPI performance. This better reflects operating reality for DNGS, which shut down only 16 days into the fourth quarter of 2016 rather than at the end of the quarter, which had 92 days.
- Other NPI scores for both DNGS and PNGS differ slightly from WANO's scores for 2016, 2017, and 2018. The differences relate to rounding: for each of the 10 metrics in the NPI calculation, a raw, or "indicator" value is multiplied by the metric's weighting to arrive at a point total. The point total for each metric is then added together to arrive at a total NPI score. WANO adds point totals for each metric rounded to the nearest tenth. OPG adds un-rounded, more precise point totals calculated in an Excel spreadsheet. The net differences of this slight arithmetic variation are not more than +/- 0.08 NPI points and are immaterial to OPG's quartile performance.

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7. USE OF BENCHMARKS IN THE BUSINESS PLANNING PROCESS

Approach

ScottMadden reviewed OPG's Nuclear Business Planning Procedure (N-PROC-AS-0080) against previous ScottMadden guidance and current industry leading practice.

Summary of Business Planning Process

OPG's nuclear business planning framework consists of five phases: (1) Performance Review, (2) Setting Strategic Direction, (3) Gap Closure Proposal, (4) Developing Detailed Business Plans, and (5) Performance Reporting. Over the course of this business planning cycle, nuclear performance is compared against the targets in the last business plan, new targets are set, and fleet-wide improvement initiatives to address performance gaps are formulated. Based on the approved strategic direction, generation, cost, and staffing plans are developed. Finally, performance is reported and monitored.

OPG has informed ScottMadden that during the 2020 business planning cycle, OPG plans to use three-year rolling average targets and normalized three-year rolling average targets for value for money metrics. The change is intended to better align with the metrics themselves, which are calculated as three-year rolling averages, and to reduce year-to-year volatility associated with Refurbishment operations. OPG will also continue to set one-year targets.

ScottMadden's Evaluation

We found that OPG's Nuclear Business Planning Procedure remains aligned with industry leading practice and ScottMadden's previous guidance. ScottMadden is comfortable with the OPG plan to set targets for three-year rolling averages for value for money metrics and we note that OPG will also continue to set one-year targets. We do not expect that the change from one-year targets to three-year targets for business planning will have any negative impact on the understanding of performance and associated goalsetting. It is possible that greater consistency will improve clarity and focus across the OPG organizations around these measures and targets. We are also comfortable with OPG similarly setting targets for normalized value for money metrics, as long as these normalized targets are always presented and pursued in conjunction with unadjusted (i.e., not normalized) targets.

8. CHANGES IN REPORT FORMAT AND PRESENTATION

Approach

We compared the 2014 and 2019 benchmarking reports for consistency in report format and presentation. Underlying data reflects changes in the availability of comparative data for the nuclear industry as well as changes in company performance.

Key Changes and their Justification

Changes to the 2019 report, compared with the 2014 report, include:

- Inclusion of call-out boxes in the "Key Highlights" section which explain trends for Pickering and Darlington performance in three out of the four nuclear cornerstones.

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- Expanded sections of the executive summary for each nuclear cornerstone. This provides greater context for benchmarking results overall.
- Placement of the executive summary nuclear cornerstone sections before sections on background, descriptions of performance indicators, industry peer groups, and report structure.

ScottMadden's Evaluation

It is ScottMadden's view that any changes from 2014 to 2019 were appropriate or immaterial to the overall purpose of the benchmarking analysis.

APPENDIX: BREAKDOWN OF DARLINGTON REFURBISHMENT NORMALIZING ADJUSTMENTS

Table 1 and Table 2 show the 2018 calculations of the percentages used in Scenario 2 and Scenario 3 in Table 3 below in accordance with the Darlington Refurbishment TGC/MWh normalization methodology. The cost attribution methodologies for Scenario 2 and Scenario 3 are explained in a separate document prepared by ScottMadden for OPG, “OPG Nuclear Cost Performance Benchmarking: Methodology to Adjust for Refurbishment and Validation of Implementation.”

Table 1: Calculation of FTE Percentage Used in Scenario 2

FTE *		
	2018	%
Refurb	986	43%
Darlington	1,311	57%
Total Refurb & Darlington FTE	2,297	

** Budget amounts utilized as per allocation methodology*

Table 2: Calculation of OM&A and Capital Cost Percentage Used in Scenario 3

OM&A and Capital Costs*		
	2018	%
Capital **		
Refurb	565.3	65%
Darlington	307.1	35%
Total Capital	872.4	
OM&A		
Refurb ***	69.4	16%
Darlington	375.1	84%
Total OM&A	444.5	
Total Costs		
Refurb	634.7	48%
Darlington	682.2	52%
Total Costs	1,316.9	

** Budget amounts utilized as per allocation methodology*

*** All Capital costs exclude External Purchased Services (EPS)*

**** Refurb OM&A includes Cyclical Outage*

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Table 3: Breakdown of 2018 Darlington Refurbishment Normalizing Adjustments

Darlington Refurb 2018 Cost Summary (C$k)

Group	OPG Method of Cost Attribution to DNGS	Total
Nuclear Station & Support	OM&A costs assigned to DNGS that are reasonably attributable to the unit(s) in Refurbishment should be removed: Cyclical Outage Costs	(63,768)
Chief Administrative Office		**(20,826)**
Environment	Scenario 1: Management Assignment or Proportionate Support Allocation	(629)
	Scenario 3: OM&A & Capital Blend	(856)
Legal, Ethics & Compliance (Less Enviro & Reg Affairs)	Scenario 1: Management Assignment or Proportionate Support Allocation	(478)
	Scenario 3: OM&A & Capital Blend	(2,072)
Real Estate & Services	Scenario 1: Management Assignment or Proportionate Support Allocation	(9,929)
	Scenario 3: OM&A & Capital Blend	(68)
Regulatory Affairs	Scenario 1: Management Assignment or Proportionate Support Allocation	(235)
	Scenario 3: OM&A & Capital Blend	(55)
Supply Chain	Scenario 1: Management Assignment or Proportionate Support Allocation	(5,474)
	Scenario 3: OM&A & Capital Blend	(850)
SVP & OPG 2025	Scenario 3: OM&A & Capital Blend	(180)
Corporate Office		**(3,643)**
Corporate Affairs	Scenario 1: Management Assignment or Proportionate Support Allocation	(1,568)
	Scenario 3: OM&A & Capital Blend	(1,926)
Executive Office	Scenario 3: OM&A & Capital Blend	(149)
Finance		**(10,141)**
Assurance & Enterprise Risk Mgmt	Scenario 1: Management Assignment or Proportionate Support Allocation	(326)
	Scenario 3: OM&A & Capital Blend	(775)
Corp Business Development & Strategy	Scenario 1: Management Assignment or Proportionate Support Allocation	(48)
	Scenario 3: OM&A & Capital Blend	(1,081)
Fund Management	Scenario 3: OM&A & Capital Blend	(283)
Treasury	Scenario 1: Management Assignment or Proportionate Support Allocation	(2,229)
	Scenario 3: OM&A & Capital Blend	(537)
Business Planning & Reporting	Scenario 1: Management Assignment or Proportionate Support Allocation	(96)
	Scenario 3: OM&A & Capital Blend	(1,319)
External Reporting & Policy	Scenario 3: OM&A & Capital Blend	(1,107)
Income Tax	Scenario 1: Management Assignment or Proportionate Support Allocation	(70)
	Scenario 3: OM&A & Capital Blend	(383)
Corporate Controllership	Scenario 3: OM&A & Capital Blend	(496)
Nuclear Finance	Scenario 1: Management Assignment or Proportionate Support Allocation	(1,144)
SVP Office & Chief Controller Office	Scenario 1: Management Assignment or Proportionate Support Allocation	(246)
Chief Information Office		**(19,051)**
CIO	Scenario 1: Management Assignment or Proportionate Support Allocation	(14,534)
	Scenario 3: OM&A & Capital Blend	(4,517)
People & Culture		**(9,034)**
Business Change & Talent	Scenario 1: Management Assignment or Proportionate Support Allocation	(539)
	Scenario 2: Full-Time Equivalents	(518)
Employee & Labour Relations and Health & Safety	Scenario 1: Management Assignment or Proportionate Support Allocation	(445)
	Scenario 2: Full-Time Equivalents	(1,452)
Business Partners	Scenario 1: Management Assignment or Proportionate Support Allocation	(607)
	Scenario 2: Full-Time Equivalents	(263)
Learning & Development	Scenario 1: Management Assignment or Proportionate Support Allocation	(4,230)
	Scenario 2: Full-Time Equivalents	(305)
SVP Office	Scenario 2: Full-Time Equivalents	(674)
Nuclear Support		**(62,969)**
Direct Report	Scenario 4: Number of Operating Units	(2,821)
Fleet Ops Maintenance & Training	Scenario 4: Number of Operating Units	(5,159)
Inspection & Reactor Innovation	Scenario 4: Number of Operating Units	(3,462)
Nuclear Engineering	Scenario 4: Number of Operating Units	(23,418)
Nuclear Oversight	Scenario 4: Number of Operating Units	(565)
Nuclear Reg Affairs & Stakeholder	Scenario 4: Number of Operating Units	(4,424)
Nuclear Training	Scenario 4: Number of Operating Units	(3,597)
Nuclear Waste Management	Scenario 4: Number of Operating Units	(157)
Projects & Modifications and Enterprise Projects	Scenario 4: Number of Operating Units	(9,489)
Security & Emergency Services	Scenario 3: OM&A & Capital Blend	(143)
	Scenario 4: Number of Operating Units	(9,733)
Nuclear Station		**(59,960)**
PNGS	Scenario 4: Number of Operating Units	(15)
Nuclear Sustaining Capital Cost	Sustaining Capital Cost Common to All Units at DNGS	(59,945)
Grand Total		**(249,392)**

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OPG Nuclear Cost Performance Benchmarking

Methodology to Adjust for Refurbishment and Validation of Implementation

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1. BACKGROUND

Context and ScottMadden's View

Darlington Nuclear Generating Station (DNGS) is one of two nuclear stations operated by Ontario Power Generation (OPG). DNGS is a four-unit station with a net output of 3,512 megawatts (MW), and it has been producing almost 20 percent of Ontario's electricity needs since the early 1990s. OPG is performing a major mid-life refurbishment of the four reactors at DNGS (Refurbishment), which involves the replacement of certain life-limiting components. The execution of the Refurbishment "mega-project" started in October 2016 with breaker-open on Unit 2.

OPG tracks and benchmarks the performance of DNGS against industry peers under its nuclear cornerstone of value for money using a suite of four cost metrics. OPG believes that two of these cost metrics, Total Generating Cost per MWh (TGC per MWh) and Non-Fuel Operating Cost per MWh (NFOC per MWh), will not be comparable to prior site performance or industry peers during Refurbishment as a result of significantly reduced MWhs of generation with no corresponding decline in costs, which are largely fixed. In order to ensure that DNGS performance can be tracked and benchmarked during Refurbishment, OPG intends to "normalize," or adjust to facilitate comparison of these two cost metrics.

ScottMadden's view:

- Refurbishment is a unique "mega-project," and the experience and perspective of other industry professionals, while useful to consider, cannot provide established practice for normalizing cost metrics during this unique project
- ScottMadden concurs with OPG that Refurbishment will significantly impact station performance indicators for these two cost metrics and that normalization will be necessary to facilitate useful comparisons to past performance and industry peers
- ScottMadden supports OPG's decision to continue to report an unadjusted (i.e., not normalized) version of these cost metrics in conjunction with any normalized version
- ScottMadden found that a more strongly supported and conventional approach to normalization of cost metrics was to adjust the distribution of actual costs to reflect performance of the operating units while using actual MWhs generated in the denominator.

Explanation of the Specific Issue

Four different Value for Money (VFM) Metrics, hereafter referred to as Cost Metrics, are used by OPG to measure its Nuclear Stations' performance and to benchmark against industry standards.

1. Total Generating Cost (TGC) per MWh
2. Non-Fuel Operating Cost (NFOC) per MWh[1]
3. Fuel Cost per MWh
4. Capital Cost per MW Design Electrical Rating[2]

[1] Non-Fuel Operating Cost (NFOC) is "total operating, maintenance & administrative cost" which is comprised of station cost, as well as attributed centralized nuclear support cost and attributed corporate support and certain centrally-held costs

[2] "Capital cost per MW," as a standalone metric uses MW Design Electrical Rating (DER) as the denominator, but nominal dollars of capital cost also contribute to the numerator in the "Total Generation Cost (TGC) per MWh" metric

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For benchmarking purposes, Cost Metrics follow the guidance provided by the Electric Utility Cost Group (EUCG) in the Nuclear Committee Nuclear Database Instructions. The first two Cost Metrics, TGC per MWh and NFOC per MWh, will not be comparable to peers (or steady state operations) during the Refurbishment for two key reasons:

1. Lower generation (MWhs in the denominator) while the Darlington units are offline and not generating electricity
2. Fixed costs which do not scale up or down proportionally with how much electricity the Darlington units generate[3]

At OPG, the following non-fuel costs are attributed to the nuclear operating stations:

- Corporate support Operating, Maintenance and Administrative (OM&A) costs
- Nuclear centralized support OM&A costs
- Nuclear station OM&A costs (excluding Refurbishment OM&A costs)
- Nuclear capital costs (excluding Refurbishment capital costs)
- Minor fixed assets
- Certain centrally held costs

2. ABOUT THE SCOTTMADDEN APPROACH

Scope, Objectives, Assumptions and Qualifications

ScottMadden is leveraging prior work, including industry research, to outline a preferred methodology through which two of Darlington's cost performance benchmarks can be normalized:

- TGC per MWh
- NFOC per MWh

The objective of this work is to facilitate useful comparisons to past performance and industry peers for the operating plant at DNGS during the extended time periods in which certain units will be offline due to Refurbishment. ScottMadden intends to accomplish this objective by:

- Clarifying which types of costs for a unit in Refurbishment could be reasonably adjusted
- Explaining how such an adjustment might be performed
- Documenting this guidance for use by OPG

In preparing this document, ScottMadden assumed that OPG attributes costs in a manner that is consistent with the description OPG shared with ScottMadden outlining the cost attribution methodologies, particularly for corporate support and nuclear support.

ScottMadden's recommendation is subject to the following qualifications:

- ScottMadden does not imply the performance of any additional, specific research beyond what is described in this document

[3] Fuel Cost per MWh and Capital Cost will continue to be comparable because fuel cost varies proportionally with generation and Capital Cost per MW DER will not be impacted by lower generation during refurbishment

- ScottMadden does not express an opinion in this document on the effectiveness of cost management practices at OPG or the appropriateness of any costs incurred by OPG
- The ScottMadden methodology was prepared for the benefit of OPG and is limited to the subject matter expressly stated in this document; no additional ScottMadden opinion is implied or may be inferred

About Cost Attribution

Like any major corporation, particularly one that employs a center-led model to provide functional support to the business, OPG employs cost attribution methods intended to appropriately assign costs to the business in a manner that is consistent with demands for the associated services.

As previously noted, TGC and NFOC at DNGS include station cost and as well as nuclear support and corporate support costs. To compare the cost performance per MWh of the operating plant to industry peers, OPG must adjust the distribution of these costs to focus only on the operating units.

In order to provide a methodology for making such an adjustment, ScottMadden developed an understanding of current cost attribution methods employed by OPG and accepted by the Ontario Energy Board (OEB). The scope of ScottMadden support did not include evaluation of the design or application of the current cost attribution methodologies.

3. METHODOLOGY TO ADJUST FOR REFURBISHMENT

Methodology Summary

As previously stated, TGC and NFOC at DNGS include station costs, nuclear support costs, and corporate support costs. The services provided by the support groups can be assigned directly to DNGS or attributed indirectly based on defined methodologies. In addition to these services, a relatively small amount of engineering and technical service OM&A costs is also attributed to DNGS from the Renewable Generation (RG) business.

The focus of the ScottMadden methodology is to allow OPG, after some detailed accounting work, to adjust the distribution of OM&A and capital costs to estimate what TGC and NFOC would look like if DNGS was presently a three-unit site rather than a four-unit site (as Unit 2 entered Refurbishment in October 2016 and remains offline). ScottMadden has examined OPG cost items and current attributions in order to identify costs that can be reasonably adjusted out to create a normalized TGC per MWh and NFOC per MWh.

The intent of normalizing the metric in this way is to facilitate useful comparisons to past performance and industry peers for the operating plant at DNGS during the extended time periods in which certain units will be offline due to Refurbishment. Within the methodology, ScottMadden provides specific guidance for each type of cost, taking into consideration how costs are currently attributed as well as the nature of the work associated with the cost.

The normalization methodology makes provision to remove OM&A and capital costs from TGC that are reasonably attributable to the unit(s) in Refurbishment.[4] While a portion of Darlington's capital costs are captured by this provision, ScottMadden is aware of certain other capital expenditures intended to support post-refurbishment operations that have not been classified by OPG as Refurbishment capital and therefore have an unfavorable impact on Darlington's TGC/MWh performance.

ScottMadden is also aware of the lost generation impact for the station associated with bulkhead installation and removal as part of the Refurbishment program. While ScottMadden acknowledges that this activity would have an unfavorable impact on Darlington's TGC per MWh performance, this type of adjustment is outside the scope of the normalization methodology set out in this report, which focuses on adjusting the distribution of costs.

Corporate Support OM&A Cost Attribution

In this section, ScottMadden identifies how each type of Corporate Support cost[5] should be removed for the purposes of normalization for both the costs directly assigned to DNGS and the costs attributed to DNGS via the OPG methodology. There are multiple scenarios to consider, and each is described below along with the specific instructions for the recommended adjustment to the associated costs.

- **Scenario 1: Management Assignment or Proportionate Support Allocation**
  - The OPG methodology attributes certain costs to DNGS based on management assignment or proportionate support allocation. Management assignment includes direct assignment and management time estimates of FTEs or other resources. Proportionate support allocation attributes certain corporate support costs in the same ratio as other corporate support costs based on the OPG allocation methodology
  - In this case, the costs attributed to DNGS can be reduced to adjust for the impact of Refurbishment by "(number of operating units in Refurbishment) divided by (total number of operating units at DNGS)"
- **Scenario 2: Full-Time Equivalents**
  - The OPG methodology attributes certain costs to DNGS based on the number of FTEs at the station relative to the total number of FTEs supported
  - In this case, to the extent station FTEs are reasonably attributable to the unit(s) in Refurbishment, DNGS costs can be reduced by "(number of station FTEs supporting Refurbishment) divided by (total number of station FTEs)"
- **Scenario 3: OM&A and Capital Blend**
  - The OPG methodology attributes certain costs to DNGS based on OM&A and capital dollar blend specific to the station relative to total blended OM&A and capital costs[6]
  - In this case, to the extent OM&A and capital costs are reasonably attributable to the unit(s) in Refurbishment, DNGS costs can be reduced by "(OM&A and capital

[4] Normalization of centrally held OM&A costs included in the cost performance benchmarks is outside the scope of the normalization methodology set out in this report

[5] Includes OM&A components of asset service fees charged to the nuclear business unit for the use of common corporate assets.

[6] Capital costs used in the calculation of the OM&A and Capital Blend allocator exclude external purchased services

costs attributable to Refurbishment) divided by (total OM&A and capital costs for DNGS)"

The following table sets out each group of costs and the associated cost attribution scenario, based on OPG's 2017 organizational structure. By applying the prescribed actions outlined above to each of the corresponding groups of costs, new TGC and NFOC values, adjusted for Refurbishment, can be calculated and divided by actual MWh of generation to produce the normalized measures of value for money.

Group	OPG Method of Cost Attribution to DNGS
Chief Administrative Office	
Environment	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 3: OM&A and Capital Blend
Law	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 3: OM&A and Capital Blend
Real Estate & Services	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 3: OM&A and Capital Blend
Regulatory Affairs	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 3: OM&A and Capital Blend
Supply Chain	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 3: OM&A and Capital Blend
Corporate Office	
Corporate Affairs	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 3: OM&A and Capital Blend
Executive Office	Scenario 3: OM&A and Capital Blend

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Group	OPG Method of Cost Attribution to DNGS
Finance	
Assurance and Enterprise Risk Management	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 3: OM&A and Capital Blend
Corporate Business Development and Strategy	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 3: OM&A and Capital Blend
Fund Management	Scenario 3: OM&A and Capital Blend
Treasury (including Insurance)	Scenario 3: OM&A and Capital Blend
Business Planning and Reporting	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 3: OM&A and Capital Blend
External Reporting and Policy	Scenario 3: OM&A and Capital Blend
Income Tax	Scenario 3: OM&A and Capital Blend
Nuclear Finance	Scenario 1: Management Assignment or Proportionate Support Allocation
Corporate Controllership	Scenario 3: OM&A and Capital Blend
Shared Financial Services	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 3: OM&A and Capital Blend
SVP Office and Chief Controller Office	Scenario 1: Management Assignment or Proportionate Support Allocation
Chief Information Office	
Infrastructure Management (outsourced)	Scenario 1: Management Assignment or Proportionate Support Allocation
Application Management (outsourced)	Scenario 1: Management Assignment or Proportionate Support Allocation
Data Center Services (outsourced)	Scenario 1: Management Assignment or Proportionate Support Allocation
Other IT Services (outsourced)	Scenario 1: Management Assignment or Proportionate Support Allocation
IT Support Costs (internal)	Scenario 1: Management Assignment or Proportionate Support Allocation
Projects	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 3: OM&A and Capital Blend
Business Infrastructure Services	Scenario 1: Management Assignment or Proportionate Support Allocation

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Group	OPG Method of Cost Attribution to DNGS
People & Culture	
Business Change and Talent	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 2: Full-Time Equivalents
Employee & Labor Relations	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 2: Full-Time Equivalents
Total Rewards & Solutions	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 2: Full-Time Equivalents
Business Partners	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 2: Full-Time Equivalents
Health and Safety	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 2: Full-Time Equivalents
Learning & Development	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 2: Full-Time Equivalents
SVP Office	Scenario 2: Full-Time Equivalents

Nuclear Support and Station OM&A Cost Attribution

In this section, ScottMadden identifies how each type of Nuclear Support or Station cost should be removed for the purposes of normalization for both the costs directly assigned to DNGS and the costs attributed to DNGS via the OPG methodology. As mentioned, ScottMadden assumed that OPG attributes costs in a manner that is consistent with the descriptions OPG provided to ScottMadden of the Nuclear cost attribution methodology. OPG indicated that the attribution methodology is driven by the two scenarios described below:

- **Scenario 1: Management Assignment or Proportionate Support Allocation**
  - The OPG methodology attributes certain costs to DNGS based on management assignment or proportionate support allocation. Management assignment includes direct assignment and management time estimates of FTEs or other resources. Proportionate support allocation attributes certain corporate support costs in the same ratio as other corporate support costs based on the OPG allocation methodology
  - In this case, the costs attributed to DNGS can be reduced to adjust for the impact of Refurbishment by “(number of operating units in Refurbishment) divided by (total number of operating units at DNGS)”
- **Scenario 4: Number of Operating Units**
  - The OPG methodology attributes certain costs to DNGS and PNGS at 40% and 60% based on the number of operating units between the two stations
  - Given this allocation approach is based on operating units, DNGS costs can be reduced by “(number of operating units in Refurbishment) divided by (total number of operating units at DNGS)”

The following table sets out each group of costs and the associated attribution scenario, based on OPG’s 2017 organizational structure. By applying the prescribed actions outlined above to each of the corresponding groups of costs, new TGC and NFOC values, adjusted for

Refurbishment, can be calculated and divided by actual MWh of generation to produce the normalized measures of value for money.

Group	OPG Method of Cost Attribution to DNGS
Nuclear Support	
Direct Report	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 4: Number of Operating Units
Fleet Ops Maintenance & Training	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 4: Number of Operating Units
Inspection & Maintenance Services	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 4: Number of Operating Units
Nuclear Engineering	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 4: Number of Operating Units
Nuclear Oversight	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 4: Number of Operating Units
Nuclear Reg Affairs & Stakeholder	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 4: Number of Operating Units
Nuclear Waste Management	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 4: Number of Operating Units
Projects & Modifications	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 4: Number of Operating Units
Security & Emergency Services	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 4: Number of Operating Units
Nuclear Station	
DNGS	Scenario 1: Management Assignment or Proportionate Support Allocation
PNGS	Scenario 1: Management Assignment or Proportionate Support Allocation Scenario 4: Number of Operating Units

Nuclear Sustaining Capital Cost Attribution

In this section, ScottMadden identifies how sustaining capital costs associated with DNGS should be removed for the purposes of normalization for both the costs directly associated with the unit(s) under Refurbishment and those that are common to all units of the station

- **Sustaining Capital Cost for Unit(s) under Refurbishment** – ScottMadden recommends that the sustaining capital costs attributed to DNGS that are directly associated with the unit(s) under refurbishment should be excluded in full for normalization purposes
- **Sustaining Capital Cost Common to All Units at DNGS** – ScottMadden recommends that the sustaining capital costs attributed to DNGS that are common to all units of the station be excluded on the basis of “(number of operating units in Refurbishment) divided by (total number of operating units at DNGS)”

By applying the prescribed actions outlined above to each of the corresponding groups of costs, new TGC and NFOC values, adjusted for Refurbishment, can be calculated and divided by actual MWh of generation to produce the normalized measures of value for money.

4. SCOTTMADDEN VALIDATION OF OPG ADJUSTMENT

Adjustment Outcome

Following the documented methodology guidance, OPG independently performed the adjustment and normalized costs for 2017 by $263.3M, resulting in:

- Decrease of 3-year TGC/MWh from 54.40 to 50.54 for 2017
- Decrease of 3-year NFOC/MWh from 39.62 to 36.89 for 2017

ScottMadden has reviewed the work to validate that:

- The approach OPG followed was in accordance with ScottMadden guidance
- OPG accurately performed the calculations

Validation

ScottMadden reproduced the OPG implementation of the methodology, adhering to OPG's described methods of cost attribution to DNGS to closely compare subtotals. Comparison of OPG's total calculated reduction and ScottMadden's total calculated reduction revealed no variance. ScottMadden found that OPG correctly interpreted and implemented the guidance provided.

OM&A and Capital Costs Calculation

For several types of costs allocated to DNGS (Scenario 3), the methodology directs that DNGS costs in a given year can be reduced by a calculated percentage found by:

$$\frac{OM\&A\ and\ capital\ costs\ attributable\ to\ Refurb}{Total\ OM\&A\ and\ capital\ costs\ for\ DNGS}$$

OPG's calculation is displayed in the table below. ScottMadden validated that OPG implemented the methodology correctly to arrive at an adjustment value of 45% for OM&A and capital cost blend attributable adjustments:

OM&A and Capital Costs Budget*		
	2017	**%**
Capital		
Refurb	375	64%
Darlington	207	36%
Total Capital	582	
OM&A		
Refurb	91	20%
Darlington	373	80%
Total OM&A	464	
Total Costs		
Refurb	466	45%
Darlington	580	55%
Total Costs	1,046	

** All Capital costs exclude External Purchased Services (EPS)*

FTE Calculation

For several types of costs allocated to DNGS (Scenario 2), the methodology directs that DNGS costs in a given year can be reduced by a calculated percentage found by:

$$\frac{Number\ of\ station\ FTEs\ supporting\ Refurbishment}{Total\ number\ of\ station\ FTEs}$$

OPG's calculation is displayed in the table below. ScottMadden validated that OPG implemented the methodology correctly to arrive at an adjustment value of 41% for adjustments attributable to number of FTEs at the station:

Budget FTE		
	2017	**%**
Refurb	862	41%
Darlington	1,253	59%
Total FTE	2,114	

Table of Adjustments

The table on the following two pages outlines the adjustments, organized by method of adjustment according to cost category and methodology.

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Group	OPG Method of Cost Attribution to DNGS	Reduction ($K)
Nuclear Station and Support	OM&A costs assigned to DNGS that are reasonably attributable to the unit(s) in Refurbishment should be removed: Cyclical Outage Costs	$ (57,894)
Chief Administrative Office		
Environment	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (685)
	Scenario 3: OM&A and Capital Blend	$ (629)
Law	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (590)
	Scenario 3: OM&A and Capital Blend	$ (1,531)
Real Estate & Services	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (8,553)
	Scenario 3: OM&A and Capital Blend	$ (319)
Regulatory Affairs	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (262)
	Scenario 3: OM&A and Capital Blend	$ (51)
Supply Chain	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (5,012)
	Scenario 3: OM&A and Capital Blend	$ (673)
Corporate Office		
Corporate Affairs	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (1,837)
	Scenario 3: OM&A and Capital Blend	$ (1,734)
Executive Office	Scenario 3: OM&A and Capital Blend	$ (465)
Finance		
Assurance and Enterprise Risk Management	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (290)
	Scenario 3: OM&A and Capital Blend	$ (682)
Corporate Business Development and Strategy	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (95)
	Scenario 3: OM&A and Capital Blend	$ (866)
Fund Management	Scenario 3: OM&A and Capital Blend	$ (256)
Treasury (including Insurance)	Scenario 3: OM&A and Capital Blend	$ (2,555)
Business Planning and Reporting	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (81)
	Scenario 3: OM&A and Capital Blend	$ (1,233)
External Reporting and Policy	Scenario 3: OM&A and Capital Blend	$ (959)
Income Tax	Scenario 3: OM&A and Capital Blend	$ (533)
Nuclear Finance	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (1,353)
Corporate Controllership	Scenario 3: OM&A and Capital Blend	$ (510)
Shared Financial Services	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (138)
	Scenario 3: OM&A and Capital Blend	$ (2,097)
SVP Office and Chief Controller Office	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (149)
Chief Information Office		
CIO	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (13,167)
	Scenario 3: OM&A and Capital Blend	$ (3,970)

Table continues on the next page.

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Group	OPG Method of Cost Attribution to DNGS	
People & Culture		
Business Change and Talent	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (567)
	Scenario 2: Full-Time Equivalents	$ (318)
Employee & Labor Relations and Health & Safety	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (315)
	Scenario 2: Full-Time Equivalents	$ (1,692)
Total Rewards & Solutions	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (364)
	Scenario 2: Full-Time Equivalents	$ (1,551)
Business Partners	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (443)
	Scenario 2: Full-Time Equivalents	$ (110)
Learning & Development	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (7,733)
	Scenario 2: Full-Time Equivalents	$ (252)
SVP Office	Scenario 2: Full-Time Equivalents	$ (618)
Nuclear Support		
Direct Report	Scenario 1: Management Assignment or Proportionate Support Allocation	
	Scenario 4: Number of Operating Units	$ (746)
Fleet Ops Maintenance & Training	Scenario 1: Management Assignment or Proportionate Support Allocation	
	Scenario 4: Number of Operating Units	$ (6,679)
Inspection & Maintenance Services	Scenario 1: Management Assignment or Proportionate Support Allocation	
	Scenario 4: Number of Operating Units	$ (4,363)
Nuclear Engineering	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (3)
	Scenario 4: Number of Operating Units	$ (25,041)
Nuclear Oversight	Scenario 1: Management Assignment or Proportionate Support Allocation	
	Scenario 4: Number of Operating Units	$ (532)
Nuclear Reg Affairs & Stakeholder	Scenario 1: Management Assignment or Proportionate Support Allocation	
	Scenario 4: Number of Operating Units	$ (3,772)
Nuclear Waste Management	Scenario 1: Management Assignment or Proportionate Support Allocation	
	Scenario 4: Number of Operating Units	$ (121)
Projects & Modifications and Enterprise Projects	Scenario 1: Management Assignment or Proportionate Support Allocation	
	Scenario 4: Number of Operating Units	$ (12,291)
Security & Emergency Services	Scenario 1: Management Assignment or Proportionate Support Allocation	$ (138)
	Scenario 4: Number of Operating Units	$ (9,776)
Nuclear Station		
DNGS	Scenario 1: Management Assignment or Proportionate Support Allocation	
PNGS	Scenario 1: Management Assignment or Proportionate Support Allocation	
	Scenario 4: Number of Operating Units	$ (5)
Nuclear Sustaining Capital Cost	Sustaining Capital Cost for Unit(s) under Refurbishment	$ (29,082)
	Sustaining Capital Cost Common to All Units at DNGS	$ (47,660)
Grand Total		**$ (263,342)**

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OPG Nuclear Cost Performance Benchmarking

A Study of Factors Impacting TGC / MWh Performance with Normalizing Adjustments to Facilitate Closer Comparison

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1. BACKGROUND

Context

Pickering Nuclear Generating Station (PNGS) is one of two nuclear stations operated by Ontario Power Generation (OPG). PNGS has six operating units (two additional units ended commercial operations in 1997), a net output of 3,094 megawatts (MW) and produces about 14 percent of Ontario's electricity needs. The site has been operating since 1971.

Darlington Nuclear Generating Station (DNGS) is one of two nuclear stations operated by Ontario Power Generation (OPG). DNGS is a four-unit station with a net output of 3,512 megawatts (MW), and it has been producing almost 20 percent of Ontario's electricity needs since the early 1990s. OPG is performing a major mid-life refurbishment of the four reactors at DNGS (Refurbishment), which involves the replacement of certain life-limiting components. The execution of the Refurbishment "mega-project" started in October 2016 with breaker-open on Unit 2.

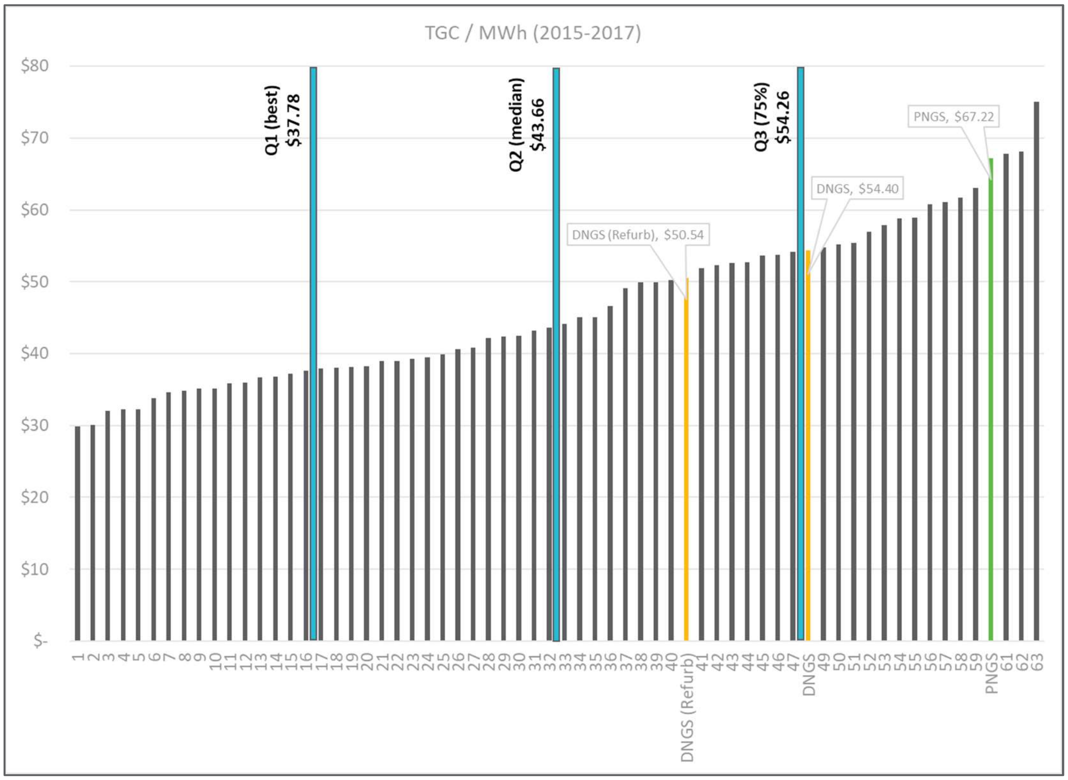
OPG tracks and benchmarks the performance of PNGS and DNGS against industry peers under its nuclear cornerstones of Safety, Reliability, Human Performance, and Value for Money. Value for Money is measured relative to an Electric Utility Cost Group (EUCG) panel of nuclear plants in North America using a suite of four cost metrics. One of these metrics, Total Generating Cost per Megawatt-Hour (TGC/MWh), has recently shown DNGS and PNGS ranking below the median relative to the panel.

OPG benchmarks performance in TGC/MWh relative to peers and sets goals for performance each year. Based on operating experience, OPG believes that certain characteristics that cannot be controlled by how well they operate DNGS and PNGS are having a meaningful influence on TGC/MWh performance. ScottMadden agrees that such static characteristics impact performance as measured by TGC/MWh. Thus, OPG asked ScottMadden to perform an independent study to determine whether and how such site characteristics influence TGC/MWh performance for a nuclear plant.

Current TGC/MWh Performance

Using the EUCG data provided by OPG, TGC/MWh performance for the most recent three-year time period (2015-2017) for PNGS and DNGS appear in the fourth quartile relative to the other sites. However, TGC/MWh performance for DNGS must be adjusted to account for the ongoing Refurbishment. ScottMadden provided OPG with a specific methodology for performing this adjustment under a separate study. The result of the adjustment was a relative improvement in TGC/MWh performance for DNGS to the third quartile, as illustrated below.

TGC/MWh performance 2015-'17 for EUCG Panel with DNGS Adjusted for Refurbishment



2. ABOUT THE SCOTTMADDEN APPROACH

Scope and Objectives

The ScottMadden study of the influence of site characteristics on TGC/MWh focused on two major areas of investigation:

- **Econometric Analysis** – analysis of EUCG data to understand and quantify the impact of certain site characteristics on total generating cost (TGC)
- **Custom Nuclear Outage Benchmarking Study** – primary research and analysis on nuclear outages across the industry to determine expected impacts on energy production (MWh)

The objectives of this investigation were to 1) determine whether and to what extent relatively static characteristics of a nuclear site influence TGC/MWh performance and 2) if possible, quantify and adjust for these characteristics to produce normalized TGC/MWh values that account for site characteristics that have a significant impact on TGC/MWh performance.

Assumptions and Qualifications

In performing this study and preparing this document, ScottMadden assumes that all EUCG data provided by OPG for this effort and all industry responses to the nuclear outage benchmarking study led by ScottMadden were complete and accurate.

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This ScottMadden report is also subject to the following qualifications:

- ScottMadden does not imply the performance of any additional, specific research beyond what is described in this document.
- ScottMadden does not express an opinion in this document on the effectiveness of management practices at OPG or the appropriateness of any of OPG's costs, outage durations, or other performance characteristics.
- The ScottMadden methodology was prepared for the benefit of OPG and is limited to the subject matter expressly stated in this document; no additional ScottMadden opinion is implied or may be inferred.

3. EXECUTIVE SUMMARY

ScottMadden focused on two major areas of investigation, econometric analysis and a custom nuclear outage benchmarking study.

In the econometric analysis, ScottMadden analyzed nine years of EUCG data (from 2009 to 2017) and 567 data points to understand which site characteristics most influence TGC over a sustained period and to what extent. We used multiple linear regression (MLR) to quantify the relationships between various combinations of reactor type, site capacity, number of units, unit size, and unit age (the independent variables) and the EUCG data for site costs (TGC, the dependent variable). Through this analysis, we were able to develop a powerful predictive model for TGC that explains ~79% of the variability in TGC across the dataset using reactor type, site capacity, and unit age. The model indicates:

- CANDU technology increases predicted TGC by over C$250[1] million per year relative to non-CANDU plants
- Each MW of site capacity increases predicted TGC by C$261 thousand per year
- Each month of average unit age increases predicted TGC by C$346 thousand per year

Once ScottMadden established a mathematically-sound quantification of the impact these site characteristics have on TGC, we adjusted for all sites in the EUCG dataset to account for these factors. However, to be conservative and ensure adjustments were easy to understand, we only performed adjustments for reactor type and unit age.

- The result of these adjustments on TGC/MWh performance was an improvement in relative performance for PNGS from 60th to 51st out of the 63 sites in the EUCG panel.
- DNGS improved from 48th to 31st after performing the same adjustments and also adjusting for refurbishment work, as previously documented and validated.

ScottMadden also initiated a custom nuclear outage benchmarking study to understand better how outage work differs across reactor technologies (BWR, CANDU, and PWR) and operators. The study used a variety of data sources, chief among them a direct survey of nuclear operators, in which

[1] All C$ values in this document are in 2017 dollars, unless otherwise indicated

responses were confidential and participation was sufficient to represent each of the three reactor technologies (19 CANDU plants, 9 BWR plants, and 19 PWR plants) in the results.

ScottMadden focused only on quantifying and adjusting for the impact of regularly recurring, planned maintenance outages on power generation, taking steps to arrive at an average annual value for days offline due to these planned outages. The output of this exercise is represented in the table below.

Reactor Type	Outage Cycle	Median Average Planned Outage Days Per Year	Incremental Additional Outage Days Per Year Above Shortest Duration
BWR	18-month cycle[2]	Not represented in study	
	24-month cycle	14 days	
PWR	18-month cycle	19 days	5 days
	24-month cycle	14 days	0 days
CANDU	24-month cycle	18 days	4 days
	30-month cycle	36 days	22 days
	36-month cycle	27 days	13 days

ScottMadden adjusted for these outage requirements by normalizing the annual values for MWh of production at each plant. Specifically, if a plant in the dataset had a reactor type and outage cycle combination that, on average, required additional outage days above the shortest duration, we added those incremental additional days back to total production for the year using the site summer capacity[3] at 100% utilization. If a plant had a reactor type and outage cycle combination that did not require additional outage days (i.e., all BWRs and PWRs on 24-month outage cycles), we left total production values unchanged.

- The result of these adjustments on TGC/MWh performance was further improvement in relative performance for PNGS from 51st to 47th out of the 63 sites in the EUCG panel, or third quartile.
- DNGS also further improved from 31st to 29th, or second quartile, after performing the same adjustments.

[2] Of the 63 operators in the EUCG dataset, only two single-unit plants are reported to be on an 18-month maintenance cycle during the 2015-2017 timeframe, and these plants were not represented in our survey of nuclear operators. Thus, for the purposes of this study, we assumed that 18-month cycle BWRs have the same annualized median outage duration as 24-month cycle BWRs.

[3] From the EIA 860 form, retrieved through SNL database, as opposed to nameplate capacity or winter capacity, which are often higher values

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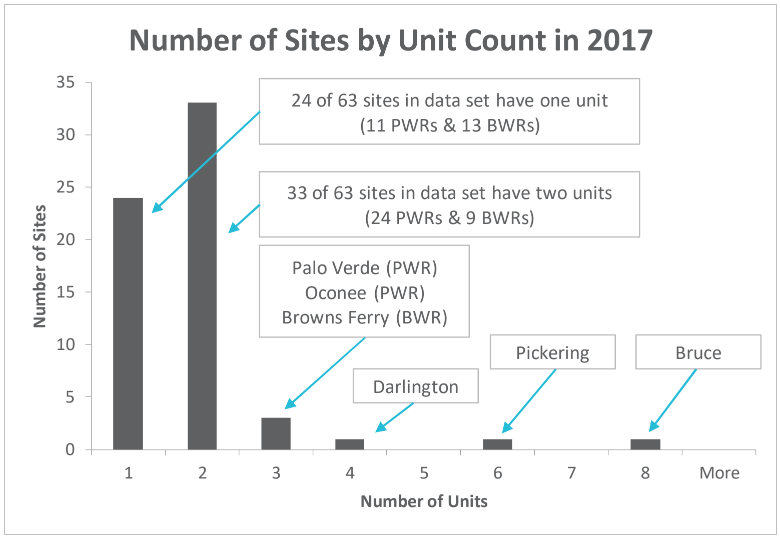
4. ECONOMETRIC ANALYSIS

About the Data

ScottMadden analyzed EUCG data to understand and quantify the impact of certain site characteristics on total generating cost (TGC) and cost performance (TGC/MWh). In this study, ScottMadden analyzed nine years of EUCG data (from 2009 to 2017) to understand which site characteristics most influence TGC over a sustained period and to what extent. The dataset used for this analysis includes:



- 63 nuclear sites and 567 total data points (one / site / year)
- Three reactor types:
    - PWRs – 37 sites
    - BWRs – 23 sites
    - CANDUs – 3 sites
- Nuclear sites with a median capacity of 1,737 MW, median unit capacity of 967 MW, and median average unit age of 397 months (~33 years)[4]
- Primarily sites with either one or two units (57 of 63), but:
    - Three sites (two PWRs and one BWR) with three units
    - One site with four units (CANDU – Darlington)
    - One site with six units (CANDU – Pickering)
    - One site with eight units (CANDU – Bruce)

It is worth noting that there are few CANDU plants in the EUCG data and the technology differs in important ways from the PWR and BWR plants. For example, CANDU plants

- Have greater numbers of smaller capacity units but larger total site capacities
- Have different online and outage maintenance requirements but can be refueled online
- Operate in Canada and are subject to a different regulatory and market environment than PWRs and BWRs operating in the US

ScottMadden used the EUCG data described above to analyze how certain site characteristics influence nuclear site costs. Before performing this analysis, ScottMadden adjusted dollar values for inflation to ensure that we could establish mathematical relationships that persisted across the nine-year dataset. Specifically, we adjusted Total Generating Costs (TGC) from 2009 to 2017 for inflation using the Gross Domestic Product Implicit Price Index Final Domestic Demand (GDP-IPI FDD) in Canada from Statistics Canada, converting all TGC values to 2017 dollars. ScottMadden found this a

[4] This number is not reflective of the current median average unit age of nuclear sites in the panel because average unit age was calculated for each year in the dataset at that specific point in time

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reasonable index to use and favored it over others for this application as it is preferred by the Ontario Energy Board (OEB).[5]

Predictive Model for Total Generating Costs

ScottMadden focused the analysis on characteristics that cannot be controlled by how well a site is operated but are likely to have a meaningful influence on site costs, including:

- Reactor type – CANDU, PWR, or BWR
- Site capacity – total site capacity across all operating units (MW)
- Number of units – total number of operating units at the site
- Unit size – average capacity of the units at the site (MW)
- Unit age – average age of the units at the site (months)

Specifically, ScottMadden used Multiple Linear Regression (MLR) to quantify the relationships between various combinations of the above site characteristics (the independent variables) and the EUCG data for, separately, site costs (TGC) and cost performance (TGC/MWh). While we were unable to develop a sufficiently predictive model for cost performance (TGC/MWh) directly, we were able to develop a powerful predictive model for site costs (TGC).

Our TGC model explains ~79% of the variability in TGC with reactor type, site capacity, and unit age and indicates:

- CANDU technology increases TGC relative to PWR and BWR reactor types
- Greater site capacity increases TGC
- Higher average unit age increases TGC

The specific, mathematical model for site costs in thousands of Canadian dollars (C$k) is: $f(TGC\ per\ year) = (-255{,}421 * (PWR)) + (-283{,}946 * (BWR)) + (261 * (site\ capacity)) + (346 * (unit\ age)) + 302{,}477$. Each coefficient in the formula is the estimated change in TGC corresponding to one unit change in that associated variable when all other variables are held constant. Specifically:

- If the PWR value is 1, indicating it is a PWR reactor, predicted TGC would decrease by C$255,421k (2017); If 0, it will remain unchanged
- If the BWR value is 1, indicating it is a BWR reactor, predicted TGC would decrease by C$283,946k (2017); If 0, it will remain unchanged
- For each MW of site capacity, predicted TGC would increase by C$261k (2017)
- For each month of average unit age, predicted TGC would increase by C$346k (2017)

[5] GDP-IPI FDD is an inflation factor that is commonly-used and frequently referenced by the OEB in multiple documents, including the most recent rate decision for OPG, EB-2016-0152.

Put more simply, with all other variables held constant:

- CANDU technology increases predicted TGC by over C$250 million per year relative to non-CANDU plants
- Each MW of site capacity increases predicted TGC by C$261 thousand per year
- Each month of average unit age increases predicted TGC by C$346 thousand per year

Once we established a mathematically-sound quantification of the impact these site characteristics have on TGC, we adjusted for all sites in the EUCG data set to account for these factors. However, we only perform adjustments for reactor type and unit age, using the process below.[6]

- Reactor Type – if the reactor is a:
  - BWR, we assign no adjustment value
  - PWR, we assign an adjustment value of ~(28,525) in 2017C$k
  - CANDU, we assign an adjustment value of ~(283,946) in 2017C$k
- Unit Age – For each month of average unit age:
  - Above the median value in the dataset (call this value “a”), we assign an adjustment value of “a” multiplied by ~($346) in 2017C$k
  - Below the median value in the dataset (call this value “b”), we assign an adjustment value of “b” multiplied by ~$346 in 2017C$k
- Inflation – We sum all assigned adjustment values and then, for any year other than 2017, we use the appropriate GDP-IPI FDD value to inflate or deflate the cost adjustment to a value for that specific year

We do not adjust costs for differences in site capacity, despite this being a significant driver of cost, since this would also have required a complex adjustment to generation.[7]

Lastly, to adjust cost for a given year, we use the GDP-IPI FDD to modify the adjustment value to the appropriate year (e.g., to adjust TGC in 2015, we take the TGC impact from the model above, which is in 2017 dollars, modify it to 2015 dollars, and adjust the value for 2015). Finally, we divided the adjusted TGC by actual MWh of generation to get the updated comparison shown in the chart below.

---

[6] Precise adjustment values were C$(28,525,521.81) / yr for PWR, C$(283,946,104.12) / yr for CANDU, and C$346,088.63 per month of average unit age at the site by a multiple of (median of the average value in months across all sites minus the average value of the specific site in months)

[7] Adjusting for site capacity would follow the logic of other adjustments to cost. In this model, that would mean adjusting costs by ~C$261k per MW per year for each site by a multiple of (median capacity in MW across all sites minus the capacity of the specific site in MW). However, such an adjustment for site capacity would also require that we adjust the MWhs produced by the site in kind. This adjustment would require determination of, for example, the capacity factor to use when determining the change in MWh, further complicating the adjustment and magnifying differences across sites in certain periods. ScottMadden thus felt it more conservative and intuitive to adjust only for technology and age of equipment.

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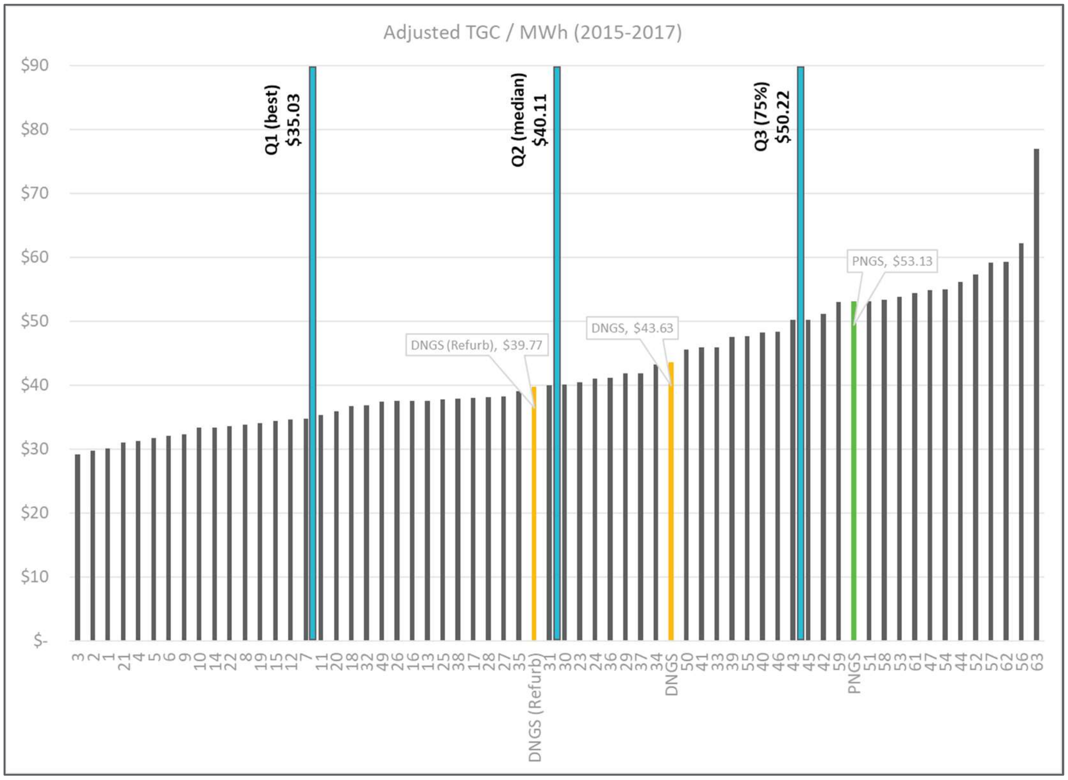
TGC/MWh performance 2015-'17 for EUCG Panel with All Sites Adjusted Based on Econometric Analysis and DNGS Also Adjusted for Refurbishment



By making these adjustments for reactor type and average unit age Pickering's relative performance improves from the 60th to 51st out of the 63 sites in the EUCG panel. Darlington's relative performance improves from 48th to 39th out of the 63 sites in the EUCG panel. Also adjusting for Darlington's refurbishment improves Darlington's relative performance to 31st out of the 63 sites in the EUCG panel.

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5. CUSTOM NUCLEAR OUTAGE BENCHMARKING STUDY

ScottMadden initiated a study of nuclear plant outages on behalf of OPG to better understand how outage work differs across reactor technologies (CANDU, PWR, and BWR) and operators. The study included research of various public and private sources[8], EUCG data provided by OPG, and confidential[9] responses to a custom ScottMadden survey from nine nuclear operators. Participants in the outage survey provided sufficient representation for each of the three reactor technologies and included 19 CANDU plants, 19 PWR plants, and 9 BWR plants. Operators were asked to provide information on:

- The overall refurbishment profile of each unit (including major component replacements, full refurbishments, etc.)
- Historical and future planned outages, including major scope, critical path and near-critical path activities, life-extension work, completion timelines, and costs
- Other, infrequent outages (e.g., vacuum building outages for CANDUs), including scope, schedule, and cost information

While some operators chose not to respond to cost information and other items in the survey, we received robust data on historical and future planned outage scopes and durations. From our various data sources and for this study, we focused on the differences in future planned outage durations across technology types and outage frequencies.

All reactor types have planned maintenance outages on either 18, 24, 30, or 36-month cycles. Planned maintenance outages for PWRs and BWRs are incorporated into refueling cycles and occur every 18 or 24 months. Planned maintenance outages for CANDU reactors occur every 24, 30, or 36 months. Work to significantly extend the operating life of a plant (life-extension activities) is also approached differently across technologies. For PWR and BWR plants, it is more common to complete this work as part of planned refueling and maintenance outages over a series of multiple outages to minimize time in outage. The scope for this work also differs from one plant to the next due to differences in plant design, market construct, and other factors. Comparable life-extension activities for CANDU plants largely occur during very long-duration refurbishment outages where multiple, major plant components are replaced, though some related work can also be incorporated into more frequently recurring planned maintenance outages.

Due to the higher variability and lower frequency of life-extension activities that occur across reactor technologies and operators, ScottMadden focused only on quantifying and adjusting for the impact of recurring, planned maintenance outages on power generation. We took the following steps to arrive at an average annual value for days offline due to these planned outages.

1. We calculated the median planned maintenance outage days for each technology type and maintenance cycle
2. We projected this schedule of outages over a 30-year period, which was the least common multiple in number of years for the different outage cycles, to determine planned maintenance outage days over a long period
3. We annualized these 30-year values into a number of days per year to determine the average annual outage days required for planned maintenance by technology type and outage cycle

[8] Primarily, S&P Global, US Nuclear Regulatory Commission, Ontario Energy Board, and New Brunswick Energy and Utilities Board

[9] ScottMadden acted as the blinding agent for all survey responses so that no participants, including OPG, would be able to view this sensitive data from other operators.

4. Finally, we calculated the incremental additional annual outage days required for any technology (CANDU, PWR, and BWR) and cycle (18, 24, 30, or 36-month) combination compared to those technologies and cycles requiring the fewest average outage days per year (which were BWRs and PWRs on 24-month cycles)

We represent the output of this exercise in the table below.

Reactor Type	Outage Cycle	Median Average Planned Outage Days Per Year, Annualized	Incremental Additional Annualized Outage Days Per Year Above Shortest Duration
BWR	18-month cycle[10]	Not represented in study	
	24-month cycle	14 days	
PWR	18-month cycle	19 days	5 days
	24-month cycle	14 days	0 days
CANDU	24-month cycle	18 days	4 days
	30-month cycle	36 days	22 days
	36-month cycle	27 days	13 days

To adjust for these outage requirements, we normalized the annual values for MWh of production at each plant. Specifically, if a plant in the dataset had a reactor type and outage cycle combination that, on average, required additional outage days above the shortest duration, we added those incremental additional days back to total production for the year using the site summer capacity[11] at 100% utilization. If a plant had a reactor type and outage cycle combination that did not require additional outage days (i.e., all BWRs and PWRs on 24-month outage cycles), we left total production values unchanged.

Although the median average planned outage durations fall in the range of 14 days to 36 days annually per unit for all reactor types, historical outages between 2015-2019 have shown many outages extending beyond stated planning assumptions, mainly due to discovery or other emergent issues identified by the operator. This indicates that, while operators aim to complete outages on schedule, these planning assumptions have recently proven to be conservative estimates, at least for our purposes.

ScottMadden adjusted the MWh values for all 63 sites from 2015-2017, as described above, to account for the impact of differences in planned outage durations across technology types and outage frequencies. The chart below shows the adjusted TGC values from the econometric analysis divided by the adjusted MWh values from the custom nuclear outage benchmarking study.

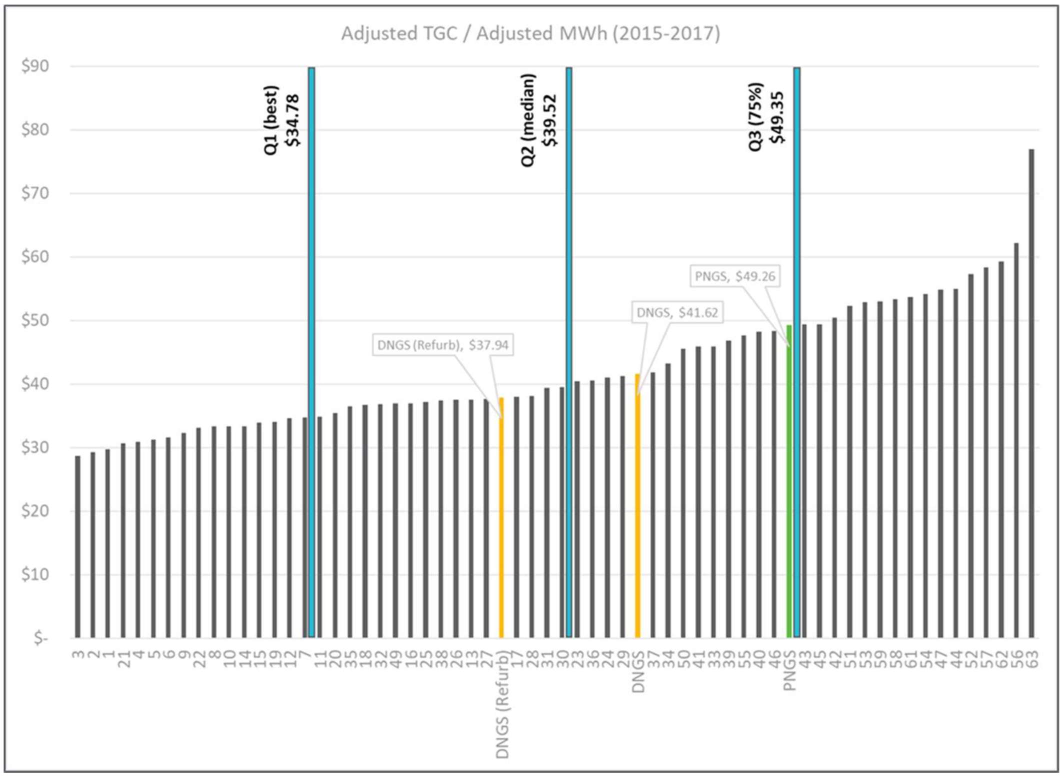
[10] Of the 63 operators in the EUCG dataset, only two single-unit plants are reported to be on an 18-month maintenance cycle during the 2015-2017 timeframe, and these plants were not represented in our survey of nuclear operators. Thus, for the purposes of this study, we assumed that 18-month cycle BWRs have the same annualized median outage duration as 24-month cycle BWRs.

[11] From the EIA 860 form, retrieved through SNL database, as opposed to nameplate capacity or winter capacity, which are often higher values

As a result of these adjustments:

- Pickering's relative performance improves further to 47th out of the 63 sites in the EUCG panel or third quartile
- Darlington's relative performance without accounting for Refurbishment improves to 37th out of the 63 sites in the EUCG panel; after accounting for Refurbishment, Darlington's relative performance is 29th out of the 63 sites in the EUCG panel or second quartile

TGC/MWh performance 2015-'17 for EUCG Panel with All Sites Adjusted Based on Econometric Analysis and Outage Study and DNGS Also Adjusted for Refurbishment



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2019 Nuclear Staffing Benchmarking Analysis

Final Report

ONTARIO POWER GENERATION

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GOODNIGHT CONSULTING

Final Report – January 21, 2020

Introduction & Methodology

- Executive Summary

Analysis

Appendix

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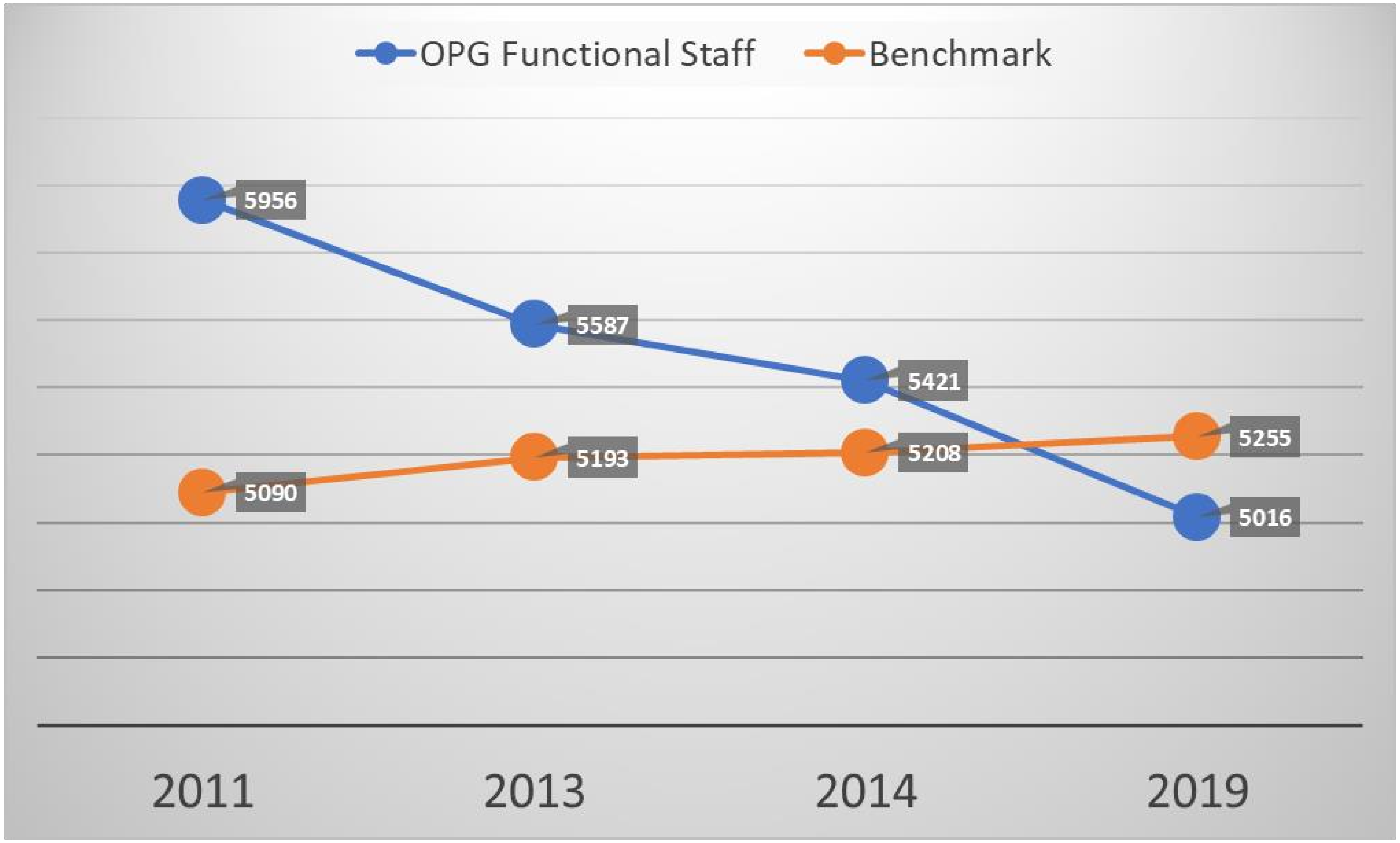
Executive Summary: OPG Is Now Below The Benchmark, A Consistent Improvement Since 2011

- OPG asked Goodnight Consulting to compare OPG Nuclear staffing to other North American nuclear operators through an approach consistent with the one we used in 2011, 2013 and 2014.
- Our current analysis shows that OPG, as of August 2019, is 239 FTEs (4.5%) *below* the total North America nuclear operator benchmark of 5,255 FTEs. The North American benchmarks have increased slightly since 2014 due to aging plants and a less-experienced workforce which required additional staff.
- We benchmarked 5,016 OPG Nuclear staff and long-term contractors; 2,404 OPG Nuclear personnel were excluded from benchmarking consistent with the methodology applied in prior studies.
- OPG is above benchmark staffing in 14 job functions, and below benchmark staffing in 28 functions.
- 13 functions have been recommended to OPG for detailed review.

Attrition, OPG Staff Management, & Increases At Benchmark Plants Brought OPG Below The Benchmark



We Identified 13 Functions That Have The Largest Functional Variances From The Benchmarks

Each of these functional areas should be further reviewed by OPG for workforce planning, process improvement, and / or organizational improvement opportunities

Facilities	208
Maintenance - Support	98
Operations Support	85
Fire Department	77
Human Resources	75
Project Management	71
Maintenance - Mechanical	59
Design/Drafting	-54
Maintenance Planning	-72
Engineering-Plant	-75
Engineering-Technical	-110
RP Applied	-114
Operations	-163

Note that these functions are not offsetting

Introduction & Methodology

- OPG Data Collection & Aggregation

Analysis

Appendix

Client Confidential Information

GOODNIGHT CONSULTING

The Objective Was To Compare OPG Nuclear Staffing To Other North American Nuclear Operators

To benchmark OPG staffing we assigned all applicable staff & contractors to standardized nuclear functions

Identify ***OPG personnel*** supporting steady-state operations

Exclude personnel whom we are ***unable to benchmark per benchmarking methodology***

Identify ***contractors*** *and include those* who provide baseline support

Assign OPG and contractor personnel/FTEs* to standardized nuclear ***work functions***

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*Full-Time Equivalents

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Goodnight Consulting's Staffing Functions Allow For "Apples-To-Apples" Comparisons

- Job descriptions, titles, and organizational structures vary from company to company
- Goodnight Consulting maintains standardized job functions and definitions to establish commonality between companies
- Functions allow benchmark comparisons between different companies by aligning common activities, independent of job position titles or organizational/group labels
- Descriptions for specific functions capture the majority of activities performed by individuals performing work in that activity

42 Unique Job Functions Were Used To Benchmark OPG Nuclear Staffing[1]

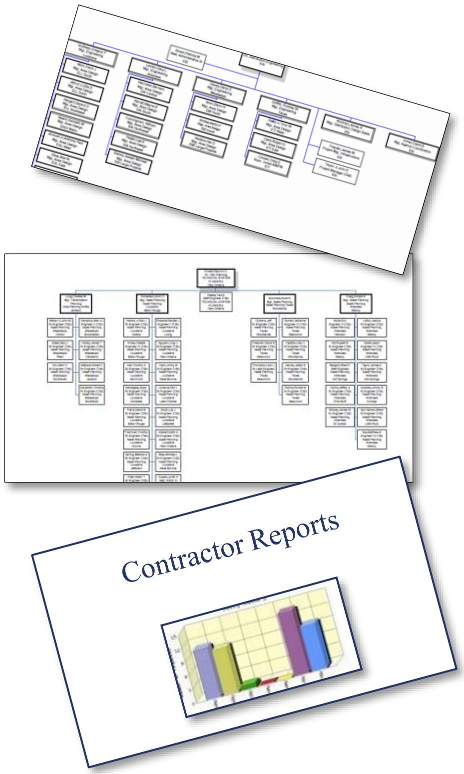
Function	Process Area
Budget/Accounting	Administrative Services
Communications	Administrative Services
Document Control/Records Mgmt.	Administrative Services
Fire Department	Below the Line
Management Support	Below the Line
Design/Drafting	Configuration Management
Engineering - Mods	Configuration Management
Nuclear Fuels	Configuration Management
Engineering - Computer	Equipment Reliability
Engineering - Plant	Equipment Reliability
Engineering - Reactor	Equipment Reliability
Engineering - Technical	Equipment Reliability
QC/NDE	Equipment Reliability
Emergency Preparedness	Loss Prevention
Licensing/Regulatory Affairs	Loss Prevention
QA	Loss Prevention
Safety Programs	Loss Prevention
Chemistry	Operate the Plant
Environmental	Operate the Plant
Operations	Operate the Plant
Operations Pipeline	Operate the Plant
Operations Support	Operate the Plant

Function	Process Area
Admin	Personnel Services
Human Resources	Personnel Services
Management	Personnel Services
Training	Personnel Services
Facilities	Plant Maintenance
Maintenance - Construction	Plant Maintenance
Maintenance - Electrical/I&C	Plant Maintenance
Maintenance - Mechanical	Plant Maintenance
Maintenance - Support	Plant Maintenance
Decon/Radwaste	Radiation Protection
RP Applied	Radiation Protection
RP Support	Radiation Protection
Security Support	Security
Contracts/Purchasing	Supply Chain
Engineering - Procurement	Supply Chain
Warehouse	Supply Chain
Maintenance Planning	Work Management
Outage Planning/Scheduling	Work Management
Project Management	Work Management
Scheduling	Work Management

[1] The Security Operations function was excluded to be consistent with OPG policy and Information Mgmt. was Benchmarked via a different method external to this study

To Ensure Proper Functionalization We Utilized OPG Data And Interviews With OPG Staff

OPG Staffing & Contractor Data



Goodnight Staffing Functions

- Safety Programs
- Operations
- Maintenance - Mech
- Emergency Prep
- Rad Pro Applied
- Others . . .

5,016 OPG Employees & Contractors Were Functionalized For Benchmarking

Process Area Summary	Regular	Term	Total Regular HC	Non-Regular	Augmented Staff	Oncore Hourly	Other Purchased Services	Total Contractor FTEs	Total OPG FTEs	2019 Goodnight Benchmark	Variance	%
Administrative Services	98		98	7				7	105	129	(24)	-19%
Configuration Management	182		182	2	4	4	13	23	205	337	(132)	-39%
Equipment Reliability	398	2	400	28	7		26	61	461	590	(129)	-22%
Loss Prevention	139		139	2	5	16	14	37	176	201	(25)	-12%
Operate The Plant	854	156	1,010	8	3		10	21	1,031	1,073	(42)	-4%
Personnel Services	580	27	607	40	24	11	3	78	685	600	85	14%
Plant Maintenance	928	149	1,077	260		114	19	393	1,470	1,225	245	20%
Radiation Protection	122	4	126	12			20	32	158	287	(129)	-45%
Security*	31		31	2	1		3	6	37	97	(60)	-62%
Supply Chain	177		177	6	1	1	1	9	186	235	(49)	-21%
Work Management	346	7	353	16	11	9	3	39	392	417	(25)	-6%
Below the Line	93	11	104	1	5			6	110	64	46	72%
Benchmarked Total	**3,948**	**356**	**4,304**	**384**	**61**	**155**	**112**	**712**	**5,016**	**5,255**	**(239)**	**-4.5%**

*Security Support is now benchmarked as subset of Security; Security Operations protected information continues to be excluded from the study

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OPG Contractor Support Data Was Reviewed To Identify Headcounts For Baseline Contractors

Staff augmentation contractor data	• *Professional staff providing specialized skills, including authorized training contractors and/or variable work support*
Other purchased service data	• *Specialized contractors, such as nuclear safety analysis, and maintenance/construction trades*
Exclusions	• *Consistent with our standard nuclear benchmarking methodology, outage execution contractors and outage overtime were both excluded*

OPG Contractor Data Was Converted From Hours Or Costs, Into Full Time Equivalents (FTEs)

Data Provided

OPG provided contractor data via contractor billed annual costs, or cumulative contractor annual hours

Spend Converted to FTEs

Cumulative contractor billed annual dollar values were first divided by an average hourly cost that include wages plus benefits, and then by estimated annual hours* to prorate the data into annual FTEs

Hours Converted to FTEs

Cumulative contractor annual hours were also divided by the same value to prorate the data into annual FTEs

*1890 hours/year = 1 FTE, consistent with previous studies

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Applicable OPG Baseline Contractors Equates To 712 FTEs In 37 Job Functions

37 job functions where OPG contractor FTEs were identified

Function	Total Contractor FTEs
Admin	30
Budget/Accounting	3
Chemistry	13
Communications	2
Contracts/Purchasing	5
Decon/Radwaste	25
Document Control/Records Mgmt.	2
Emergency Preparedness	5
Engineering-Computer	10
Engineering-Mods	22
Engineering-Plant	35
Engineering-Procurement	1
Engineering-Reactor	9
Engineering-Technical	4
Environmental	4
Facilities	137
Human Resources	8
Licensing/Regulatory Affairs	1
Maintenance - Construction	8
Maintenance-Electrical/I&C	51
Maintenance - Mechanical	77
Maintenance - Support	120
Maintenance Planning	6
Management	3
Management Support	6
Nuclear Fuels	1
Operations Support	4
Outage Management	3
Project Management	27
QA	4
QC/NDE	3
RP Support	7
Safety Programs	27
Security Support	6
Scheduling	3
Training	37
Warehouse	3
Total	**712**

Number of OPG contractor FTEs identified in each function (712 total)

Contractor FTEs have increased from 531 FTEs included in the previous study to offset Regular staff attrition and achieve OPG's strategic objectives, aligned with labour relations agreements.

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CANDU-Specific Activities Were Not Benchmarked As Part Of This Study To Facilitate Comparison with Peers

- We contacted all of the other operating CANDU NPPs around the world requesting CANDU-specific data for benchmarking:
  - ➢ Argentina: NA-SA/Embalse
  - ➢ Canada: Bruce Power/Bruce, NB Power/Point LePreau
  - ➢ China: CNNC/Quinshan
  - ➢ Romania: SNN/Cernavoda
  - ➢ South Korea: KHNP/Wolseong
- Staffing data from other non-OPG CANDU reactors was not sufficient to develop realistic benchmarks for OPG
- No CANDU-specific functions were benchmarked in this study (see the next page)
- This approach is consistent with the approach taken on prior studies

2,404 OPG Nuclear Personnel Could Not Be Benchmarked

CANDU-Specific Exclusions*

- *Fuel Handling:* Comparable function in PWRs only occurs during outages
- *Heavy Water Handling*
- *Tritium Removal Facility*
- *Feeder and Fuel Channel Support*
- *Other CANDU-Specific support to excluded functions e.g. Refueling Ops*

*Unique to CANDU design with no comparable PWR activity

OPG-Specific Exclusions

- *Pickering Units 2 & 3 Safe Store Support:* However, cross-tied operations for Units 2 & 3 ***were counted***
- *Major Projects/ One-time initiatives:* e.g., Darlington Refurbishment, New Build, etc.

Generic Exclusions**

- *Nuclear waste and used fuel*: Functions not performed by plants in the benchmark
- *Outage execution activities:* Excluded for consistency with counts at benchmark plants
- *Water treatment*: Functions not performed by plants in the benchmark

**Both CANDU & PWR activities but excluded as non-baseline/non-steady state

Other Exclusions

- *Information Management:* Benchmarked via a different method external to this study
- *Long Term Leave Personnel*: Excluded consistent with Goodnight Consulting benchmarking methodology

Out of Scope

- Consistent with previous methodology, areas such as Security Operations and Corporate Support not directly supporting the Nuclear program (e.g., treasury, tax) are out of scope and additional to the 2404 not benchmarked for the study.

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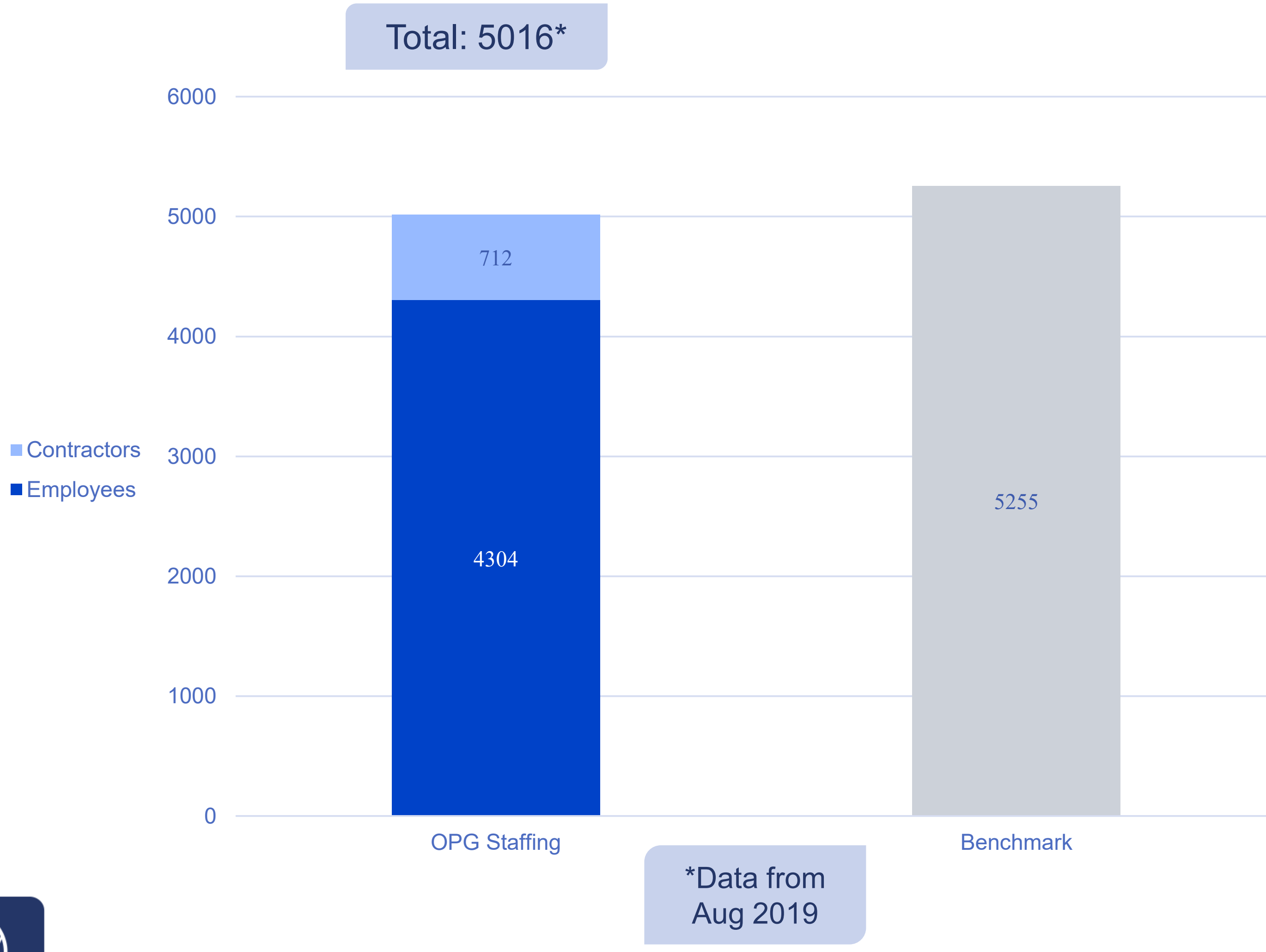
OPG Is 239 FTEs (-4.5%) Below The Benchmark of 5,255



We Developed Functional Benchmarks Utilizing The Same Methodology Applied In Prior Studies

Function	Total Regular HC	Total Contractor FTEs	Total OPG FTEs	2019 Benchmarks	Variance
Facilities	181	137	318	110	208
Maintenance - Support	173	120	293	195	98
Operations Support	166	4	170	85	85
Fire Department	100		100	23	77
Human Resources	93	8	101	26	75
Project Management	126	27	153	82	71
Maintenance - Mechanical	294	77	371	312	59
Admin	147	30	177	137	40
QC/NDE	78	3	81	41	40
Operations Pipeline	172		172	135	37
Engineering-Computer	45	10	55	30	25
Safety Programs	61	27	88	63	25
Budget/Accounting	67	3	70	47	23
Chemistry	120	13	133	120	13
Contracts/Purchasing	76	5	81	82	-1
Outage Management	83	3	86	87	-1
QA	45	4	49	51	-2
Communications	7	2	9	13	-4
Decon/Radwaste	27	25	52	56	-4
Management	186	3	189	197	-8
Engineering-Reactor	42	9	51	60	-9
RP Support	56	7	63	74	-11
Emergency Preparedness	18	5	23	36	-13
Engineering-Procurement	36	1	37	51	-14
Environmental	15	4	19	33	-14
Training	181	37	218	240	-22
Scheduling	66	3	69	92	-23
Management Support	4	6	10	41	-31
Warehouse	65	3	68	102	-34
Licensing/Regulatory Affairs	15	1	16	51	-35
Nuclear Fuels	19	1	20	56	-36
Engineering-Mods	148	22	170	212	-42
Document Control/Records Mgmt.	24	2	26	69	-43
Design/Drafting	15		15	69	-54
Maintenance - Construction	15	8	23	79	-56
Security Support	31	6	37	97	-60
Maintenance-Electrical/I&C	414	51	465	529	-64
Maintenance Planning	78	6	84	156	-72
Engineering-Plant	188	35	223	298	-75
Engineering-Technical	47	4	51	161	-110
RP Applied	43		43	157	-114
Operations	537		537	700	-163
Total	**4304**	**712**	**5016**	**5255**	**-239**

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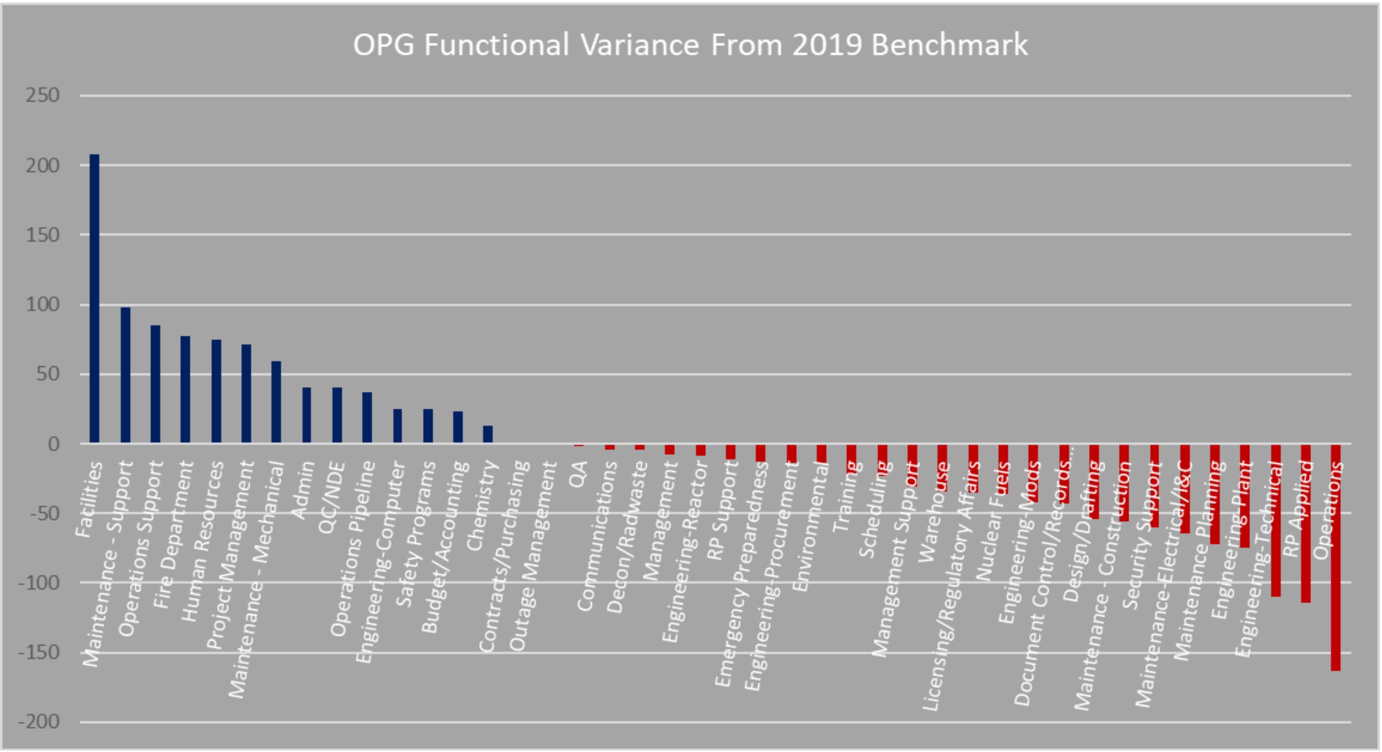
14 Functions Are Above The 2019 Benchmark; 28 Functions Are Below The 2019 Benchmark



Function	Variance
Facilities	208
Maintenance - Support	98
Operations Support	85
Fire Department	77
Human Resources	75
Project Management	71
Maintenance - Mechanical	59
Admin	40
QC/NDE	40
Operations Pipeline	37
Engineering-Computer	25
Safety Programs	25
Budget/Accounting	23
Chemistry	13
Contracts/Purchasing	-1
Outage Management	-1
QA	-2
Communications	-4
Decon/Radwaste	-4
Management	-8
Engineering-Reactor	-9
RP Support	-11
Emergency Preparedness	-13
Engineering-Procurement	-14
Environmental	-14
Training	-22
Scheduling	-23
Management Support	-31
Warehouse	-34
Licensing/Regulatory Affairs	-35
Nuclear Fuels	-36
Engineering-Mods	-42
Document Control/Records Mgmt.	-43
Design/Drafting	-54
Maintenance - Construction	-56
Security Support	-60
Maintenance-Electrical/I&C	-64
Maintenance Planning	-72
Engineering-Plant	-75
Engineering-Technical	-110
RP Applied	-114
Operations	-163
Total	**-239**

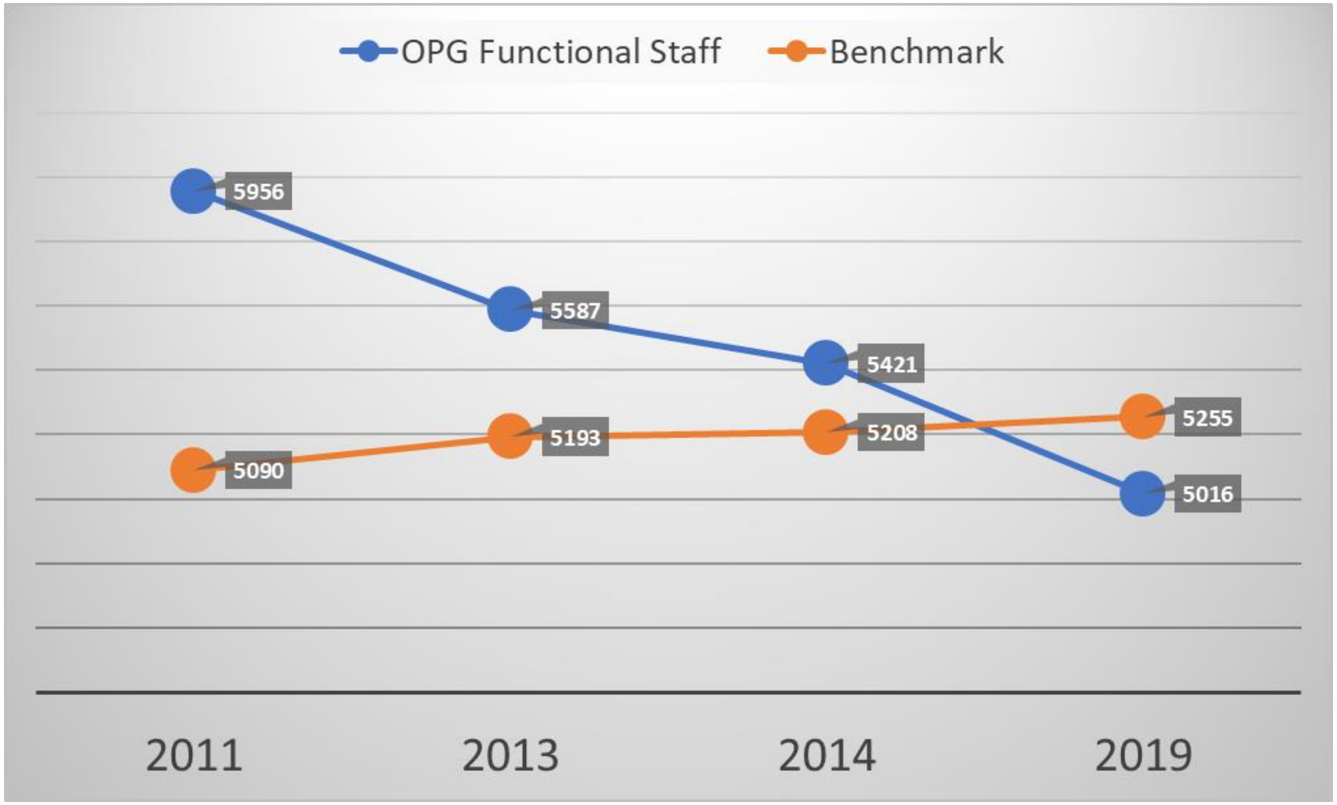
The 13 Functions We Identified Represent The Majority Of OPG's Total Variance From The Benchmark

Each of these functional areas should be further reviewed by OPG for workforce planning, process improvement, and / or organizational improvement opportunities

Facilities	208
Maintenance - Support	98
Operations Support	85
Fire Department	77
Human Resources	75
Project Management	71
Maintenance - Mechanical	59
Design/Drafting	-54
Maintenance Planning	-72
Engineering-Plant	-75
Engineering-Technical	-110
RP Applied	-114
Operations	-163

Note that these functions are not offsetting

Attrition, OPG Staff Management, & Increases At Benchmark Plants Brought OPG Below The Benchmark



The past centre-led initiatives involved a major reorganization effort, decreasing staffing in several functions since 2011

The Pickering station amalgamation in the past has helped OPG achieve efficiencies and improve variances from the benchmark in several functions since 2011

As Pickering approaches shutdown, attrition occurs and some vacant positions go unfilled while management takes steps to continuously improve and find efficiencies.

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Operations Function Issues

- Operations/Operations – Pipeline – Ops Pipeline staffing above the benchmark (+37) indicates that OPG is aware of low on-shift Operations staffing (-163) and is executing a plan to help close the gap. However, even if most of the Ops Pipeline personnel successfully migrate to on-shift Ops, the gap will still be >100.
- Operations – Pipeline (Darlington) – Some of the personnel in the Operations – Pipeline count (operators in training) will be slated to go directly to the TRF or into Fuel Handling. This helps explain the size of the staffing level in this functional area.
- Operations Support (Pickering) - Additional staff are currently required to support life extension of the remaining operating units. There has also been additional focus on tritium management since the 2011 staffing benchmarking study. These activities are not required at benchmarked plants and helps explain higher staffing levels.
- Operations Support (Pickering) – Additional Operations Support staff are also required for support to outage planning as outages are now more focused on life extension.
- Operations Support – Some of the above-benchmark staffing in this function appears to be making up for lower on-shift Operations staffing levels
- Operations Support (Pickering) – Additional operations support staff are required for Units 5-8 due to specific licensing requirements.

Chemistry, Environmental, and Radiation Protection Function Issues

- Chemistry (Darlington) – A few of the Operations/Chemistry & Environmental personnel were excluded from benchmarking due to support for the on-site Tritium Removal Facility (TRF). These exclusions included 1 for Heavy Water and 1 for Water Treatment.
- Environmental (Darlington) - A few of the Operations/Chemistry & Environmental personnel were excluded from benchmarking due to support for the on-site Tritium Removal Facility (TRF). These exclusions included 1 for Heavy Water and 1 for Water Treatment.
- RP Applied - Low staffing is offset by line personnel qualified to provide self monitoring and also, if certified, to monitor the activities of groups

Maintenance Function Issues

- Maintenance – Mechanical, Electrical, I&C, Support, and Construction – Darlington maintenance staff currently perform both steady-state and outage(refurbishment) maintenance activities. Boundaries between the steady-state and refurbishment levels of effort have been established.

- Maintenance – Mechanical, Electrical/I&C, and Support - Additional Pickering staff are currently required to support life extension of the remaining operating units. There has also been additional focus on tritium management since the 2011 staffing benchmarking study.

- Maintenance Support – Some personnel may be being applied to make up for relatively low staffing in the Maintenance - Planning function.

- Facilities – The Civil Maintenance at Pickering organization has a contract management oversight department to oversee contract trades, as required by law. This is not required at benchmarked plants and helps explain part of the higher staffing levels. Overall Facilities functional staffing above the benchmark level continues to be driven by the large number of off-site facilities maintained by OPG, which are being consolidated in the future as part of their Campus Plan announcement.

Engineering & Related Function Issues

- Engineering – Plant (Pickering) - Additional Pickering staff are currently required to support life extension of the remaining operating units. These conditions are exacerbated by below benchmark staffing. Benchmark plants have slightly higher than average Engineering – Plant staffing as an approach to provide a "first line of defense" for Operations and Maintenance.

- Engineering – Technical – It appears OPG Modifications/Design Engineers do more technical work than at benchmark plants, which is reflected in OPG staffing below the benchmark for this function.

- Design Drafting – Many benchmark plants still use draftspersons as support to design/modification engineering; it appears OPG does this less so, reflecting in staffing below the benchmark level.

- Project Management - Staffing above the benchmark reflects OPG's current capital program and increased focus on strengthening their project management office as part of their strategic imperative.

Training Function Issues

- Training – Staffing levels below the benchmark reflect lower than benchmark Operations staffing levels
- Training – A notable effort to reduce “nuclear” qualifications is underway in Training. Some longstanding “nuclear” specific qualifications are being systematically eliminated in favor of industry or provincial qualifications. For example, the Project Manager qualification is being eliminated in favor of experience (exemption) and non-nuclear professional development. Craft qualifications in fork-lift operation, fall protection, and other common industrial knowledge / experience areas will be handled similarly.
- Training – Use of technology is seen as a means to accommodate a planned “glide slope.” Both information technology (elimination of paper, lists, filing) and instructional technology (augmented reality) are being employed to reduce labor requirements.

Other Functional Area Issues

- Management Support – These individuals have no direct reports and perform a variety or tasks for their direct supervisor that do no fit into one of the other nuclear work functions. The benchmark has significantly increased in the past few years due to aging workforce at benchmark plants that management has decided to retain due to their experience levels, and to apply them as direct support / advisors to younger managers.

- Fire Department – OPG has dedicated fire department staff, compared to most benchmark plants that rely on Operations and Security personnel for fire watch, and external fire departments for fire response. These differences in the approach to this function explain the large variance from the benchmark.

- Human Resources – OPG's approach to the HR function provides more support and services to the organization and to the employees compared to benchmark plants. Additionally, OPG has a significantly larger percentage of staff represented by labor unions, requiring more Labor Relations effort than at benchmark plants.

- Exclusions for Darlington Refurbishment – 629 individuals were excluded due to dedication to the Darlington Refurbishment project. At the completion of these individuals' Refurbishment assignments OPG will need to determine their roles in the organization relative to overall staffing and organizational goals.

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- Benchmark development methodology

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To Identify Staffing Benchmarks, We Used The Same Methodology As Prior OPG Engagements

Identify Plants	Identify Benchmarks	Adjust For Technology	Adjust For Work Rules	Finalize Benchmarks
Identify applicable nuclear plants/nuclear organizations as the benchmarking sources	Identify staffing benchmarks reflecting steady-state operations from functional staffing data using selected nuclear plants	Adjust for technical/design differences (i.e., PWR vs. CANDU)	Adjust for regulatory and/or work rule differences (i.e., 35 vs. 40 hour work week)	Apply adjustments and identify final functional staffing benchmarks

We Applied Several Key Assumptions In Our Staffing Benchmarking Methodology

Benchmarks Are From Steady State, On-Power Activities

Plants are considered to be in steady state operation:

- Short-term & outage contractors *excluded*
- Baseline contractors are *included*
- Major initiatives (i.e., Darlington Refurbishment, PWR Steam Generator Replacement, PWR Vessel Head replacements, etc.) are *excluded*

Average Productivity Is Assumed

No productivity adjustments are applied to the benchmarks or OPG staffing; *however, the benchmarks were adjusted for 35 vs. 40 hour work weeks where applicable*

Current Vacancies Excluded

Benchmark staffing levels do not include permanent vacancies, i.e., vacancies not planned to be filled in the next 30 days are not counted. Regular staff absences (e.g., maternity leave or long-term disability leave) are not counted as "regular staff", but may be captured as non-regular staff i.e., temporary backfills

Our Approach Begins With Current Staffing Data From Large PWRs (Most Complex US Designs)

1. Apply Goodnight Consulting Nuclear Plant Staffing Database

2. Select The Most Similar Plants
   - Apply functional staffing data from large US (>800 MWe) Pressurized Water Reactors (see the following page)

3. Identify Benchmark Functional Staffing
   - Apply adjustments for PWR to CANDU design differences
   - Apply adjustments for OPG conditions

4. Develop Functional Staffing Comparison

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Large 2-Unit PWRs Provide The Closest Comparison to CANDUs For Benchmarking

Approach

- Goodnight Consulting applies current information from plants that are the most similar in design to the client's operating plants

Design Similarities

- CANDU plants are similar to PWRs in that there are steam generators with similar primary and secondary loops

Later-Model PWRs

- Larger capacity, later-model PWRs are more complex than earlier models; this increased complexity is closer to the CANDU design than smaller PWRs of an earlier vintage

"Most Similar" to CANDU

- Thus, the "most similar" plants in our database are large (over 800 MWe) 2-unit PWRs

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To Determine Adjustments For CANDU Design Differences, We Reviewed Many Technical Areas

Design & Operational Consideration Areas – PWR to CANDU Benchmark Conversion

- Vacuum Building
- Gadolinium Nitrate Injection
- Liquid Zone Control System
- Health Physics / ALARA / Environmental
- Annulus Gas Systems
- Inspection and Testing
- In Service Inspection / Non-Destructive Examination
- Surveillance Testing
- Materials
- Carbon Steel Primary Heat Transport System
- Fuel Channels (Zr Alloy)
- Systems and Major Components
- 12 steam generators & 16 Main HTS Pumps/unit at Pickering
- Engineering and Maintenance Programs
- PM Program Tasks / Activities
- Mechanical Components
- Electrical Components
- Instrumentation and Controls /Computers
- Reactivity Management in Calandria design, Fuels
- Corrective / Elective / Preventive Maintenance Backlogs
- Radioactive Source Term
- Building and Support Systems Maintenance
- Canadian Nuclear Safety Commission (CNSC)
- OPG as initial point of contact for CANDU Generic Issues
- Nominal 5-year License Interval
- Supply Chain
- Demineralized Water Consumption
- Design Philosophy Differences
- Separation of Control and Safety Channels
- PWR Systems, Programs, and Issues
- Turbine Driven Auxiliary Feedwater
- Condensate Polishing
- Boric Acid Corrosion
- Etc.

Our technical team reviewed the differences between PWR and CANDU and accounted for those differences in a staffing model discussed later in this section of the report – This is the same methodology we applied in 2011, 2013, and 2014.

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2-Unit CANDU Staffing Benchmark Is 1,044* (Includes Corporate & Contractor FTEs)

Staffing Function	2019 2-UNIT US PWR Bmk	Raw Adjustments 2019	Total Bmk (2019
Admin	31	3	34
Budget/Accounting	11	1	12
Chemistry	26	0	26
Communications	3	0	3
Contracts/Purchasing	15	0	15
Decon/Radwaste	9	3	12
Design/Drafting	12	1	13
Document Control/Records Mgmt.	11	2	13
Emergency Preparedness	7	0	7
Engineering - Computer	5	0	5
Engineering - Mods	38	3	41
Engineering - Plant	48	8	56
Engineering - Procurement	8	2	10
Engineering - Reactor	6	5	11
Engineering - Technical	26	5	31
Environmental	4	2	6
Facilities	24	0	24
Fire Department	5	0	5
Human Resources	6	1	7
Licensing/Regulatory Affairs	9	1	10
Maintenance - Construction	14	2	16
Maintenance-Electrical/I&C	102	13	115
Maintenance - Mechanical	61	7	68
Maintenance - Support	39	3	42
Maintenance Planning	33	1	34
Management Support	8	0	8
Nuclear Fuels	11	-1	10
Operations	139	0	139
Operations Pipeline	27		27
Operations Support	17	0	17
Outage Planning/Scheduling	16	3	19
Project Management	15	1	16
QA	9	0	9
QC/NDE	8	1	9
RP Applied	31	3	34
RP Support	13	1	14
Safety Programs	15	0	15
Scheduling	18	2	20
Security Support	21		21
Training	49	3	52
Warehouse	17	2	19
Total	**966**	**78**	**1044**

The ***Raw Adjustments*** account for technical differences between PWR and CANDU plants and are detailed on the next page

*Does not include Management. A Separate Management Benchmark was developed and is discussed later in this section

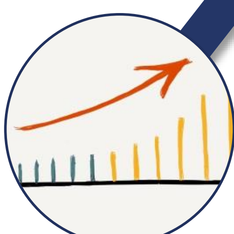
Technical Adjustments Were Utilized To Derive The 2-Unit CANDU Staffing Benchmark From PWRs*

Staffing Function	Raw Adjustments 2019	Total Bmk (2019	Rationale
Admin	3	34	Approximately 1 additional admin/clerical person is needed for each additional 25 staff
Budget/Accounting	1	12	1 FTE additional functional staff needed to support the added personnel due to CANDU technology differences
Chemistry	0	26	No basis for adjustment
Communications	0	3	No basis for adjustment
Contracts/Purchasing	0	15	No basis for adjustment
Decon/Radwaste	3	12	"Hotter shop" tritium, alpha radiation pervasive, more opportunities for deconning-more equipment, bigger source of radiation and more space. Larger volumes of I&LLW generated and packaged.
Design/Drafting	1	13	Greater number of systems
Document Control/Records Mgmt.	2	13	Higher number of systems, more control documents to manage
Emergency Preparedness	0	7	No basis for adjustment
Engineering - Computer	0	5	No basis for adjustment
Engineering - Mods	3	41	Greater number of systems
Engineering - Plant	8	56	Greater number of systems
Engineering - Procurement	2	10	Higher number of commercial parts dedications due to a smaller vendor market, lower availability of conforming parts
Engineering - Reactor	5	11	Adjusted to 2-unit equivalent of OPG CANDU stated requirements
Engineering - Technical	5	31	Higher number of systems, diversity instead of redundancy design philosophy
Environmental	2	6	Tritium monitoring, Canadian regulatory requirements
Facilities	0	24	No basis for adjustment
Fire Department	0	5	No basis for adjustment
Human Resources	1	7	1 FTE additional functional staff needed to support the added personnel due to CANDU technology differences
Licensing/Regulatory Affairs	1	10	Different regulatory scheme, greater number of safety systems, design philosophy of diversity over redundancy
Maintenance - Construction	2	16	Higher number of systems, diversity instead of redundancy design philosophy-track IMS impacts on numbers
Maintenance-Electrical/I&C	13	115	Higher number of systems, diversity instead of redundancy design philosophy-track IMS impacts on numbers
Maintenance - Mechanical	7	68	Higher number of systems, diversity instead of redundancy design philosophy-track IMS impacts on numbers
Maintenance - Support	3	42	Higher number of systems, diversity instead of redundancy design philosophy
Maintenance Planning	1	34	Higher number of systems, diversity instead of redundancy design philosophy
Management Support	0	8	No basis for adjustment
Nuclear Fuels	-1	10	Adjusted to 2-unit equivalent of OPG CANDU stated requirements
Operations	0	139	Additional systems to monitor= increases, common systems = decreases
Operations Pipeline		27	
Operations Support	0	17	Additional systems to monitor= increases, common systems = decreases
Outage Planning/Scheduling	3	19	Non fueling outages=decreases, more systems to deal with during an outage=increase
Project Management	1	16	Higher number of systems, diversity instead of redundancy design philosophy
QA	0	9	No basis for adjustment
QC/NDE	1	9	Due to additional maintenance work, additional QC/NDE work is required, "Innate" IMS counted here,
RP Applied	3	34	Additional radiation sources, differences in staffing are due to choices in program structures
RP Support	1	14	Additional radiation sources, differences in staffing are due to choices in program structures
Safety Programs	0	15	No basis for adjustment
Scheduling	2	20	Greater number of systems resulting in more scheduling work
Security Support		21	
Training	3	52	Additional trainers required to handle additional maintenance training requirements
Warehouse	2	19	Additional parts and components needed for more systems and to overcome more materials kept on hand due to a smaller vendor base
Total	**78**	**1044**	

*Does not include Management. A Separate Management Benchmark was developed and is discussed later in this section

We Developed Functional Scaling Factors* Based On Our Experience & Best Estimates

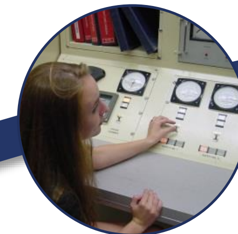
This is the same approach that was applied in 2011, 2013 and 2014



For most functions, we applied a scaling factor of 1.8 times the 2-unit level for a 4-unit plant

This approach was based on staffing levels we have observed at several international 4-unit sites relative to our 2-unit benchmark

Several exceptions from the 1.8x scaling factor were applied, and are shown on the next page



For example, Operations requires fully staffed shift crews for each reactor or 2-unit set of reactors from our international observations

*Scaling factor not used for Management benchmark. A separate Management benchmark was developed and is discussed later in this section

2-Unit OPG CANDU Benchmark Is 1,044*
Adjusted 4-Unit OPG CANDU Benchmark Is 1,973*

- Where applicable, adjustments were made for OPG's 35 Hour work week vs. 40 hours at U.S. plants
- The net increase in the 2-Unit benchmarks from the work week adjustment is 52 FTEs
- CANDU 2-Unit then scaled up to a 4-Unit model

*Scaling factor not used for Management benchmark. A Separate Management Benchmark was developed and is discussed later in this section

Staffing Functions	2-Unit CANDU Benchmark	35 hour week	Adjustment for 35 hour work week	Scaling Factor from 2 to 4 Units	4 Unit CANDU Benchmark
Admin	34	1	39	Ratio	49
Budget/Accounting	12	1	13	Ratio	17
Chemistry	26		26	1.8	47
Communications	3		3	1.8	5
Contracts/Purchasing	15	1	18	1.8	32
Decon/Radwaste	12		12	1.8	22
Design/Drafting	13	1	15	1.8	27
Document Control/Records Mgmt.	13	1	15	1.8	27
Emergency Preparedness	7	1	8	1.8	14
Engineering - Computer	5	1	6	2	12
Engineering - Mods	41	1	46	1.8	83
Engineering - Plant	56	1	64	1.8	115
Engineering - Procurement	10	1	11	1.8	20
Engineering - Reactor	11	1	12	2	24
Engineering - Technical	31	1	35	1.8	63
Environmental	6	1	7	1.8	13
Facilities	24		24	1.8	43
Fire Department	5		5	1.8	9
Human Resources	7	1	8	Ratio	9
Licensing/Regulatory Affairs	10	1	11	1.8	20
Maintenance - Construction	16		16	1.8	29
Maintenance-Electrical/I&C	115		115	1.8	207
Maintenance - Mechanical	68		68	1.8	122
Maintenance - Support	42		42	1.8	76
Maintenance Planning	34		34	1.8	61
Management Support	8	1	9	1.8	16
Nuclear Fuels	10	1	12	1.8	22
Operations	139		139	2	278
Operations Pipeline	27		27	2	54
Operations Support	17		17	2	34
Outage Planning/Scheduling	19		19	1.8	34
Project Management	16	1	18	1.8	32
QA	9	1	11	1.8	20
QC/NDE	9		9	1.8	16
RP Applied	34		34	1.8	61
RP Support	14	1	16	1.8	29
Safety Programs	15	1	17	Ratio	23
Scheduling	20		20	1.8	36
Security Support	21		21	1.8	38
Training	52		52	1.8	94
Warehouse	19	1	22	1.8	40
Total	**1044**		**1096**		**1973**

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Adjustments For Pickering Units 1-4 Increase The OPG 2-Unit CANDU Benchmark To 1,096*

- Some cross-tied systems remain active at Pickering Units 2 & 3: We adjusted the benchmark to include personnel required to support those systems (16)
- FTEs assigned to SAFESTORE activities at Pickering Units 2 & 3 were **not** included in the benchmark

Staffing Functions	Unit CANDU Bench	35 hour week	Adjustment for 35 hour work wee	Adjustments for Units 2 & 3	Pickering A Benchmark	Rationale
Admin	34	1	39		39	
Budget/Accounting	12	1	13		13	
Chemistry	26		26		26	
Communications	3		3		3	
Contracts/Purchasing	15	1	18		18	
Decon/Radwaste	12		12		12	
Design/Drafting	13	1	15		15	
Document Control/Records Mgmt.	13	1	15		15	
Emergency Preparedness	7	1	8		8	
Engineering - Computer	5	1	6		6	
Engineering - Mods	41	1	46		46	
Engineering - Plant	56	1	64	4	68	**One additional System Engineer per discipine (M, E, I&C, Civil)**
Engineering - Procurement	10	1	11		11	
Engineering - Reactor	11	1	12		12	
Engineering - Technical	31	1	35		35	
Environmental	6	1	7		7	
Facilities	24		24		24	
Fire Department	5		5		5	
Human Resources	7	1	8		8	
Licensing/Regulatory Affairs	10	1	11		11	
Maintenance - Construction	16		16	5	21	**Estimated Additional staff (FIN-like)**
Maintenance-Electrical/I&C	115		115		115	
Maintenance - Mechanical	68		68		68	
Maintenance - Support	42		42	1	43	**Ratio of support to additional Maintenance/Construction**
Maintenance Planning	34		34		34	
Management Support	8	1	9		9	
Nuclear Fuels	10	1	12		12	
Operations	139		139	5	144	
Operations Pipeline	27		27		27	
Operations Support	17		17		17	
Outage Planning/Scheduling	19		19		19	
Project Management	16	1	18		18	
QA	9	1	11		11	
QC/NDE	9		9		9	
RP Applied	34		34	1	35	**One additional Rad Pro technican to conduct surveillances**
RP Support	14	1	16		16	
Safety Programs	15	1	17		17	
Scheduling	20		20		20	
Security Support	21		21		21	
Training	52		52		52	
Warehouse	19	1	22		22	
Total	**1044**		**1096**	**16**	**1112**	

*Scaling factor not used for Management benchmark. A Separate Management Benchmark was developed and is discussed later in this section

GOODNIGHT CONSULTING

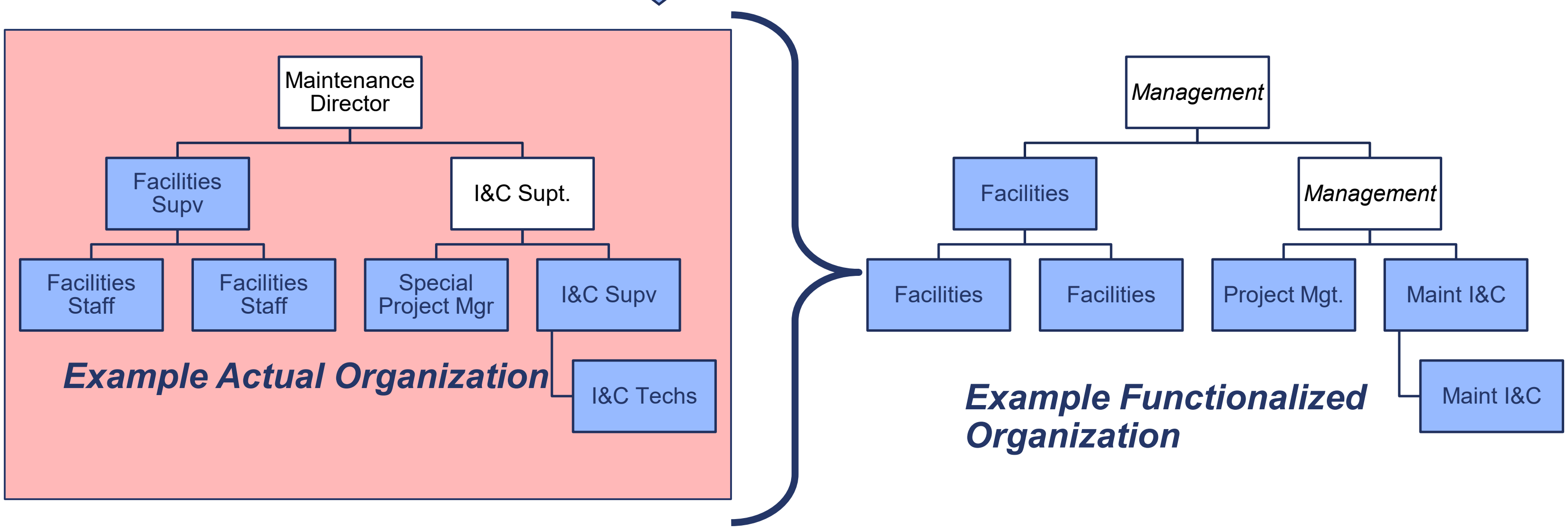
Management Is A Function, Not A Title, In Our Model; It Includes All Personnel Above 1st Line Supervisors

Management Function

- All those above first line supervisor
- Job title not a factor
- At least one of their direct reports must also have a direct report

All Other Functions

- First Line Supervisors
- Individual Contributors



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A Separate Methodology Was Used For Developing The Staffing Benchmark For The Management Function

OPG *Management* Function Benchmark = 197

- These account for distributed Management Function staff from benchmark Corporate Nuclear organizations
- These 197 FTEs are calculated from a ratio of 3.9% of total benchmarked staff

Applying the aforementioned scaling to the Management function produced an output not reflective of a reasonable organizational structure

The benchmark for this function is based on a reasonable organizational structure for OPG

We accounted for OPG's fleet environment, which provides opportunities for efficiency

Final Benchmark Nuclear Organizational Chart has 197 Management Function personnel (excluding managers for not-benchmarked activities such as Info Management, Security, Refueling Ops, Etc.)

Benchmarking *Summary*: Total 2019 OPG Nuclear Benchmark Is 5,255

	Pickering 1-4	Pickering 5-8	Darlington	Total
Large 2-Unit PWR Benchmark	966	966	966	
CANDU Technology Adjustment	78	78	78	
35 Hour Work Week Adjustment	52	52	52	
Scale From 2 to 4 Units		877	877	
Adjust for Pickering Units 2 & 3	16			
Add Management Benchmarks	43	77	77	
Total	1155	2050	2050	5255

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EB-2020-0290
Exhibit F2-1-1
Attachment 7
Page 1 of 2

NEWS RELEASE

Ontario Supports Plan to Safely Extend the Life of the Pickering Nuclear Generating Station

Updated schedule keeps high quality jobs in Durham region longer

August 14, 2020
Energy, Northern Development and Mines

PICKERING - The Ontario government is supporting a plan by Ontario Power Generation (OPG) to safely extend the life of the Pickering Nuclear Generating Station. The updated schedule will provide electricity consumers with emission-free, low-cost energy and allow 4,500 high-quality jobs to remain in Durham region longer.

Under its proposed plan, Ontario Power Generation (OPG) will keep Pickering's units 1 and 4 operating until the end of 2024 and units 5 to 8 operating until the end of 2025, allowing for the safe, sequential shutdown of all units while maximizing the economic benefits of the generation station in the community.

"The safe operation of Ontario's nuclear assets is our top priority," said Greg Rickford, Minister of Energy, Northern Development and Mines. "I'm pleased that OPG (Ontario Power Generation) has developed an innovative proposal that will provide Ontarians with emission-free, low cost energy, and keep highly-skilled Ontarians working in their communities longer."

OPG (Ontario Power Generation) informed the government that ongoing testing demonstrates the plant is safe to operate beyond its previously scheduled shutdown date of 2024 and the continued improved performance at the plant provides value to electricity consumers. In December 2019, Pickering was given an exemplary performance rating from the World Association of Nuclear Operators.

"Our extensive analysis has shown that we can safely and reliably operate Pickering until the end of 2025 and provide a solid benefit to the ratepayer," said Ken Hartwick, OPG (Ontario Power Generation) President and CEO. "I want to recognize every one of the Pickering staff for their commitment to safety and for their role in improving performance year over year. The station's performance is better than ever and Ontario electricity users will continue to benefit from clean and stable baseload power for several more years."

OPG (Ontario Power Generation) requires approval from the Canadian Nuclear Safety Commission (CNSC) for its revised schedule. The final decision regarding the safe operating life of the Pickering site will be made by the CNSC (Canadian Nuclear Safety Commission), which employs a rigorous and transparent process, including public hearings for decisions on licensing of major nuclear facilities.

Supporting OPG's (Ontario Power Generation's) efforts to optimize the Pickering Nuclear Generating Station's shutdown schedule is part of the government's plan to maintain a reliable and affordable energy system while keeping good jobs in local communities.

Quick Facts

- OPG (Ontario Power Generation) employs approximately 4,500 staff to support ongoing operation at its Pickering Nuclear Generating Station. In total, there are about 7,500 jobs across Ontario related to the Pickering Nuclear Generating Station.
- The Pickering Nuclear Generating Station currently provides enough power to meet the needs of a city of 1.5 million people.
- Under this proposal, all nuclear generation at Pickering would end in 2025.
- The plan was developed using data and analysis from the Independent Electricity System Operator (IESO) on capacity needs and was incorporated into its Annual Planning Outlook.

Additional Resources

- Learn more about Pickering Nuclear Generating Station

Related Topics

Business and Economy

Information about Ontario's economy and how to do business here. Includes economic development opportunities, research funding, tax credits for business and the Ontario Budget. Learn more

Environment and Energy

Learn more about how Ontario protects and restores wildlife and the environment. Includes information on conservation and the electricity system. Learn more

Government

Learn about the government services available to you and how government works. Learn more

Jobs and Employment

We've got the resource and supports to help connect job seekers with employers. Learn more

Media Contacts

Alex Puddifant

Minister's Office
Alex.Puddifant@ontario.ca
647-201-8821

Natasha Demetriades

Communications Branch
Natasha.Demetriades@ontario.ca
416-327-3855

Numbers may not add due to rounding.

Table 1
Operating Costs Summary - Nuclear ($M)

Line No.	Cost Item	2016 Actual	2017 Actual	2018 Actual	2019 Actual	2020 Budget	2021 Budget	2022 Plan	2023 Plan	2024 Plan	2025 Plan	2026 Plan
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)
	OM&A:											
	Nuclear Operations OM&A											
1	**Base OM&A**	1,267.5	1,301.1	1,255.5	1,265.6	1,310.0	1,311.3	1,322.7	1,313.3	1,298.2	1,069.5	616.3
2	**Project OM&A**	89.1	122.7	119.1	106.1	107.9	122.3	89.1	85.0	80.6	76.7	62.0
3	**Outage OM&A**	306.7	317.4	344.9	264.3	292.1	431.2	279.1	361.2	212.4	192.6	61.3
4	**Subtotal Nuclear Operations OM&A**	1,663.4	1,741.3	1,719.4	1,636.0	1,710.0	1,864.8	1,690.9	1,759.5	1,591.2	1,338.8	739.7
5	**Darlington Refurbishment OM&A**	3.1	36.1	31.3	1.7	12.3	42.9	24.2	23.6	29.3	25.0	8.4
6	**Darlington New Nuclear OM&A**	0.8	0.7	2.4	5.0	66.0	206.0	2.2	2.2	2.3	2.3	2.3
7	**Allocation of Corporate Costs**	360.5	377.0	368.6	361.7	380.3	396.1	387.9	380.0	375.3	334.3	252.9
8	**Allocation of Centrally Held Costs**	306.0	242.9	256.2	238.6	164.7	197.2	184.5	161.6	143.9	98.9	14.7
9	**Asset Service Fees**[1]	34.1	35.6	37.0	47.8	57.1	54.6	51.5	55.2	65.1	69.7	65.3
10	**Subtotal Other OM&A**	704.5	692.3	695.6	654.8	680.4	896.8	650.3	622.6	615.9	530.2	343.6
11	**Total OM&A**	2,367.9	2,433.6	2,415.0	2,290.8	2,390.4	2,761.5	2,341.2	2,382.0	2,207.1	1,869.0	1,083.3
12	**Nuclear Fuel Costs**	262.1	225.2	231.6	244.5	238.2	202.5	178.3	182.1	209.4	188.6	148.2
	Other Operating Cost Items:											
13	**Depreciation and Amortization**	281.6	366.1	324.1	333.0	452.1	545.2	553.0	471.5	578.7	521.6	568.6
14	**Income Tax**	(39.5)	(27.7)	(4.2)	33.1	66.8	(17.6)	(16.5)	(16.3)	(16.4)	(16.1)	(15.9)
15	**Property Tax**	14.1	13.0	12.7	12.5	12.0	12.6	12.9	13.2	13.6	12.7	9.8
16	**Total Operating Costs**	2,886.2	3,010.2	2,979.2	2,913.9	3,159.4	3,504.2	3,068.9	3,032.6	2,992.4	2,575.8	1,793.9

Notes:

1 Includes asset service fees of $2.3M (2022), $2.2M (2023), $2.0M (2024), $3.5M (2025) and $3.2M (2026) charged to Laurentis Energy Partners for the use of Darlington reactors to produce Molybdenum-99 (Ex. F3-1-4)

Numbers may not add due to rounding.

Table 2
Nuclear Staff Summary - Regular and Non-Regular (FTEs)

Line No.	Group	2016 Actual	2017 Actual	2018 Actual	2019 Actual	2020 Budget	2021 Budget	2022 Plan	2023 Plan	2024 Plan	2025 Plan	2026 Plan
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)
	NUCLEAR OM&A:											
1	**Regular Staff**	5,084.7	5,058.9	4,858.5	4,607.0	4,495.4	4,207.4	3,970.8	3,863.5	3,684.2	3,067.9	2,115.7
	Non-Regular Staff											
2	Term and Extended Temporary	11.3	86.0	207.3	348.5	611.6	787.2	885.3	875.1	881.6	600.7	0.0
3	Temporary	704.0	723.2	763.7	746.1	735.0	780.0	557.6	520.1	412.5	180.6	115.4
4	EPSCA	46.3	72.3	84.9	71.3	42.4	81.9	87.6	84.1	79.3	55.9	49.5
5	**Total Non-Regular Staff**	761.7	881.5	1,055.9	1,165.9	1,388.9	1,649.0	1,530.6	1,479.3	1,373.5	837.2	164.9
6	**Subtotal Nuclear OM&A**	5,846.4	5,940.3	5,914.4	5,772.9	5,884.3	5,856.4	5,501.4	5,342.8	5,057.7	3,905.1	2,280.6
	NUCLEAR CAPITAL:											
7	**Regular Staff**	227.9	248.0	238.8	230.6	237.4	242.8	220.5	221.0	224.7	207.7	186.7
	Non-Regular Staff											
8	Term and Extended Temporary	0.0	0.1	0.8	0.9	4.0	15.3	17.0	17.6	15.9	2.9	0.0
9	Temporary	30.7	36.5	38.1	45.1	67.3	88.0	85.4	83.3	82.8	76.7	72.2
10	EPSCA	24.2	26.1	25.5	39.6	52.5	52.7	44.1	36.6	22.9	21.9	20.6
11	**Total Non-Regular Staff**	55.0	62.6	64.5	85.7	123.8	155.9	146.5	137.4	121.6	101.5	92.8
12	**Subtotal Nuclear Capital**	282.9	310.6	303.2	316.3	361.2	398.7	367.0	358.4	346.2	309.2	279.5
	DARLINGTON REFURBISHMENT:											
13	**Regular Staff**	429.4	540.8	550.0	536.7	581.3	503.7	545.0	545.3	500.2	417.2	247.9
	Non-Regular Staff											
14	Temporary	38.9	56.3	74.8	120.4	137.2	154.5	155.8	161.2	142.5	96.0	52.6
15	EPSCA	73.1	187.5	249.8	200.8	181.5	221.7	243.1	284.6	215.6	149.1	55.0
16	**Total Non-Regular Staff**	111.9	243.8	324.6	321.2	318.7	376.2	398.9	445.7	358.2	245.0	107.5
17	**Subtotal Darlington Refurbishment**	541.3	784.6	874.6	857.9	900.0	879.9	944.0	991.0	858.4	662.2	355.4
	NUCLEAR PROVISION:											
18	**Regular Staff**	313.5	335.8	334.6	329.6	410.6	403.5	413.4	420.6	522.5	796.9	1,432.0
	Non-Regular Staff											
19	Term and Extended Temporary	0.2	1.0	3.6	4.3	2.0	5.0	6.0	6.0	6.0	17.2	92.0
20	Temporary	29.7	36.4	36.9	40.8	53.1	43.7	45.6	45.5	49.9	42.3	35.0
21	EPSCA	0.9	3.5	4.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
22	**Total Non-Regular Staff**	30.8	40.9	44.7	48.1	58.1	51.7	54.6	54.5	58.9	62.5	130.0
23	**Subtotal Nuclear Provision**	344.2	376.7	379.3	377.7	468.8	455.2	468.0	475.1	581.3	859.4	1,562.0
	NUCLEAR NON-ENERGY DIRECT:											
24	**Regular Staff**	23.1	15.9	17.7	21.9	26.0	26.0	26.0	26.0	26.0	13.0	13.9
	Non-Regular Staff											
25	Temporary	4.5	6.1	6.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	**Subtotal Nuclear Non-Energy Direct**	27.5	22.0	23.9	23.9	26.0	26.0	26.0	26.0	26.0	13.0	13.9
27	**Total Nuclear**	7,042.4	7,434.2	7,495.5	7,348.8	7,640.3	7,616.2	7,306.4	7,193.3	6,869.6	5,748.9	4,491.4