UNDERTAKING J3.5
(NON-CONFIDENTIAL)

Undertaking

To provide the update to the Phase 1 report prepared by OPG.

Response

The 2010 Benchmarking Report prepared by OPG is provided as Attachment 1. The name of comparator companies have been redacted as discussed at Ex. F5-T1-S1 page 1. Although marked as "OPG Confidential", the redacted report as filed is not confidential.

The best quartile All Injury Rate, as reported by the Canadian Electrical Association ("CEA") is ██████. The CEA does not report a median value.

July 2010

ONTARIO**POWER**
GENERATION

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NUCLEAR

2010 NUCLEAR BENCHMARKING REPORT

Nuclear Finance - Business Planning and Performance Reporting

Table of Contents

1.0 EXECUTIVE SUMMARY

Background

This report presents a comparison of Ontario Power Generation (OPG) Nuclear's performance to that of nuclear industry peer groups both in Canada and the United States. The report was prepared as part of OPG's commitment to "performance informed" business management. The results of this report are used during business planning to drive a top-down target setting with business improvement being the objective.

Benchmarking involves three key steps: (a) identifying key performance metrics to be benchmarked, (b) identifying the most appropriate industry peer groups for comparison, and (c) preparing supporting analyses and charts. OPG personnel responsible for specific performance metrics provided insight into the factors contributing to current operational performance.

Performance Indicators

Good benchmarked performance indicators are defined as metrics with standard definitions, reliable data sources, and utilization across a good 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. As such, 20 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 listed in Table 1 and are divided into four categories aligned with OPG Nuclear's four cornerstone values: safety, reliability, value for money and human performance.

A new metric, Human Performance Error Rate, has been added to the 2010 Benchmarking Report. This ensures a focus on improving human performance by comparing OPG Nuclear to industry peers through the use of consistent, comparable data. Additionally, the effects of good or poor human performance affect areas like 2-Year Industrial Safety Accident Rate, 2-Year Forced Loss Rate and 2-Year Unit Capability Factor.

Industry Peer Groups

Different peer groups are selected depending upon performance indicators widely utilized within the nuclear industry. In all, five different peer groups were used as illustrated in Table 1 and panel members are detailed in Section 7.0, Tables 7, 8, 9, 10 and 11.

Table 1: Industry Peer Groups

	COG CANDUs (WANO)	All North American PWR and PHWRs (WANO)	INPO AP928 Workgroup	INPO	CEA	EUCG North American Plants (US and Canada)
Safety						
All Injury Rate					X	
2-Year Industrial Safety Accident Rate*		X				
Fuel Reliability*	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					
2-Year Collective Radiation Exposure*	X					
Airborne Tritium Emissions per Unit	X					
Reliability						
WANO NPI	X					
2-Year Forced Loss Rate*	X					
2-Year Unit Capability Factor*	X					
2-Year Chemistry Performance Indicator*	X					
1-Year On-line Elective Maintenance Backlog (OEMB)			X			
1-Year On-line Corrective Maintenance Backlog (OCMB)			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 (OM&A) / MWh						X
3-Year Capital Costs / MW DER						X
Human Performance						
Human Performance Error Rate				X		

* Subindicator of WANO NPI

Data provided by the World Association of Nuclear Operators (WANO) is the primary source of benchmarking data for operational performance indicators. Eleven out of twenty benchmarking metrics have been compared to the COG CANDU panel. All WANO performance indicators are measured at the unit level as well as at the plant level except for Industrial Safety Accident Rate, Emergency AC Power Unavailability and Airborne Tritium Emissions per Unit.

For a few of the specialized operating metrics, different peer groups were used since WANO data is not available for these metrics. For comparing maintenance backlog, the peer group consists of all plants participating in the Institute of Nuclear Power Operations (INPO) AP928 workgroup. For All Injury Rate comparison, the Canadian Electricity Association (CEA) panel is used.

For financial performance comparisons, data compiled by the Electric Utility Cost Group (EUCG) is used. EUCG is a nuclear industry operating group and the recognized source for cost benchmark information. EUCG cost indicators are available at the plant level only and compared on a net MWh generated basis (to be referred to as MWh subsequently) and a per MW design electrical rating (DER) basis. The only CANDU operators reporting EUCG data in 2009 were OPG and Bruce Power which is not a sufficiently large panel to provide a basis for comparison. Should more CANDU operators choose to join EUCG in the future comparisons to a CANDU specific panel will be reconsidered.

For human performance comparisons, data is obtained from the INPO.

Report Structure

The report is structured to focus on the four OPG Nuclear cornerstone areas, with detailed comparisons at the plant, and where applicable, unit level (Sections 2.0-5.0). Each indicator is displayed graphically from best to worst (in bar chart format) for the most recent year in which data is available. Zero values are excluded from all calculations except where zero is a valid result. Missing data was inputted by averaging the prior and subsequent year if possible. If this was not possible, the average of the two most recent years is used.

Next, the historical trend is graphed (in line chart format) using data for the last three to five years (depending upon availability and metric). Each graph also includes median and best quartile results, and for some WANO operating metrics, the graph also shows the values required to achieve full WANO NPI points.

Following the graphical representation, performance observations are documented, as well as, insights into the key factors driving performance at OPG Nuclear.

Section 6.0 of the report is designed to provide an operator level summary across a few high-level metrics. The operator level analysis looks at fleet operators across North America, utilizing a simple average of the results (mean) from each of their units/plants. Operations related results are averaged at the unit level and cost related results are averaged at the plant level.

Section 7.0 provides an appendix of supporting information, including common acronyms, definitions and panel composition details.

Benchmarking Results – Plant Level Summary

Table 2 provides a summary of OPG Nuclear's performance compared to benchmark results.

Since achievement of full WANO NPI points is recognized within the industry as a measure of desirable performance, performance gaps are assessed against full WANO NPI points in addition to median and best quartile performance. Green shaded boxes indicate that maximum NPI points were achieved or that performance is above best quartile, white shaded boxes indicate that performance was between best quartile and median, yellow shaded boxes indicate that performance is between median and the worst quartile, and red shaded boxes indicate that performance is within the worst quartile. Each metric represented is further analyzed in Sections 2.0-5.0.

Table 2: Plant Level Performance Summary

2009 Benchmarking Results

Metric	NPI Max	2009 Actuals				
		Best Quartile	Median	Pickering A	Pickering B	Darlington
Safety						
All Injury Rate (#/200k hours worked)		■	■	1.11	0.64	0.75
2-Year Industrial Safety Accident Rate (#/200k hours worked)	0.20	0.03	0.07	0.21 ⇩	0.11	0.06
2-Year Collective Radiation Exposure (man-rem per unit)	80.00	67.78	93.58	78.01	93.10 ⇧	61.44 ⇧
Airborne Tritium Emissions (Curies) per Unit[2]		1,878	3,784	7,073 ⇩	1,628 ⇧	1,081
Fuel Reliability (microcuries per gram)	0.000500	0.000001	0.000041	0.000041 ⇧	0.000056 ⇧	0.000247
2-Year Reactor Trip Rate (# per 7,000 hours)	0.50	0.00	0.21	0.74	0.27	0.00
3-Year Auxiliary Feedwater System Unavailability (#)	0.0200	0.0002	0.0036	0.0063	0.0043	0.0000
3-Year Emergency AC Power Unavailability (#)	0.0250	0.0021	0.0093	0.0106	0.0107	0.0059
3-Year High Pressure Safety Injection Unavailability (#)	0.0200	0.0000	0.0006	0.0011	0.0001	0.0001
Reliability						
WANO NPI (Index)		92.6	70.8	61.1	70.2	95.1 ⇧
2-Year Forced Loss Rate (%)	1.00	0.42	1.98	26.66	14.63	1.13 ⇩
2-Year Unit Capability Factor (%)	92.0	91.2	85.2	68.0	77.7 ⇧	90.2 ⇩
2-Year Chemistry Performance Indicator (Index)	1.01	1.00	1.04	1.09 ⇧	1.11	1.01
1-Year Online Elective Maintenance (work orders per unit)		201	245	364	644	286
1-Year Online Corrective Maintenance (work orders per unit)		2	5	14	24	12
Value for Money						
3-Year Total Generating Costs per MWh ($ per Net MWh)		30.68	35.77	95.41	54.64	32.77
3-Year Non-Fuel Operating Costs per MWh ($ per Net MWh)		18.50	21.94	82.70	48.37	26.94
3-Year Fuel Costs per MWh ($ per Net MWh)		5.35	5.83	3.24	3.13	3.11
3-Year Capital Costs per MW DER (k$ per MW)		38.02	50.14	48.26 ⇩	20.81	21.19
Human Performance						
Human Performance Error Rate (# per ISAR hours)		0.00758	0.01332	0.01579	0.01052	0.00710

Notes

1. No median benchmark available.

2. 2009 benchmark data unavailable. 2008 used for benchmark and results.

Green = maximum NPI points achieved or best quartile performance

White = 2nd quartile performance

Yellow = 3rd quartile performance

Red = worst quartile performance

⇩ Declining Benchmark Quartile Performance vs. 2008

⇧ Improving Benchmark Quartile Performance vs. 2008

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 was ignored and 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 period 2002-2009 was obtained and averages are as provided by WANO.

The All Injury Rate was calculated using data from the Canadian Electricity Association (CEA). Median information and individual company information was not available for this metric; therefore only trend and best quartile information is presented. The peer group for this metric is limited to members of CEA (Section 7.0, Table 10).
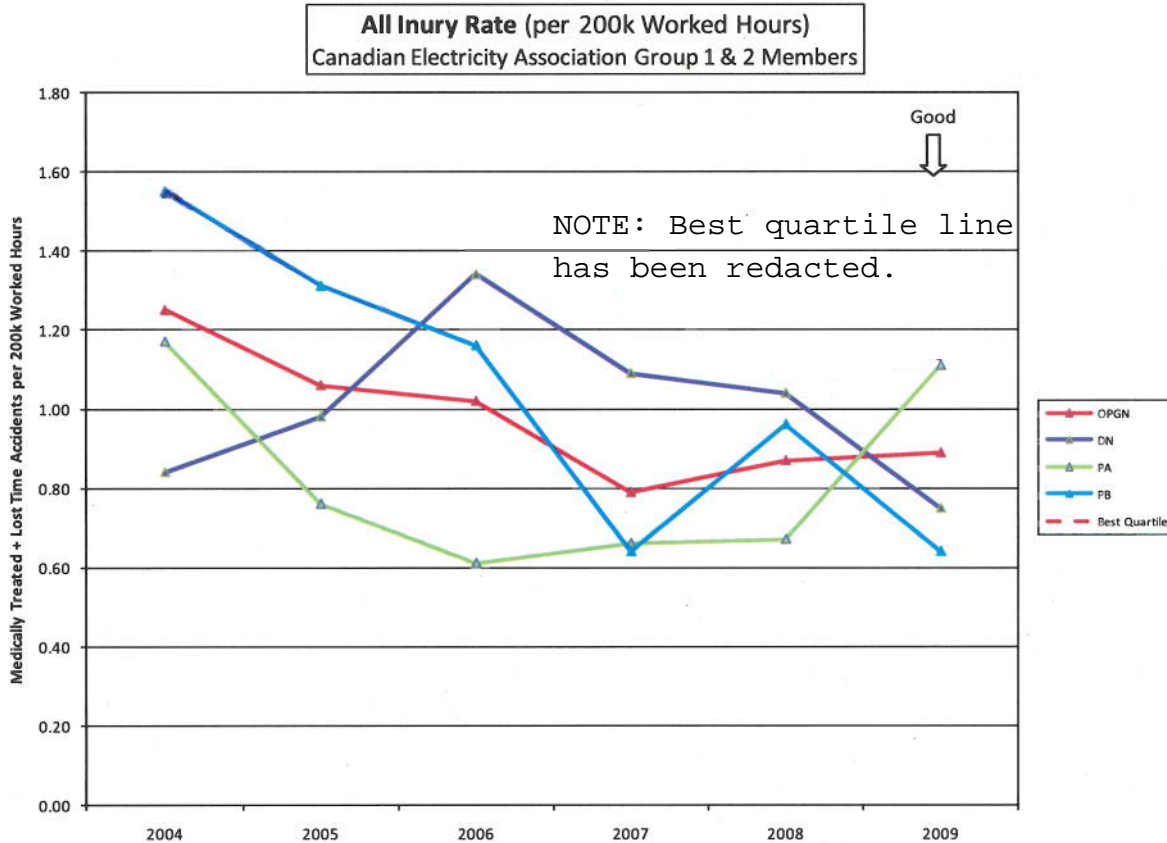
Airborne Tritium Exposure per Unit data was collected from COG for 2004 to 2008. Data for 2009 was unavailable at the time that this report was produced. The peer group for this metric is all CANDUs which are members of COG.

Discussion

Nine metrics are included in this benchmarking report to reflect safety performance, including seven of the ten metrics which comprise the WANO NPI index: Industrial Safety Accident Rate, Collective Radiation Exposure, Fuel Reliability, Unplanned Automatic Reactor Trips, Auxiliary Feedwater Safety System, Emergency AC Power Safety System and High Pressure Safety Injection. The remaining WANO NPI metrics are included in Section 3.0 under the Reliability cornerstone. Additionally, the CEA All Injury Rate and the COG Airborne Tritium Emissions per unit are included.

Overall, OPG Nuclear's performance in the WANO NPI safety metrics is strong, achieving full NPI points for many of the metrics. Pickering A's performance is poor for three indicators, with its performance being in the fourth quartile among CANDU plants in 2009. Pickering B achieved best quartile performance in all safety metrics except for the Collective Radiation Exposure where it achieved second quartile performance. Darlington achieved best quartile performance in all safety metrics.

All Injury Rate

All Inury Rate (per 200k Worked Hours)
Canadian Electricity Association Group 1 & 2 Members

NOTE: Best quartile line has been redacted.


Observations – All Injury Rate

Trend
- All OPG plants are performing better than best quartile and have been since 2004.
- OPG has shown improvement in the number of medically treated and lost time accidents since 2004.
- Darlington experienced increasing injuries from 2004-2006, but has steadily improved since 2006.

**Factors Contributing to Performance**

- OPG has a very robust reporting culture for all injuries (including minor, repetitive, and chronic injuries that exceed other utilities) in the benchmarking panel.
- The metric is more inclusive than the Industrial Safety Accident Rate (ISAR) as it incorporates all medically treated injuries.
- The benchmark panel for this metric includes transmission and distribution personnel.
- Targeted programs and initiatives addressing common injuries, such as musculoskeletal disorders, have reduced the frequency of these types of injuries and lost time accidents.
- Pickering A experienced an increase in the number of medically treated injuries in 2009 but recorded 0 lost time accidents for the year.

2-Year Industrial Safety Accident Rate

2009 2-Year Industrial Safety Accident Rate (per 200,000 man-hours worked)
North American PWR & PHWR Plant Level Benchmarking

Accidents per 200,000 Man-hours Worked
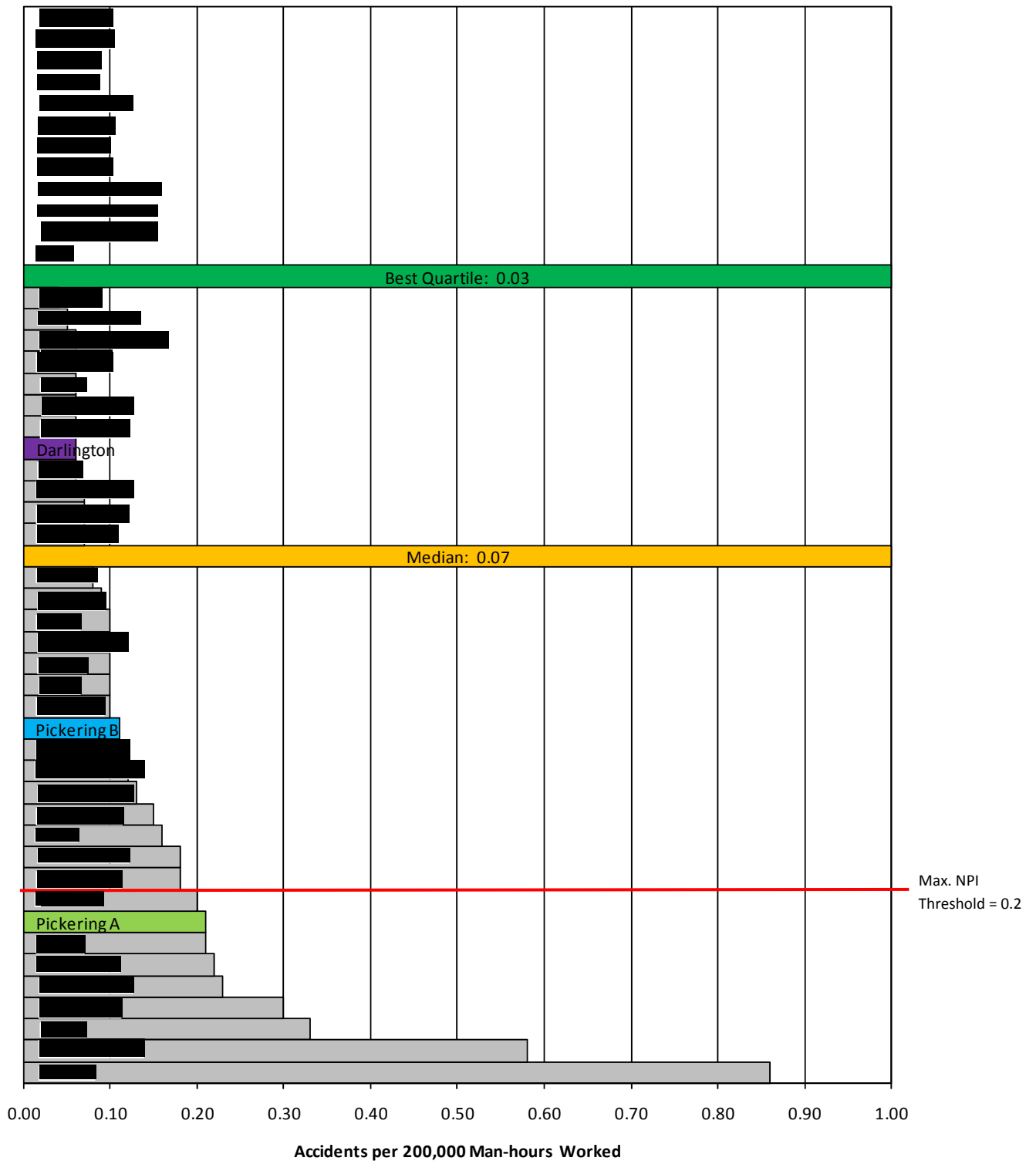
2009 2-Year Industrial Safety Accident Rate (per 200k man-hours worked)
North American PWR & PHWR Plant Level Benchmarking
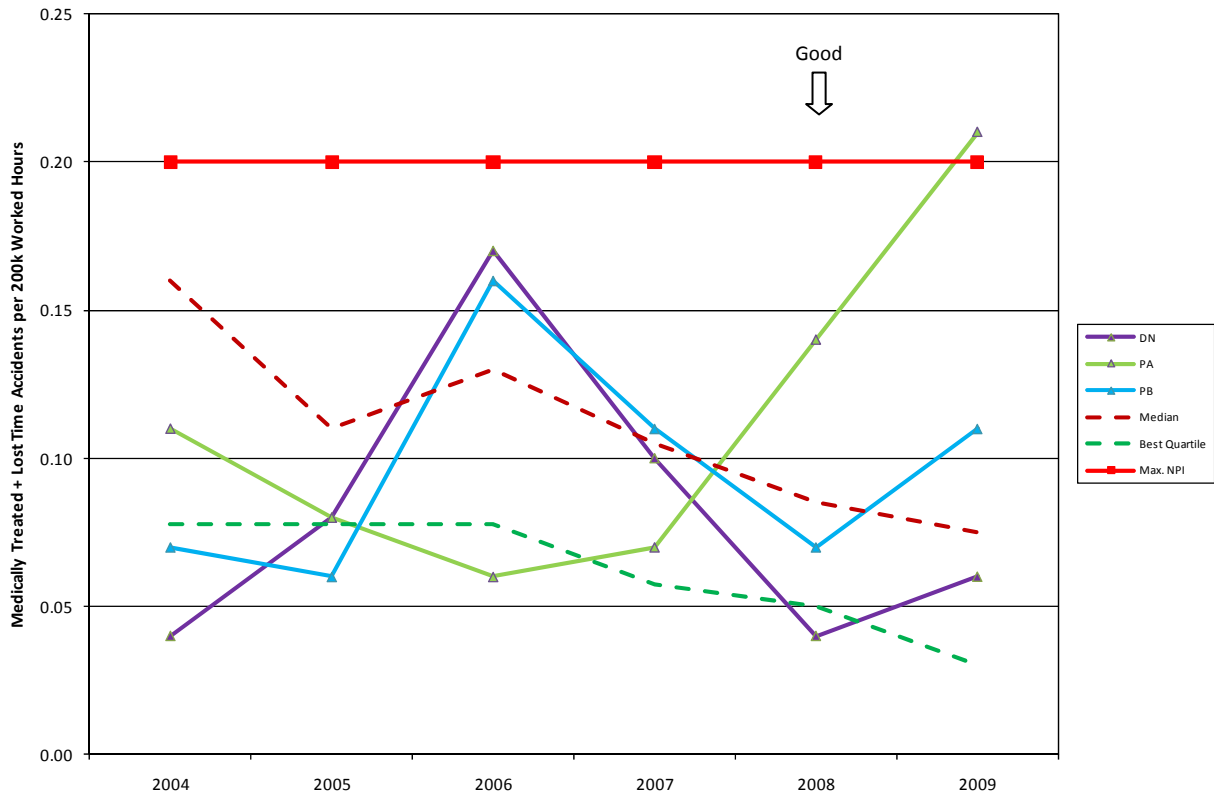
Observations – 2-Year Industrial Safety Accident Rate (ISAR)

2009 (2-Year Rolling Average)
- Best quartile for 2009 was 0.03 which improved from 2008 (0.05).
- Darlington ISAR performance is below best quartile for 2009 at 0.06, but above the median of 0.07 which still achieved full NPI points.
- Pickering A and Pickering B are below the median of 0.07 for 2009, but only Pickering A did not meet full NPI points.

Trend
- Darlington fell to below best quartile in 2006, but returned to best quartile in 2008 before sliding once again in 2009. It earned full WANO NPI points.
- Pickering A performance remained close to best quartile for 2004-2007, but declined in 2008 and 2009.
- Pickering B performance declined in 2006, returned to better than the median in 2008, but declined again in 2009.

Factors Contributing to Performance

- Lost time and restricted duty injuries to non-station staff (support staff) who "reside at the station" are counted against station ISAR performance.
- Greater focus on lost time accident prevention through targeted initiatives on sources of lost time accidents, such as musculoskeletal injury prevention, will improve OPG performance.
- ISAR is a measure of "permanent utility personnel" and does not include contractors. Many of the utilities in the benchmarking panel utilize contractors to a greater extent than OPG for higher risk work activities (e.g. outages).

Pickering A
- Pickering A must have zero lost-time injuries in order to achieve best quartile, and experienced 2 lost-time accidents in 2008 and 1 restricted duty injury in 2009 which resulted in a Pickering A ISAR that is worse than median.
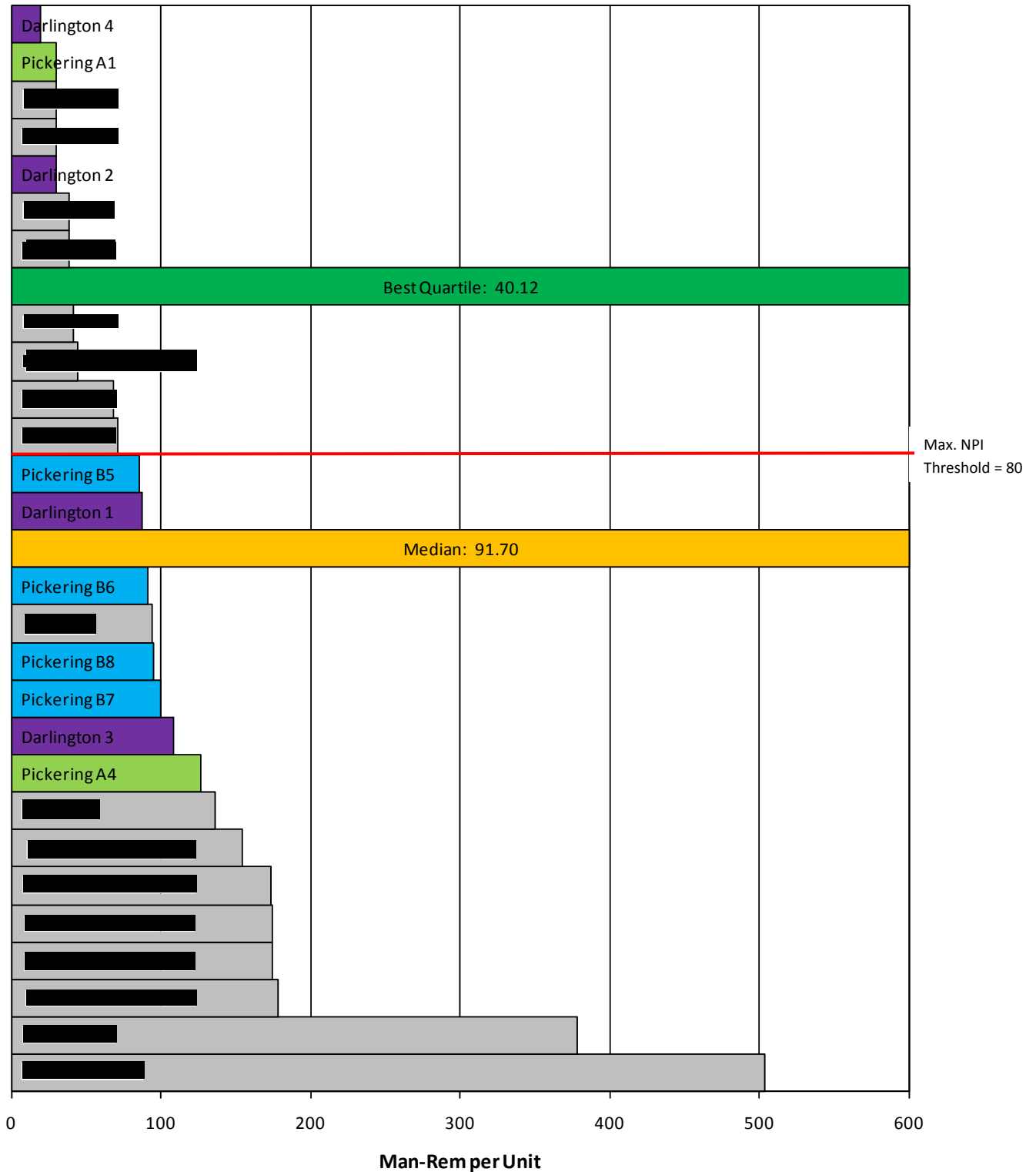
Pickering B
- Pickering B must have less than one lost time injury in order to achieve best quartile and experienced 2 ISAR events in 2008 and 2 in 2009, which put Pickering B ISAR between best quartile and median.
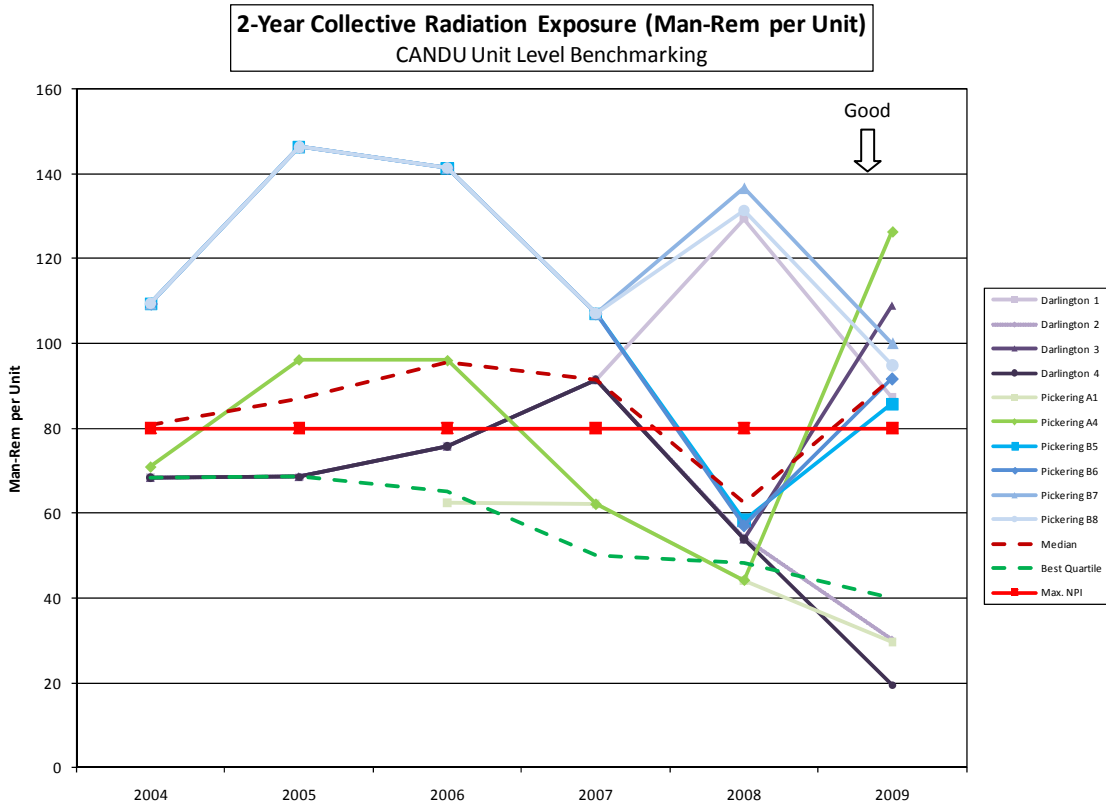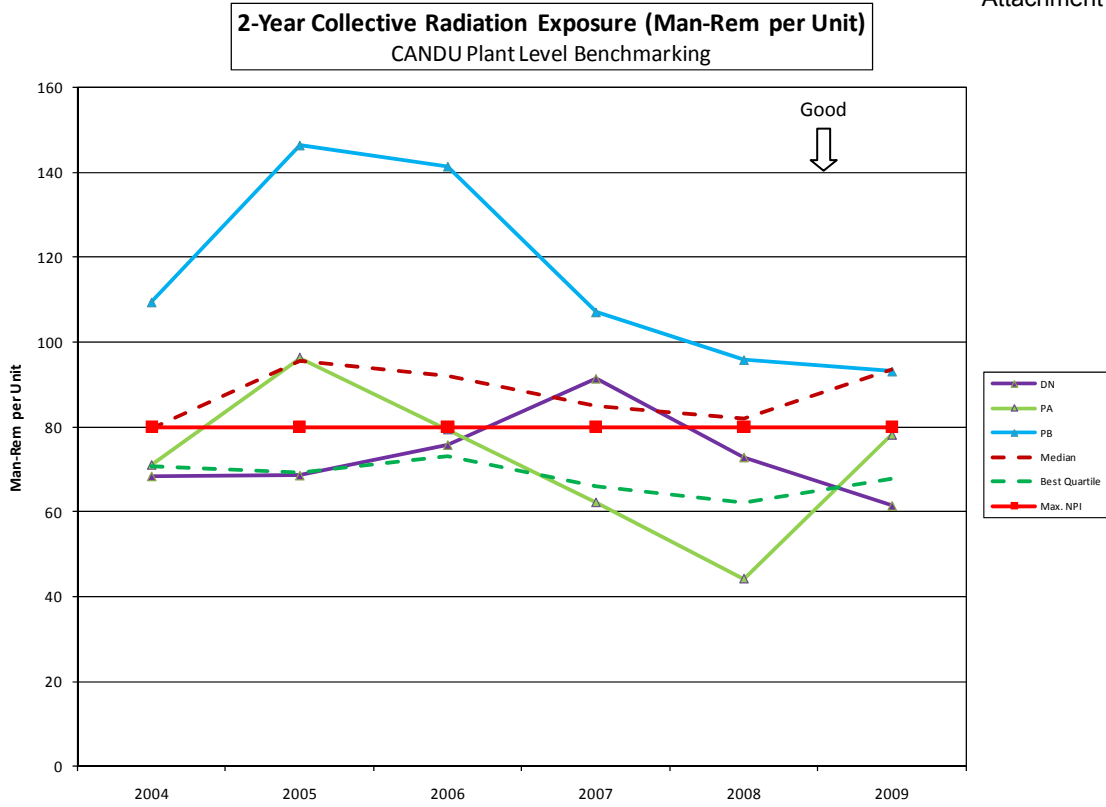
2-Year Collective Radiation Exposure

2009 2-Year Collective Radiation Exposure (Man-Rem per Unit)
CANDU Plant Level Benchmarking

2009 2-Year Collective Radiation Exposure (Man-Rem per Unit)
CANDU Unit Level Benchmarking

2-Year Collective Radiation Exposure (Man-Rem per Unit)
CANDU Plant Level Benchmarking
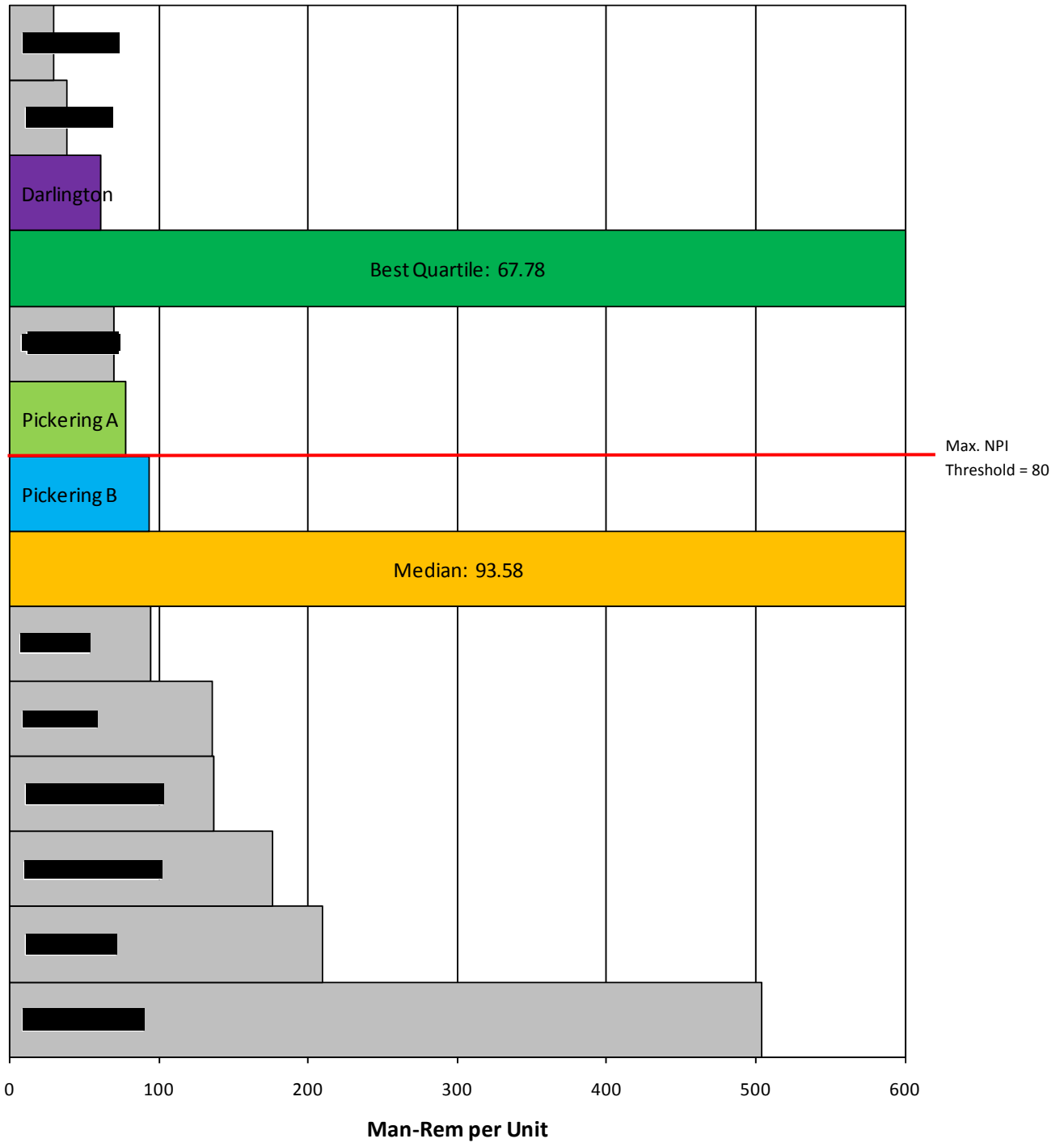
2-Year Collective Radiation Exposure (Man-Rem per Unit)
CANDU Unit Level Benchmarking

Observations – 2-Year Collective Radiation Exposure (CANDU)

2009 (2-Year Rolling Average)
- Darlington is currently better than best quartile.
- Pickering A is currently better than median.
- Pickering B is currently better than median.

Trend

Darlington
- In 2008, Darlington had one planned outage, D811 and one forced outage D821 resulting in an annual CRE performance of 43.0 man-rem/unit versus a target of 75 due to some significant ALARA improvements in shielding and reducing vault tritium during outages.
- In 2009, Darlington had a vacuum building outage and three forced outages. Collective Radiation Exposure (CRE) performance was 79.9 man-rem/unit versus a target of 85.
- The 2-year CRE CANDU unit level benchmarking graph shows that the radiation levels within the vault and associated systems have been decreasing since 2004. This is attributed to the change in pH level from 10.8 to 10.2, and the introduction of submicron filtration in the primary heat transport (PHT). The reason for the increasing trend in CRE since 2008 is higher workload associated with outages, i.e. single fuel channel replacement, horizontal flux detector cable replacement, and feeder inspections and replacements.

Pickering A
- Since 2007, Pickering A Units 2 and 3 have been undergoing a process called safe storage which required some dose expenditure, but significantly less than for an operating unit. Safe storage dose does not make up a large percentage of the overall Pickering A dose.
- Pickering A CRE performance in 2008 (44.20 man-rem/unit) benefited short term when the planned outage for Unit 4 (P841) was deferred from 2008 until the first quarter of 2009. As a result, Pickering A received full NPI points.
- Pickering A plant age (oldest OPG units) and design (including more stellite components and poor dryer performance) results in higher radiation source term and dose rates compared to the industry.
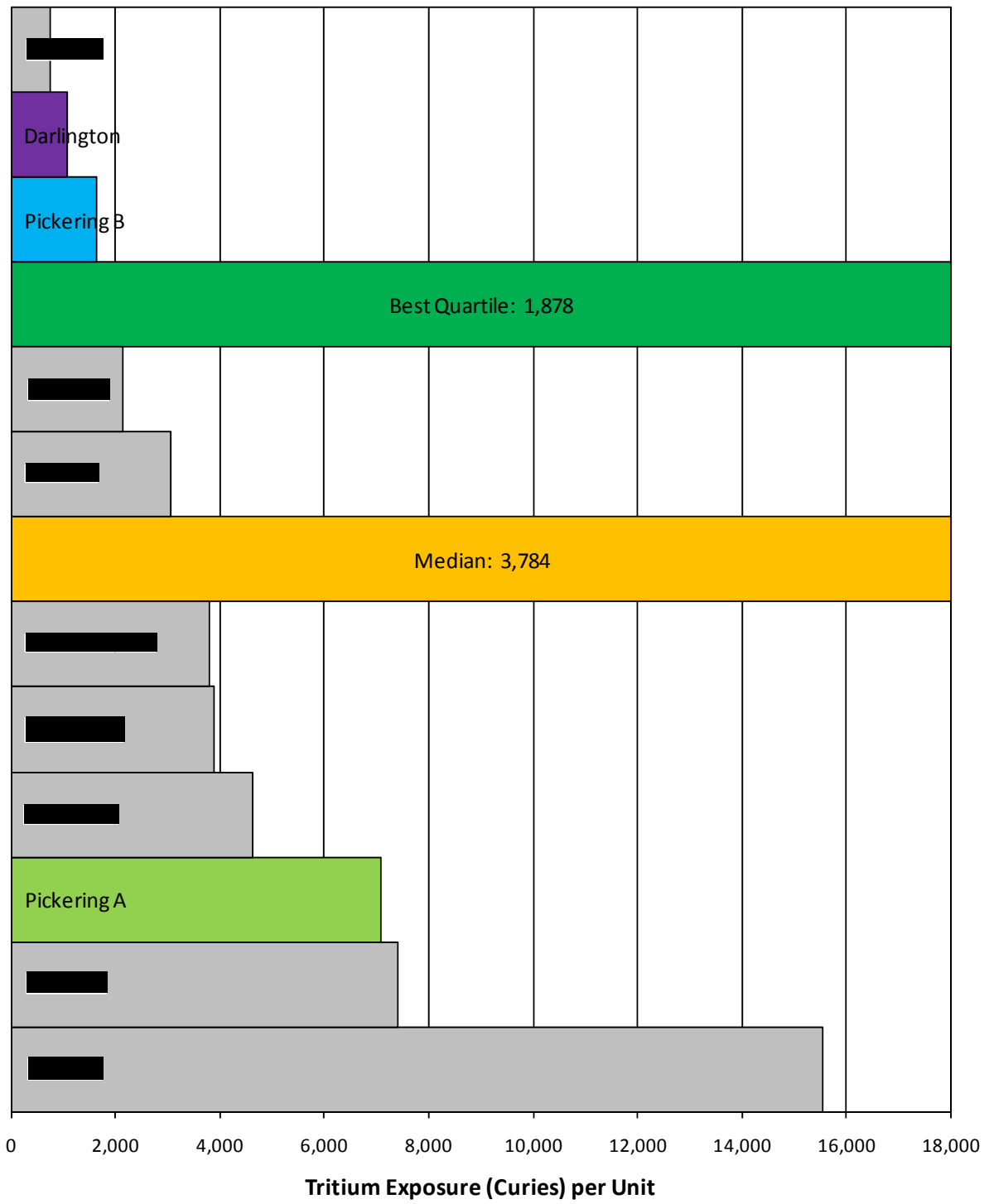
Pickering B
- Pickering B had two planned outages in 2009 and five forced outages that resulted in an annual year-end CRE performance of 87.7 man-rem/unit versus a target of 86
- In 2008, Pickering B had two planned outages, P871 and P881, which resulted in an annual year-end CRE performance of 98.5 man-rem/unit versus a target of 98.8. Included in P871 was a Single Fuel Channel Replacement which resulted in a dose of 37 rem.
- Decreasing trend in CRE since 2005 for Pickering B is believed to be attributed to the change in pH from 10.8 to 10.2 and the introduction of submicron filtration in the PHT system.

Factors Contributing to Performance
- The number of outages is a significant driver of CRE due to extended exposure during specific maintenance activities performed only during outages. Other key performance drivers for this metric include: source term, outage duration, human performance, and technology.

Airborne Tritium Emissions per Unit

**2008 Airborne Tritium Emissions (Curies) per Unit
COG CANDUs**

Tritium Exposure (Curies) per Unit

Airborne Tritium Emissions (Curies) per Unit
COG CANDUs
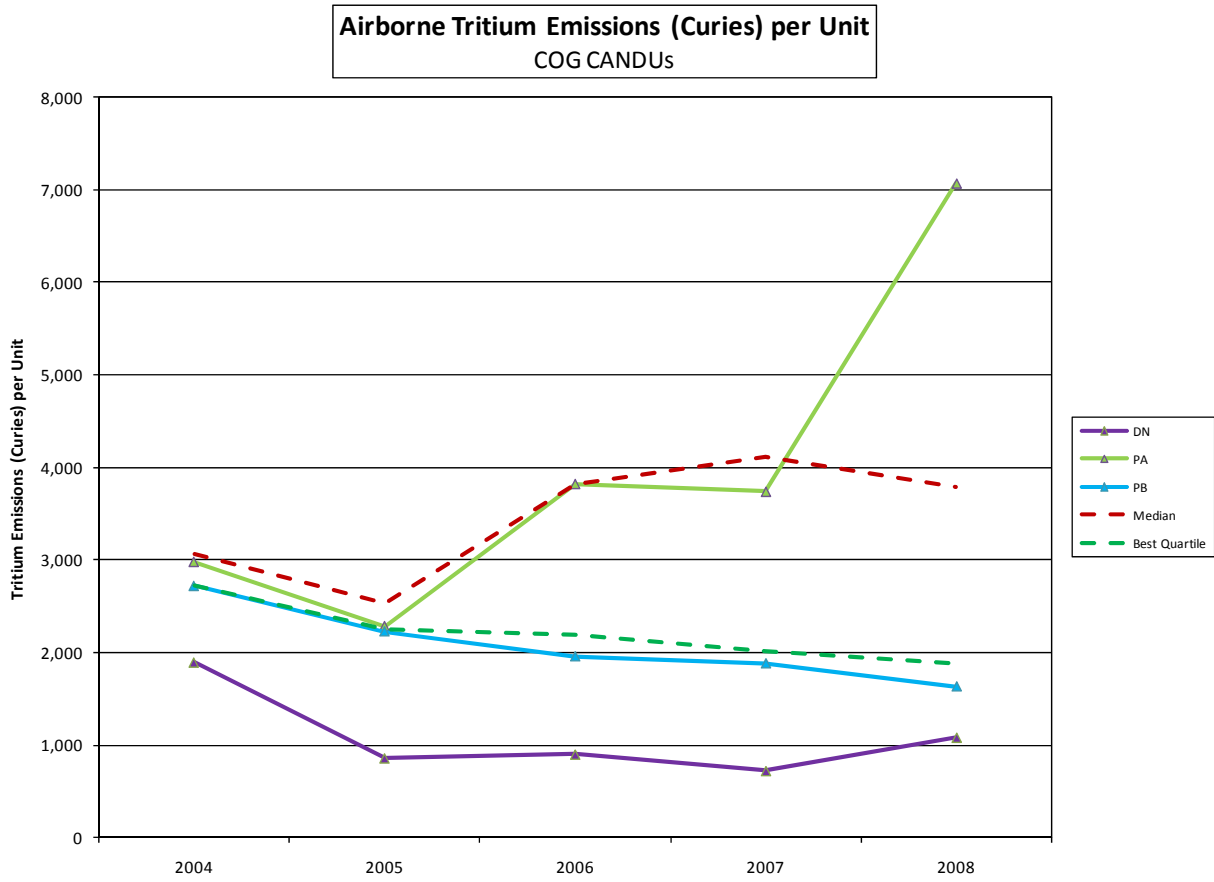
Observations – Airborne Tritium Emissions (Curies) per Unit

2008 Performance
- 2008 data is used because 2009 data is unavailable at the time of benchmarking.
- Curies/Unit at top quartile CANDU plants was 1,878 or lower.
- Darlington and Pickering B performed better than best quartile.
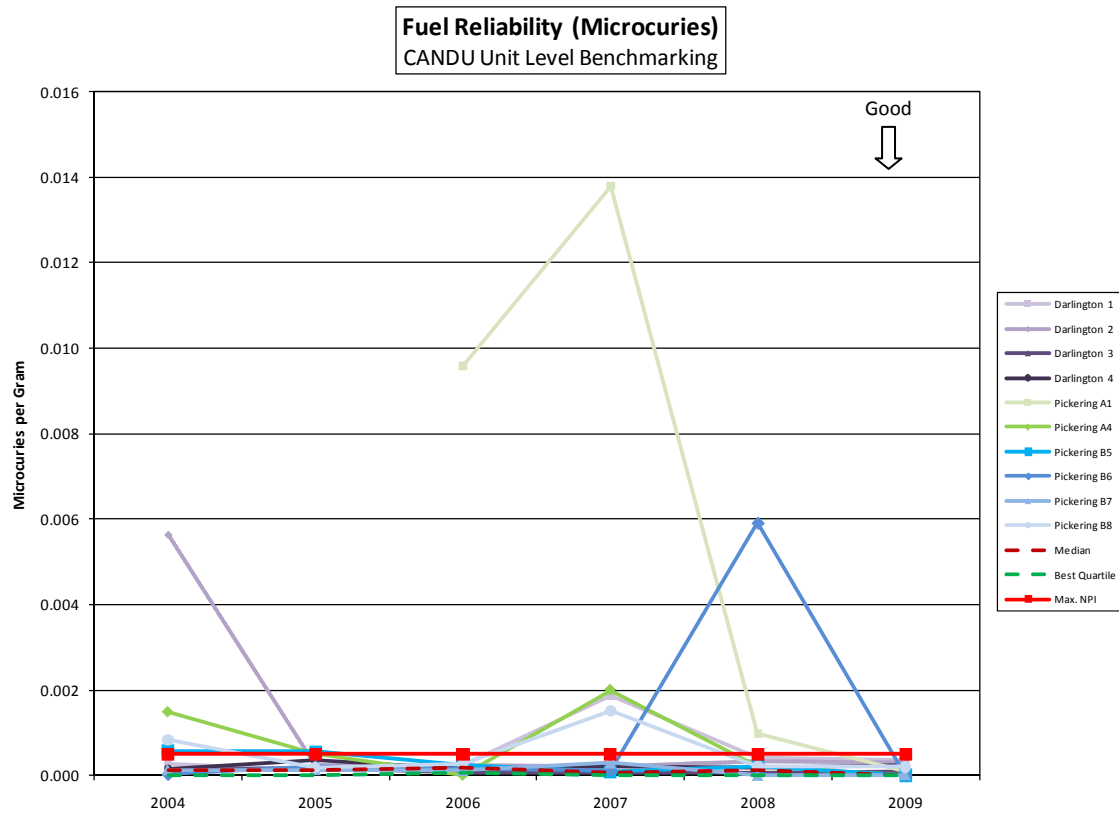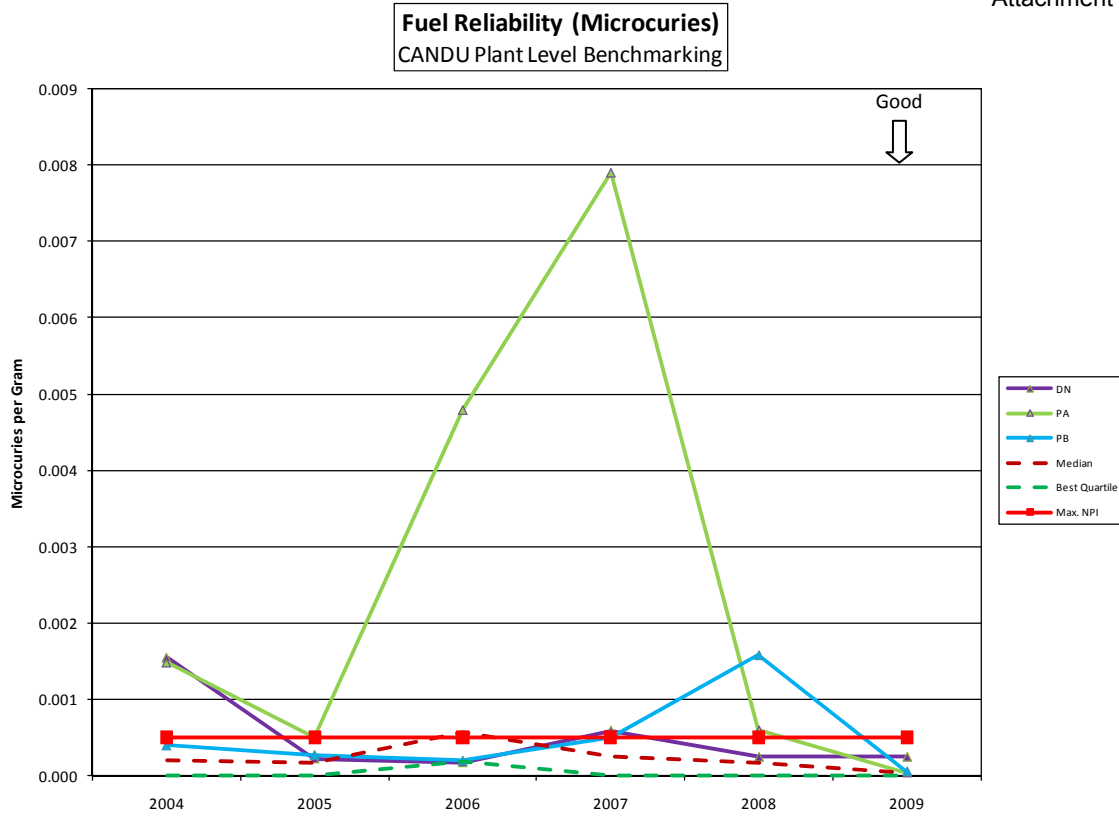- Pickering A placed in worst quartile.

Trend
- Darlington and Pickering B sites have demonstrated consistent strong performance over the last five years.
- The industry trend line graph shows that best quartile performance continues to improve. Median performance is likely reflective of both aging and higher tritium source terms in facilities without access to detritiation capability.

Factors Contributing to Performance

- Facilities with access to a tritium removal facility (Darlington, Pickering) fare better in this measure, having the benefit of a reduced source term.
- Darlington's attachment to a tritium removal facility brings benefits which are mitigated by the emissions from the tritium removal facility itself which also processes tritiated water from other sites.
- Sites having units that are in the process of being placed in a long-term "safe state" (Pickering A) are hindered by emissions from those units.

Pickering A
- In 2008, Pickering A emitted almost 2.5 times more tritium than Pickering B, but operated half as many units.
- The increase in tritium emissions was due to the absence of vapour barriers on Unit 4 fuelling machine Service Rooms from January to August and the presence of moderator water in Unit 1 moderator room.
- The tritium source term in Pickering Units 2 and 3 produces emissions without generation and its removal is essential for Pickering A's sites to move toward best quartile.
- Consistently executing moderator swaps, thereby taking full advantage of access to detritiation capabilities, would also reduce Pickering A's gap to best quartile.

Fuel Reliability

2009 Fuel Reliability (Microcuries)
CANDU Plant Level Benchmarking

Fuel Reliability (Microcuries)
CANDU Plant Level Benchmarking

Fuel Reliability (Microcuries)
CANDU Unit Level Benchmarking

Observations – Fuel Reliability (CANDU)

2009
- Fuel reliability at best quartile CANDU plants was 0.000001 for plants and equally negligible for units.
- All units at Darlington performed well, although not all are at best quartile. Darlington received full WANO NPI points.
- Pickering A showed significant improvement in 2009.
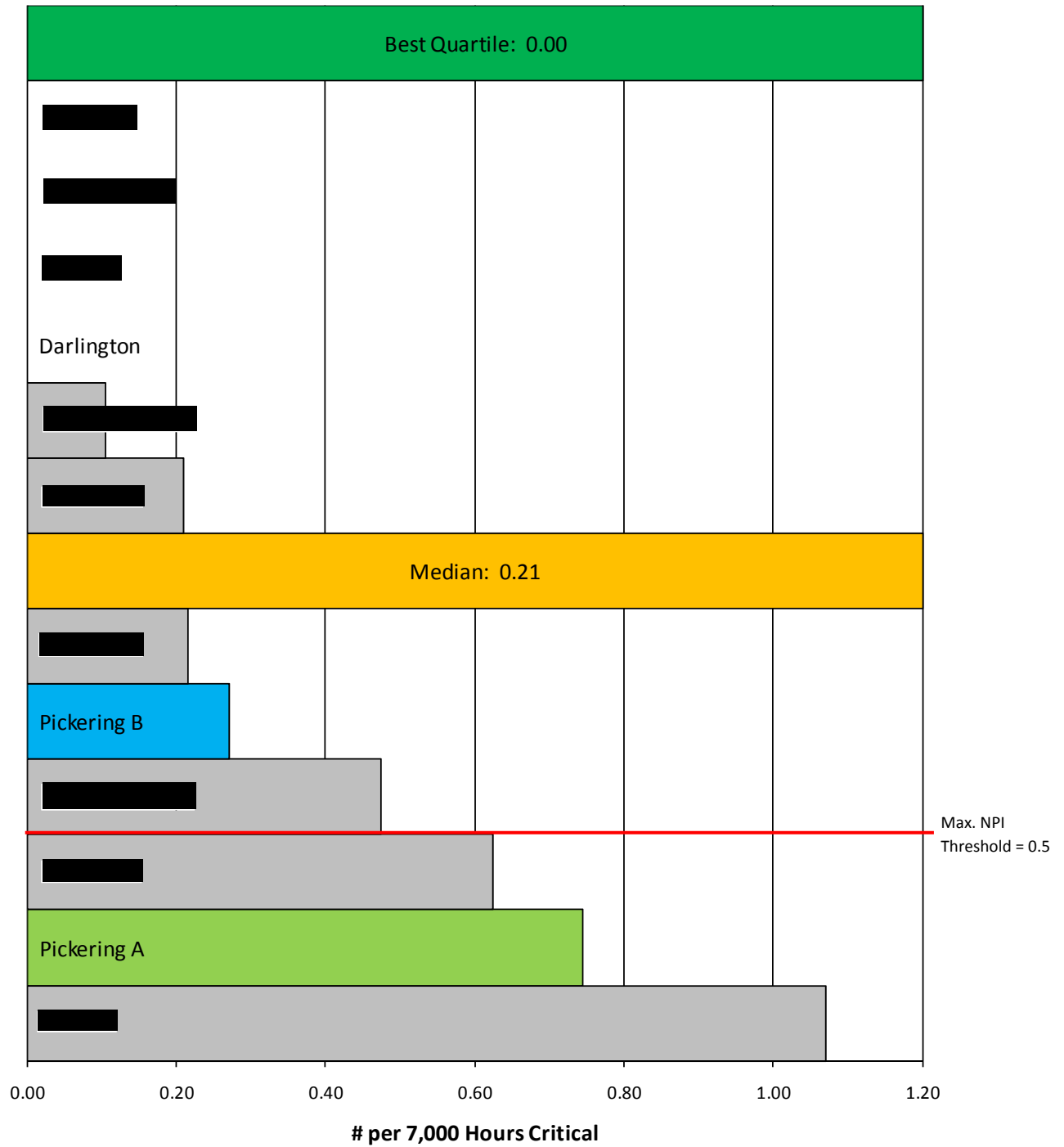- Pickering B showed significant improvement in 2009.

Trend
- Darlington performance was consistently strong.
- Pickering A performance spiked negatively in 2007, but improved in 2008 and 2009. This caused it to go from third quartile performance in 2008 to meeting full NPI points in 2009.
- Pickering B performance was overall strong for the review period and showed a positive trend in 2009, causing it to go from fourth quartile performance in 2008 to full NPI points in 2009.

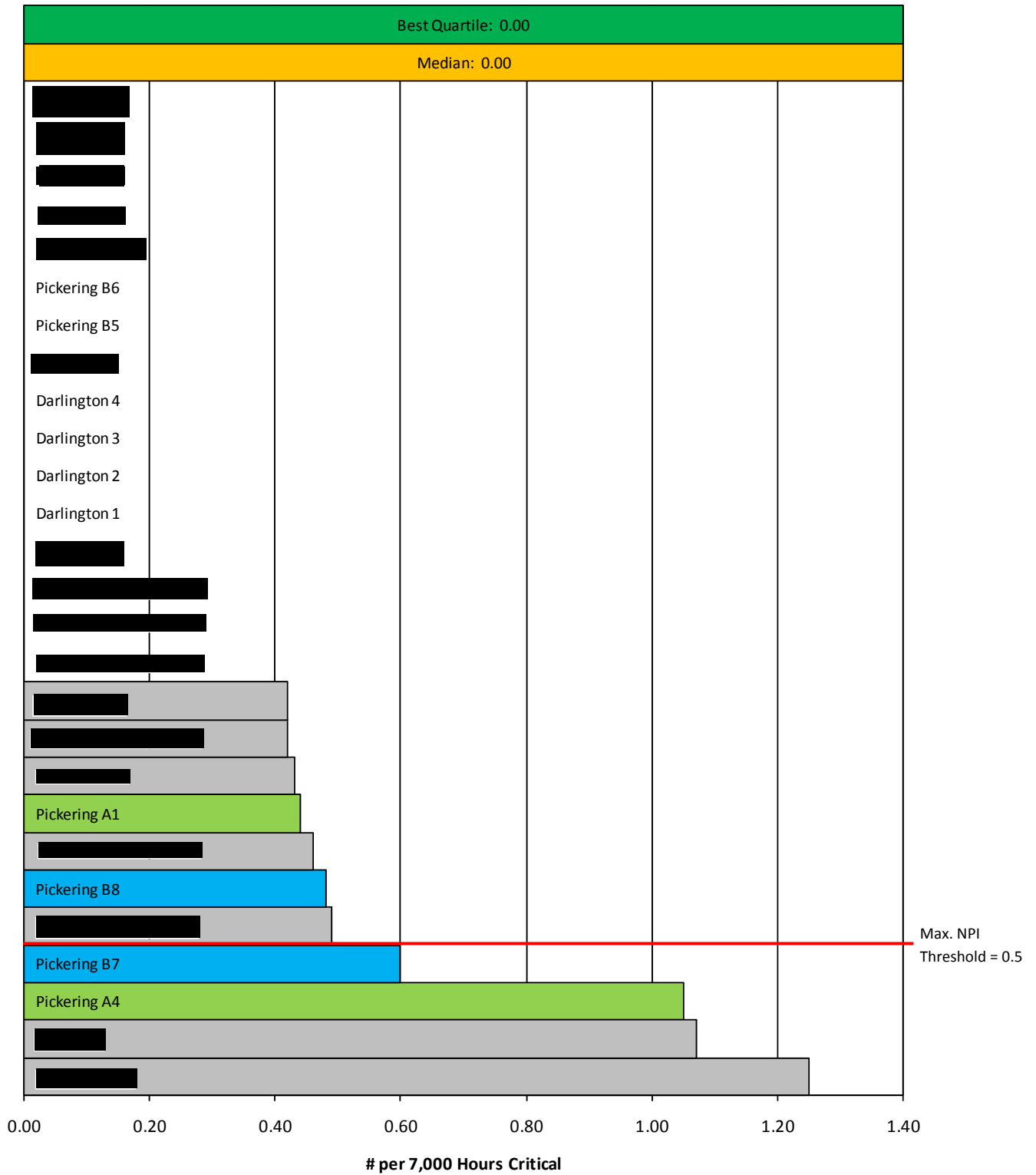## Factors Contributing to Performance

Darlington
- Darlington had no fuel defects in 2009. However, it appears that Fuel Reliability Index calculations put significant weight on correcting for tramp uranium which adversely impacts performance at Darlington. It is worth noting that, while higher levels of iodines may be present at certain plants, albeit with lower purification flows, their calculated FRI value may be lower due largely to the fact that they have more tramp uranium present. Darlington is currently investigating this finding.

2-Year Unplanned Automatic Reactor Trips

2009 2-Year Unplanned Automatic Reactor Trips
CANDU Plant Level Benchmarking

Best Quartile: 0.00

Darlington

Median: 0.21

Pickering B

Max. NPI Threshold = 0.5

Pickering A

 # per 7,000 Hours Critical

(x-axis: 0.00, 0.20, 0.40, 0.60, 0.80, 1.00, 1.20)

2009 2-Year Unplanned Automatic Reactor Trips
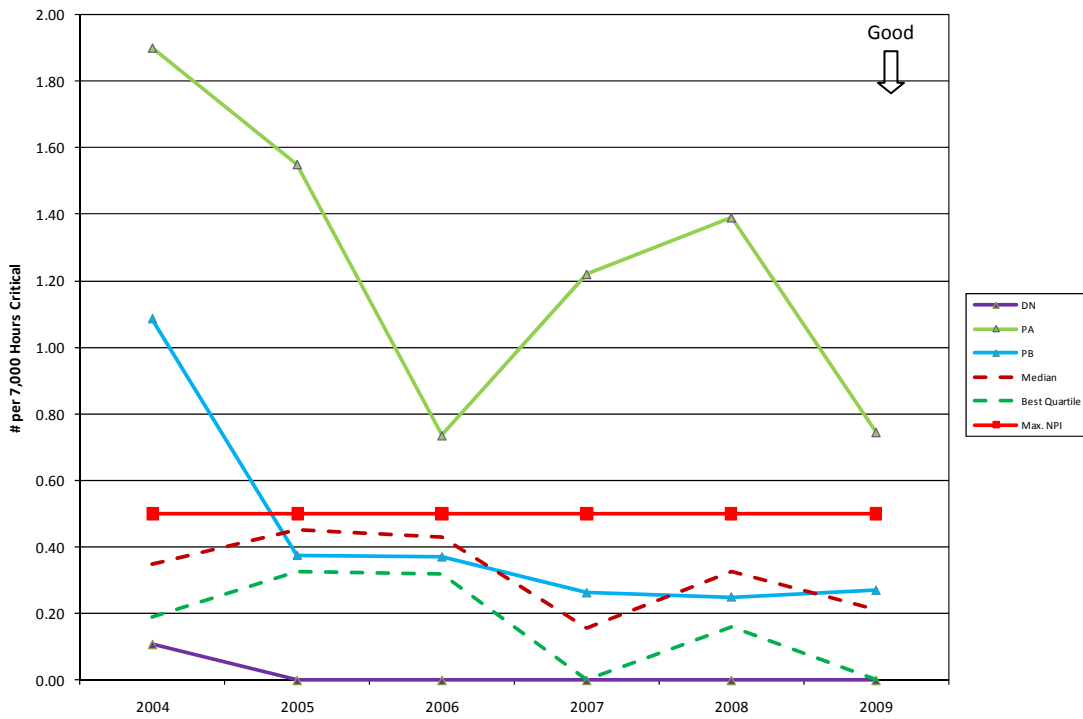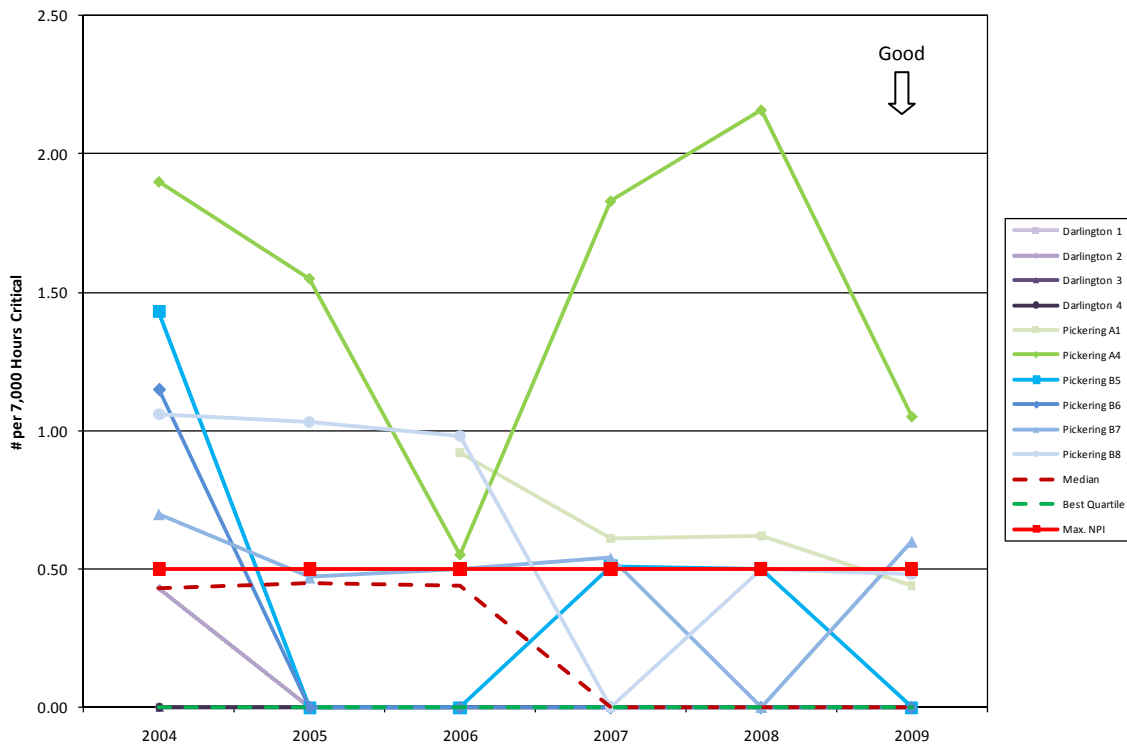## CANDU Unit Level Benchmarking

 # per 7,000 Hours Critical

2-Year Unplanned Automatic Reactor Trips
CANDU Plant Level Benchmarking

2-Year Unplanned Automatic Reactor Trips
CANDU Unit Level Benchmarking

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

2009 (2-Year Rolling Average)
- The unplanned automatic reactor trips best quartile for CANDU plants is 0 for the plant average and for individual units.
- Darlington performed better than best quartile as a station and all units had zero reactor trips, earning full WANO NPI points.
- Pickering A performed worse than median as a plant and all units were worse than median. Pickering A received 7.2 of 10 WANO NPI points for unplanned automatic reactor trips.
- Pickering B performance was slightly worse than median for plant average, as two of four units were at zero (Units 5 and 6) for the most recent period, and two units performed worse than the median with 0.60 trips and 0.48 trips for Units 7 and 8, respectively. Pickering B received 9.7 of 10 WANO NPI points for unplanned automatic reactor trips.
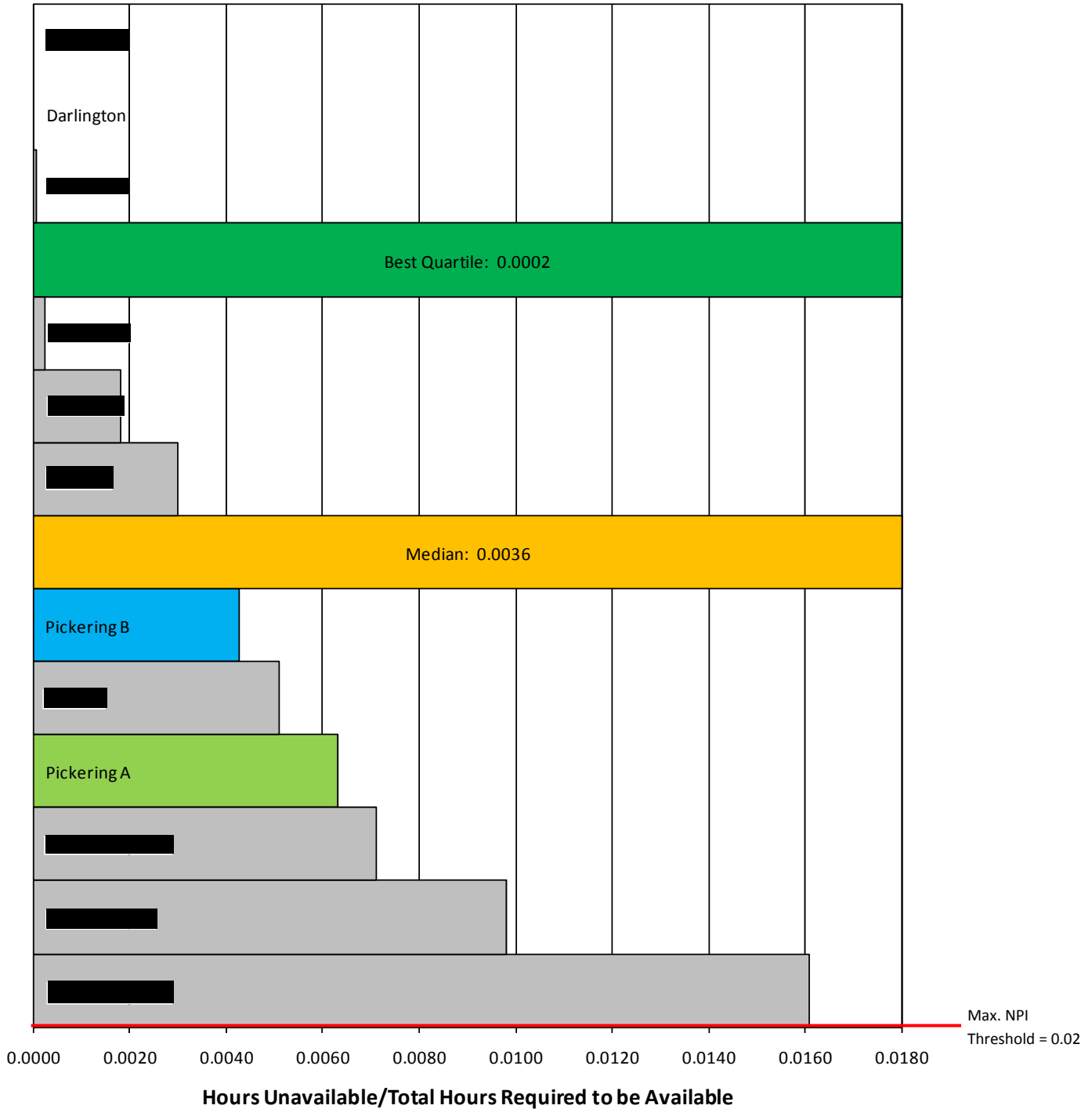
Trend
- Best quartile for the panel shows improvement in performance at the end of the review period.
- Darlington's performance overall achieved best quartile for the last five years consecutively.
- Pickering A had a limited time period compared to the other stations due to the restart of Unit 4 in September 2003 and Unit 1 in November 2005.
- Pickering A performance improved from just under 2.0 trips at the beginning of the time period to under 0.8 trips by 2009.
- Pickering B performance has improved over the review period from worse than median at 1.1 trips (in 2004), to almost reaching median for the most recent time period (2009). Two out of four units have consistently performed at zero trips since 2005.

Factors Contributing to Performance

- Key performance drivers for this metric include: general equipment reliability, material condition, and human performance.

3-Year Auxiliary Feedwater Safety System Unavailability

**2009 3-Year Auxiliary Feedwater Safety System Performance (Unavailability)
CANDU Plant Level Benchmarking**

2009 3-Year Auxiliary Feedwater Safety System Performance (Unavailability)
CANDU Unit Level Benchmarking
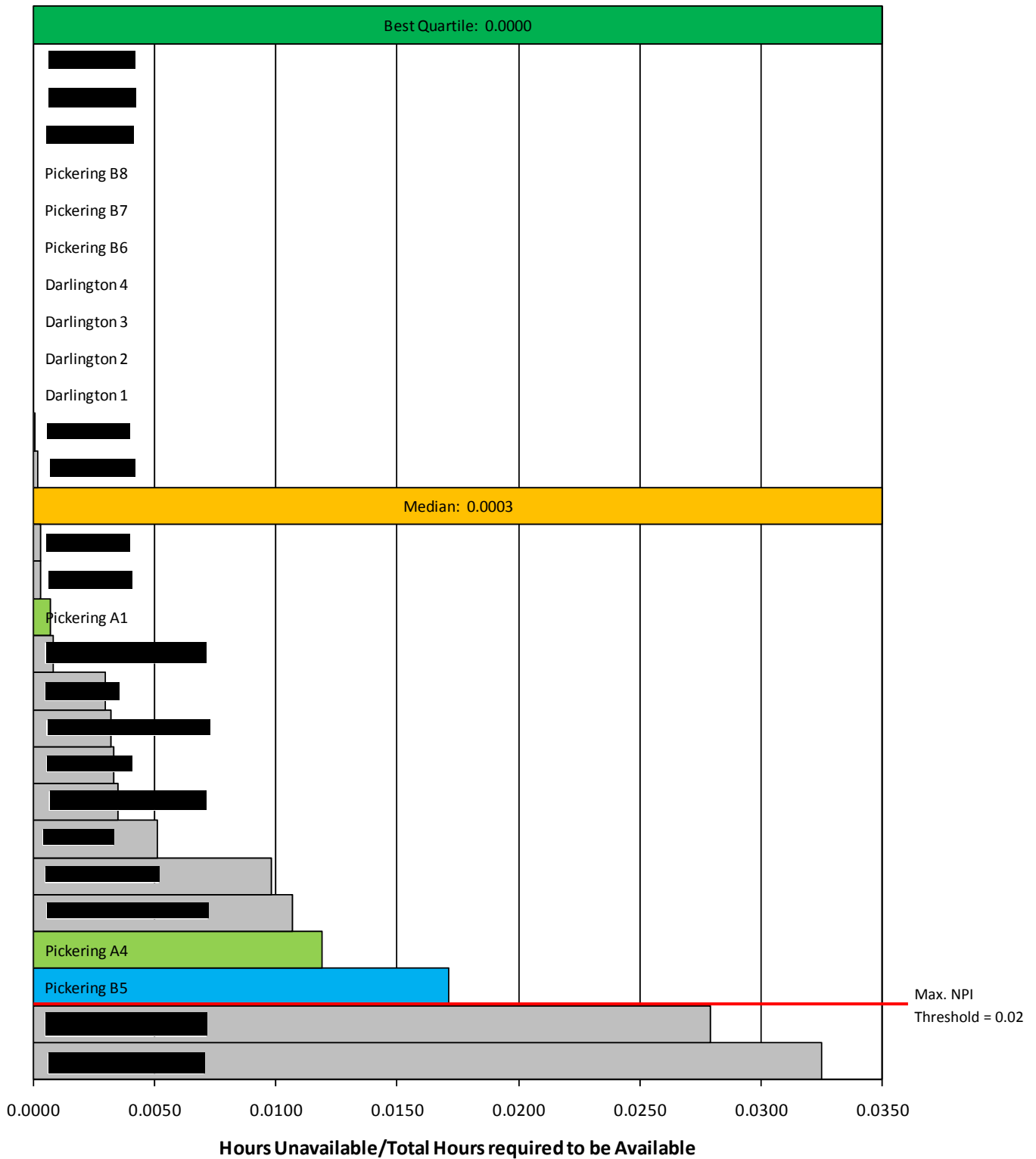
3-Year Auxiliary Feedwater Safety System Performance (Unavailability)
CANDU Plant Level Benchmarking

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

Observations – 3-Year Auxiliary Feedwater System (CANDU)

2009 (3-Year Rolling Average)

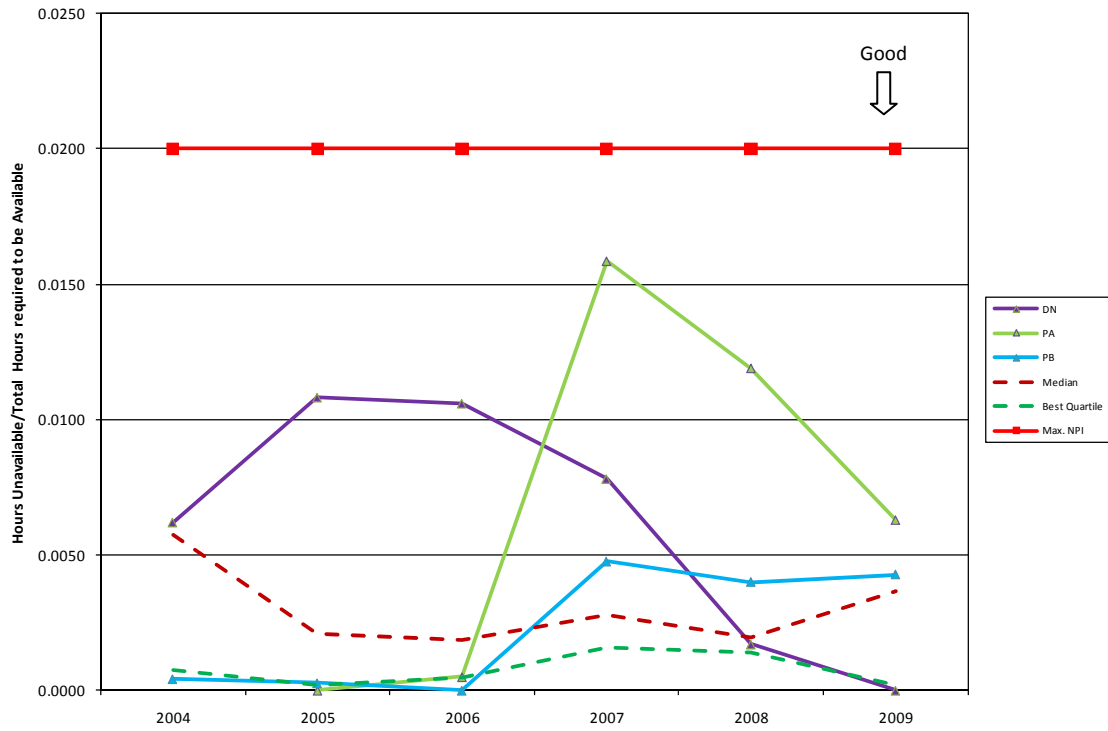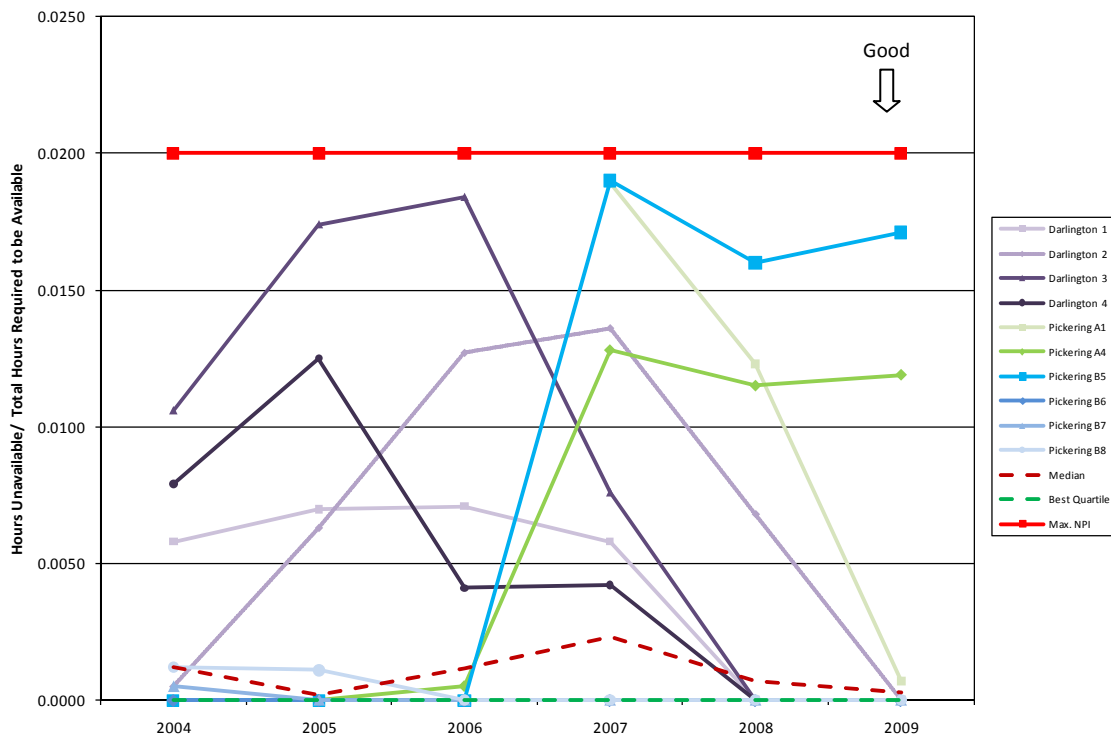- Auxiliary feedwater safety system performance at best quartile CANDU plants was 0.0002 for plant level and 0.0000 for unit level.
- Darlington performed better than best quartile receiving full WANO NPI points.
- Pickering A and Pickering B both performed worse than median quartile but both earned full WANO NPI points.

Trend

- Best quartile was consistently mathematically low, not displaying any trend.
- Darlington performance showed consistent improvement to reach better than median performance by 2008 and better than best quartile performance by 2009.
- Pickering A was worse than median for 2007 and 2008, but showed significant improvement in 2009.
- Pickering B performance improved in 2008, showing slightly worse performance in 2009.

3-Year Emergency AC Power Safety Unavailability

**2009 3-Year Emergency AC Power Safety System Performance (Unavailability)
CANDU Plant Level Benchmarking**

Hours Unavailable/Total Hours Required to be Available

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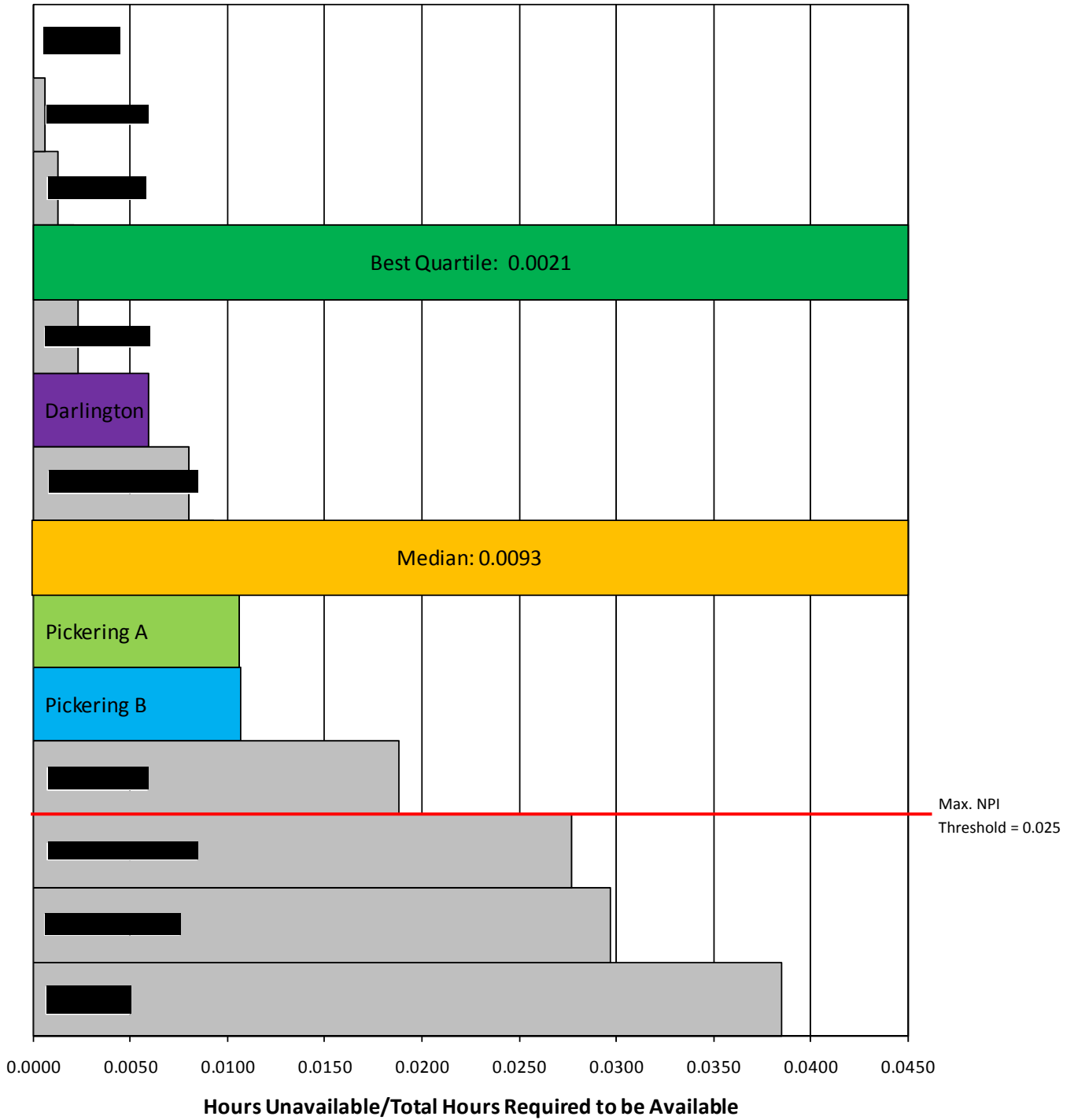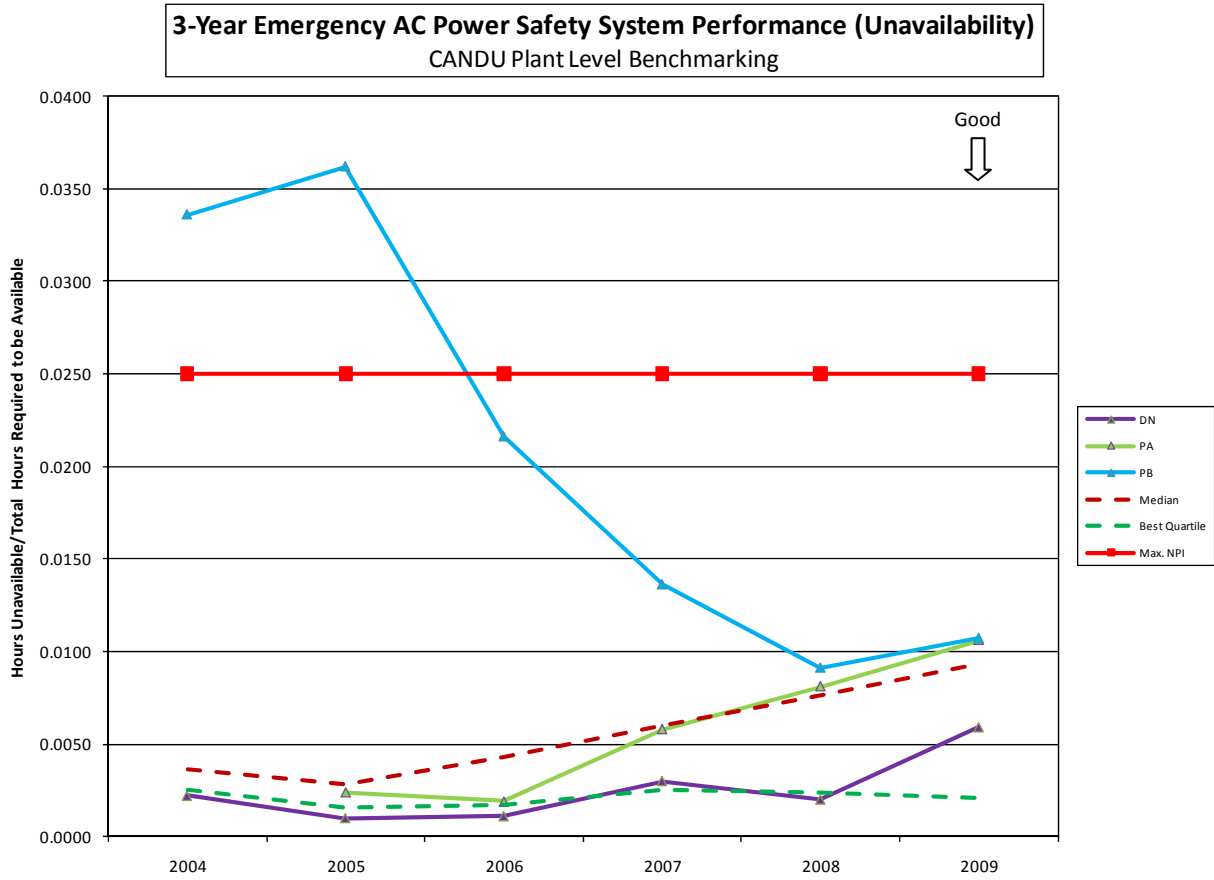
Observations – 3-Year Emergency AC Power Safety System (CANDU)

2009 (3-Year Rolling Average)
- Emergency AC power system safety performance at best quartile CANDU plants was 0.0021.
- Darlington performed better than median and earned full WANO NPI points.
- Pickering A performed worse than median but earned full WANO NPI points.
- Pickering B performed worse than median but earned full WANO NPI points.

Trend
- Best quartile was consistently mathematically low, showed improving trends in recent years.
- Darlington performed consistently at best quartile for the review period but performance was only better than median in 2009.
- Pickering A trended worse during the last three years of the review period.
- Pickering B improved performance consistently from 2005 to 2008, but showed an unfavourable spike in 2009.

3-Year High Pressure Safety Injection

2009 3-Year High Pressure Injection (ECI) Safety System Performance (Unavailability)
CANDU Plant Level Benchmarking

Hours Unavailable/Total Hours Required to be Available
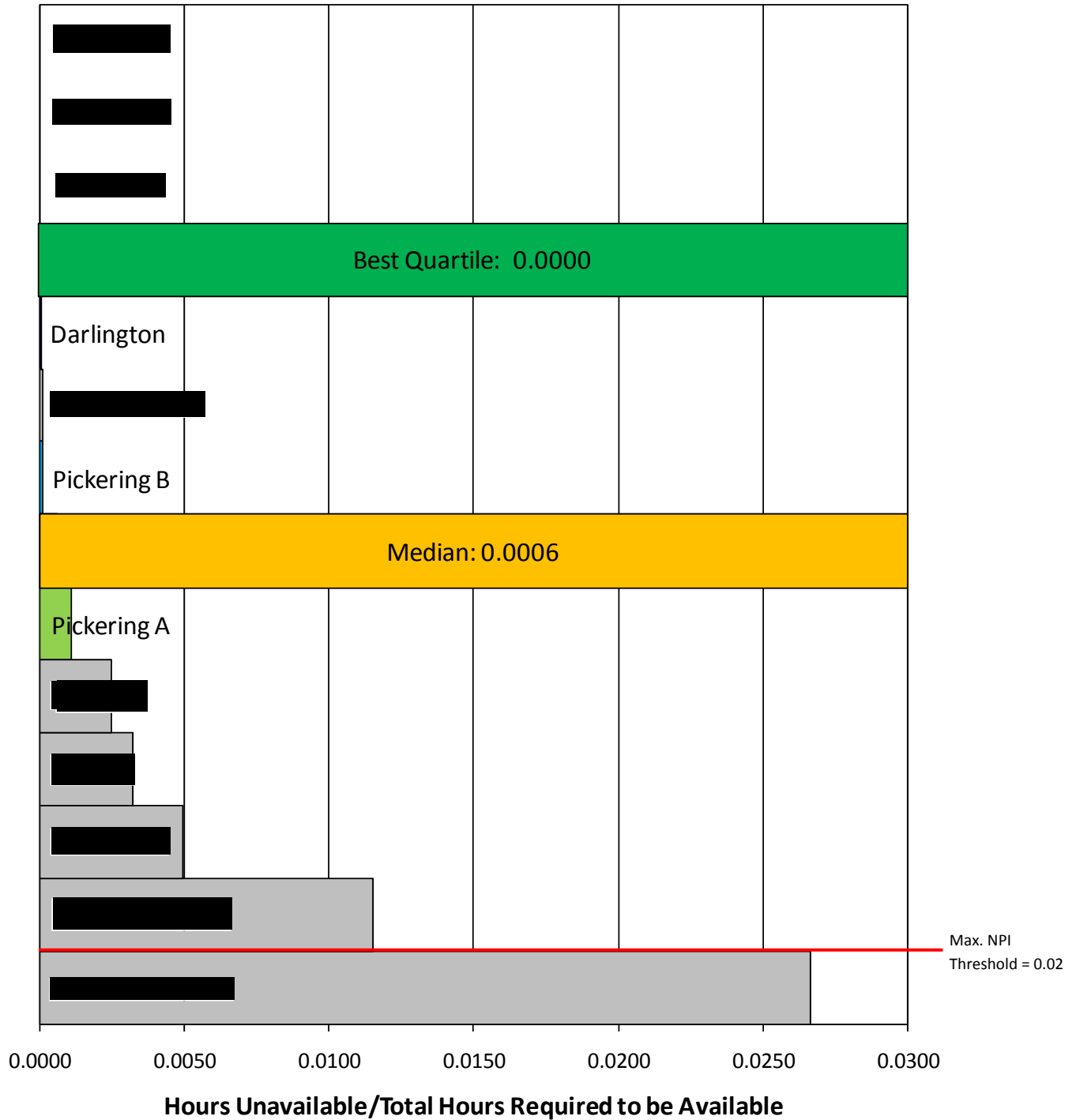
**2009 3-Year High Pressure Injection (ECI) Safety System Performance
(Unavailability)
CANDU Unit Level Benchmarking**
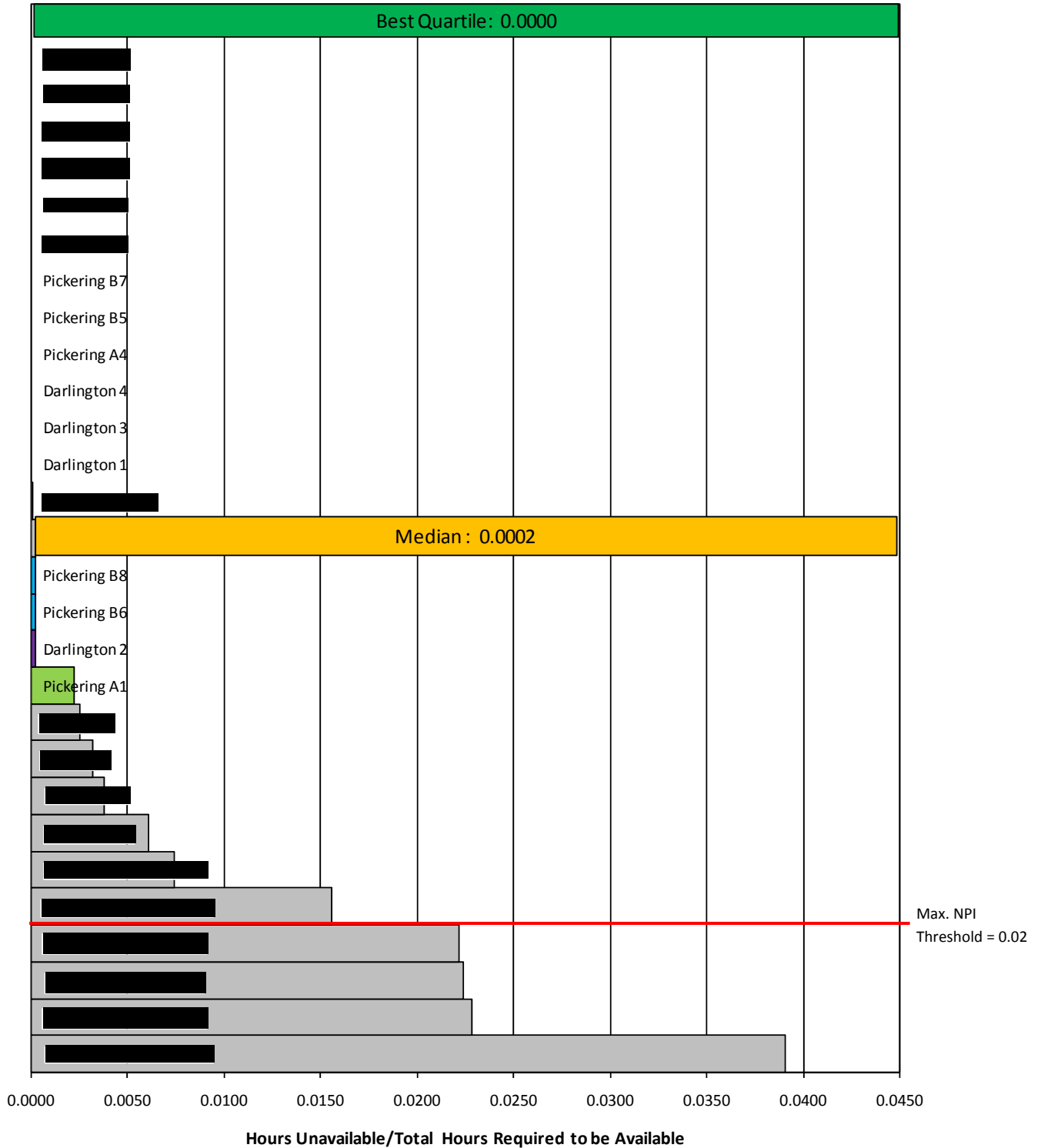
3-Year High Pressure Injection (ECI) Safety System Performance (Unavailability)
CANDU Plant Level Benchmarking
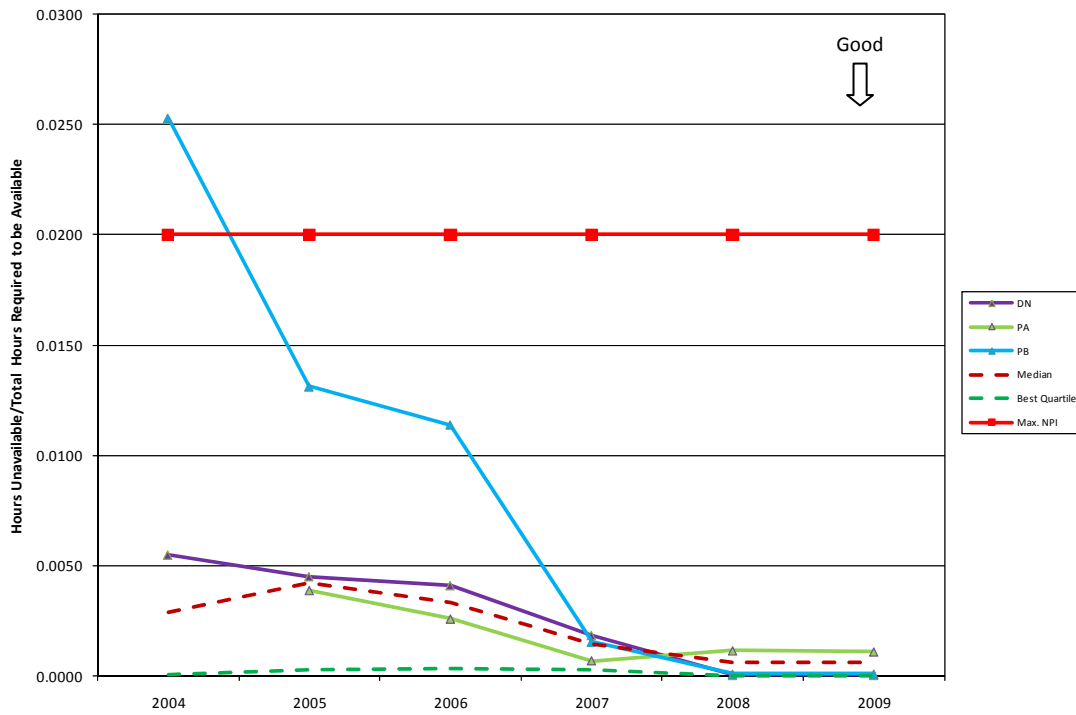
3-Year High Pressure Injection (ECI) Safety System Performance (Unavailability)
CANDU Unit Level Benchmarking
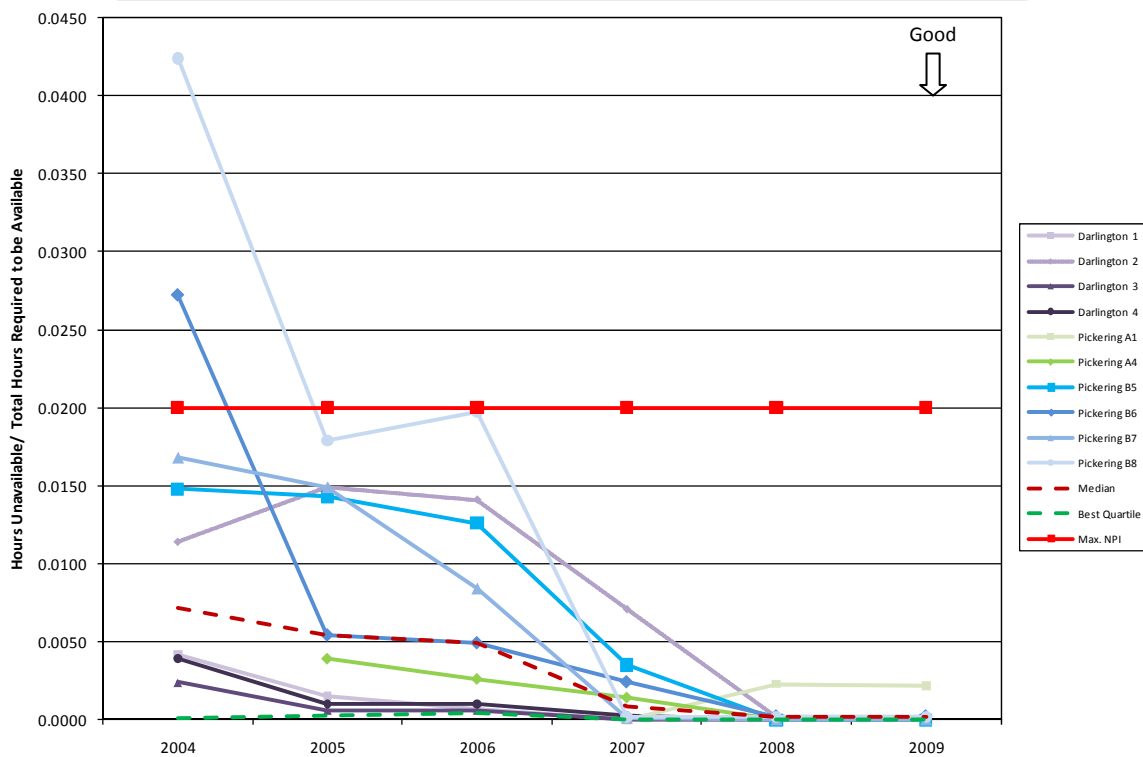
Observations – 3-Year High Pressure Safety Injection Unavailability (CANDU)

2009 (3-Year Rolling Average)
- High Pressure Safety Injection system performance at best quartile CANDU plants was zero for plant and for unit.
- Darlington performed better than median.
- Pickering A performed better than median.
- Pickering B performed better than median.

Trend
- Best quartile was consistently mathematically low.
- Darlington performance trended better over the review period and received full WANO NPI points.
- Pickering A performance trended better over the review period and received full WANO NPI points.
- Pickering B performance trended better over the review period and received full WANO NPI points.

3.0 RELIABILITY

Methodology and Sources of Data

The majority of reliability metrics were calculated using the 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 period 2002-2009 was obtained and averages are as provided by WANO.

The two backlog metrics, elective and corrective maintenance, are also included within this section and the data comes from an industry sponsored INPO AP-928 subcommittee rather than from a more formal third-party source. The years included are 2006 to 2009 because the data is most reliable over that period. Data points benchmarked are a single point in time, not a rolling average. All of the data is self-reported. INPO AP-928 Revision 3 was approved on June 11, 2010. 2010 will be a transition year where the industry will be moving to new definitions for backlogs, aligning with the Equipment Reliability industry working group. In that light, we anticipate industry backlog numbers to be higher. OPG will be transitioned by the end of January 2011, with Darlington being reclassified to the new standard in July 2010 while still carrying the old classifications through the rest of the year.

Discussion

The primary metric within the reliability section is the WANO NPI. The WANO NPI is an operational performance indicator comprised of 10 metrics, three of which are also 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).

For WANO NPI, Darlington performed well achieving best quartile performance against CANDU plants in 2009. Pickering A and Pickering B both need to improve performance significantly to achieve best quartile. The metrics with the poorest performance at the Pickering stations are Unit Capability Factor and Forced Loss Rate.

All of the plants have shown consistent improvement for the elective and corrective backlog metrics, but because of continuous industry improvement, best quartile has not yet been achieved by Darlington, Pickering A or Pickering B.

WANO NPI

2009 WANO NPI
CANDU Plant Level Benchmarking

2009 WANO NPI
CANDU Unit Level Benchmarking

WANO NPI
CANDU Plant Level Benchmarking
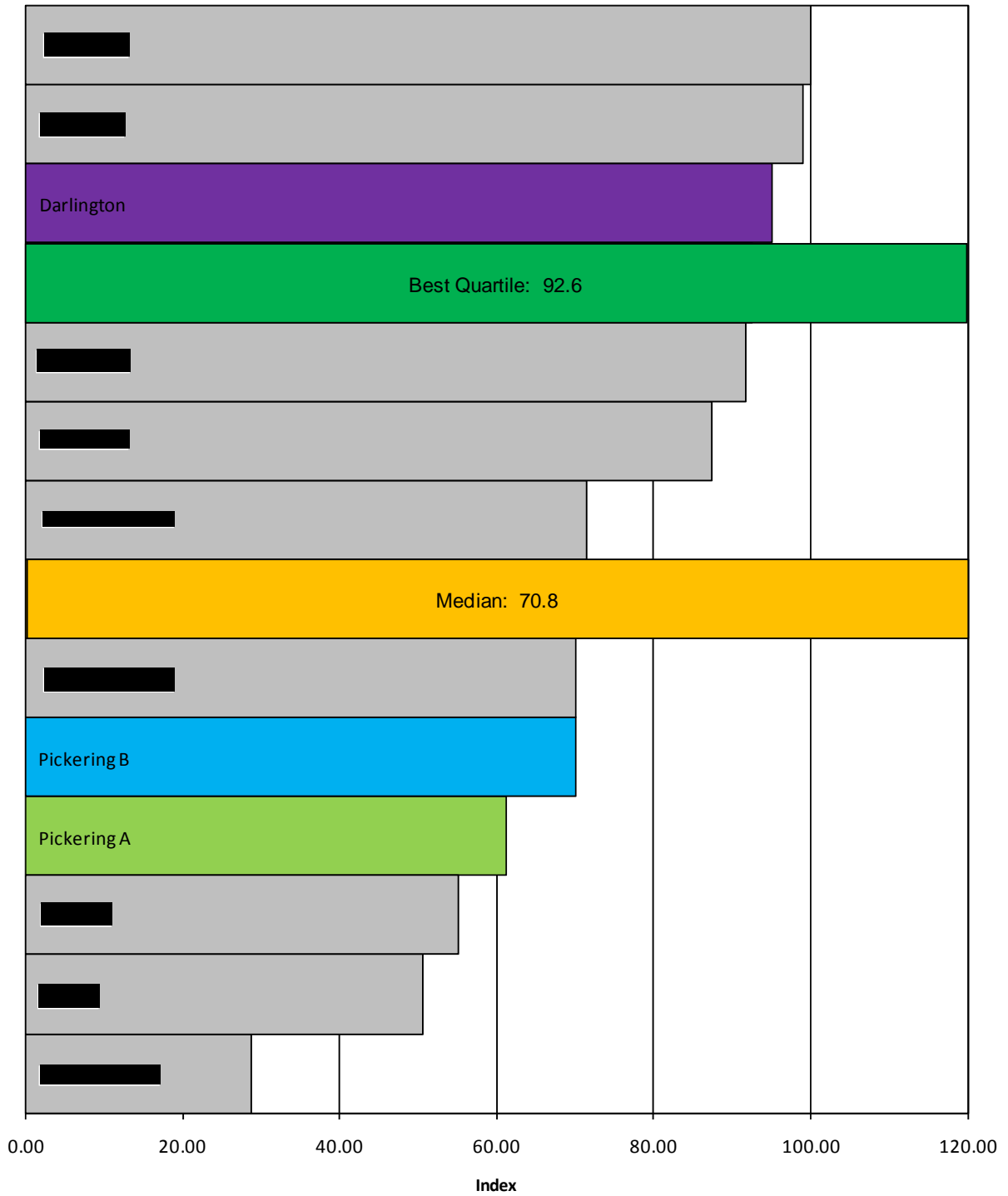
WANO NPI
CANDU Unit Level Benchmarking
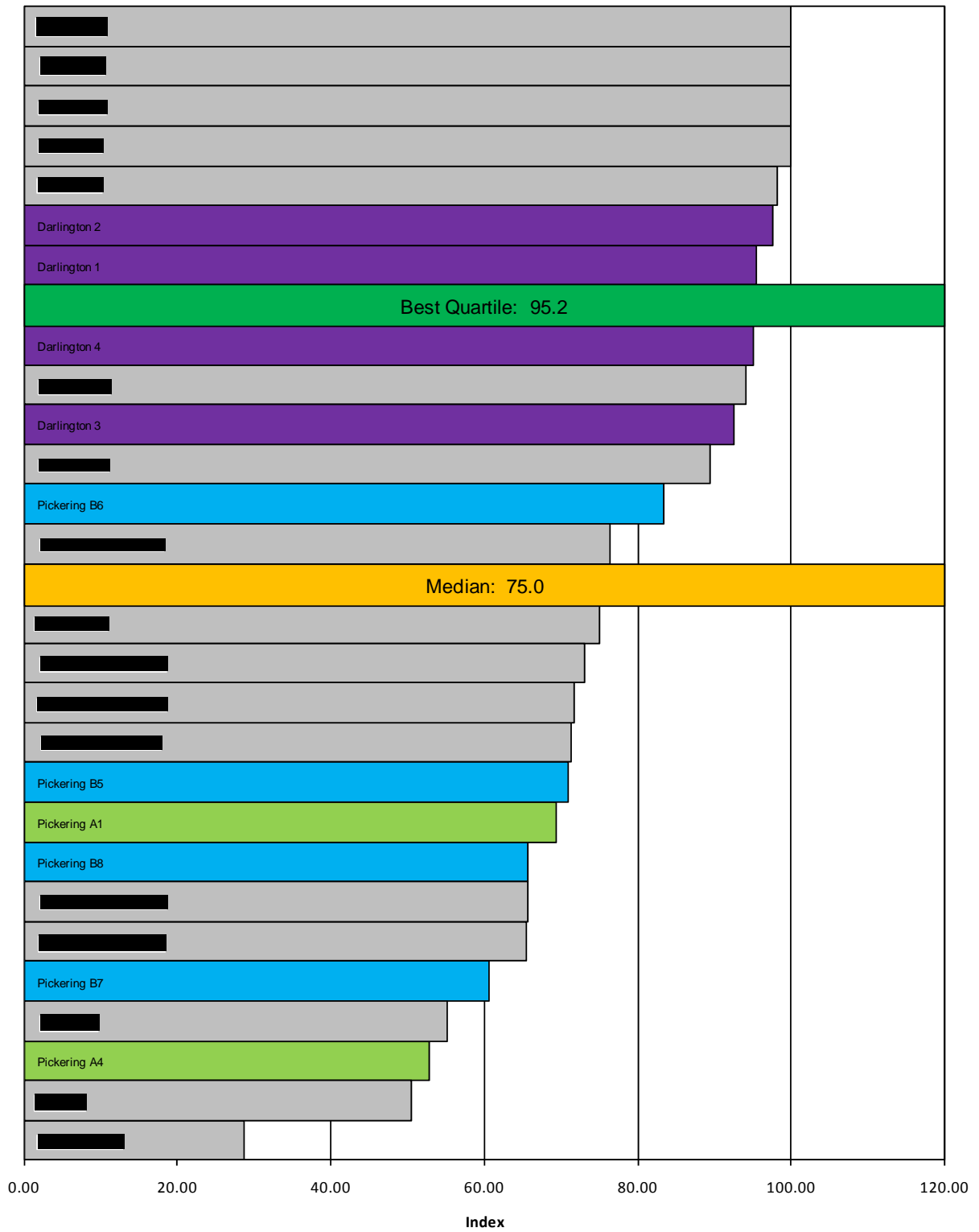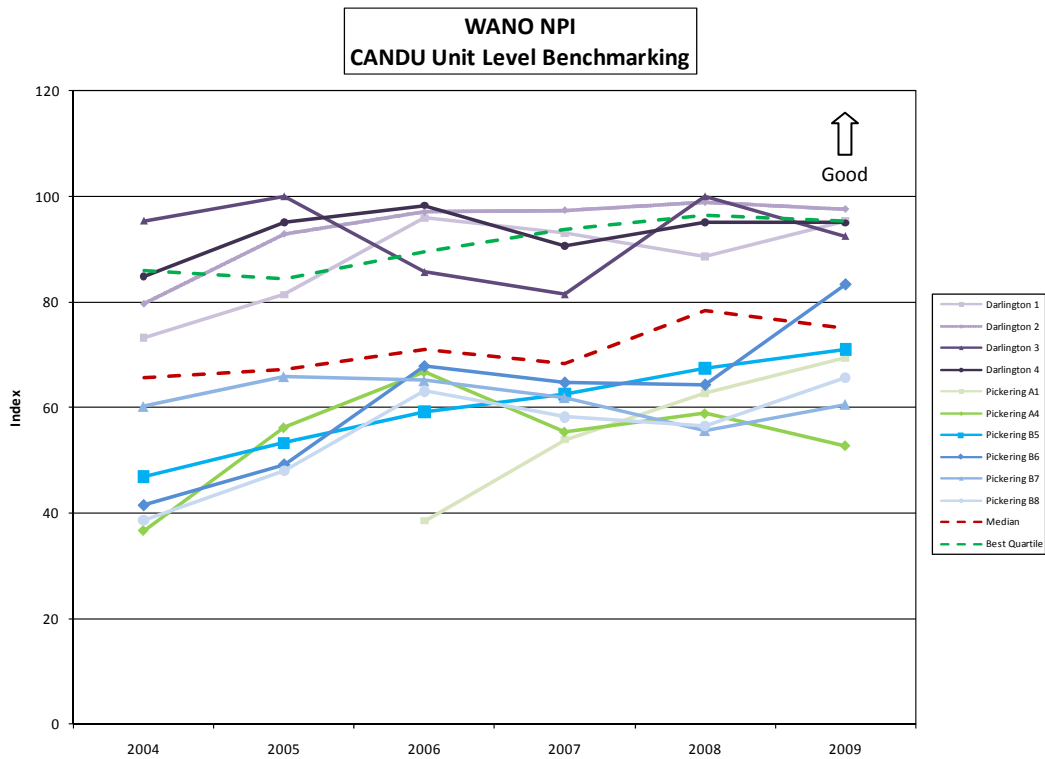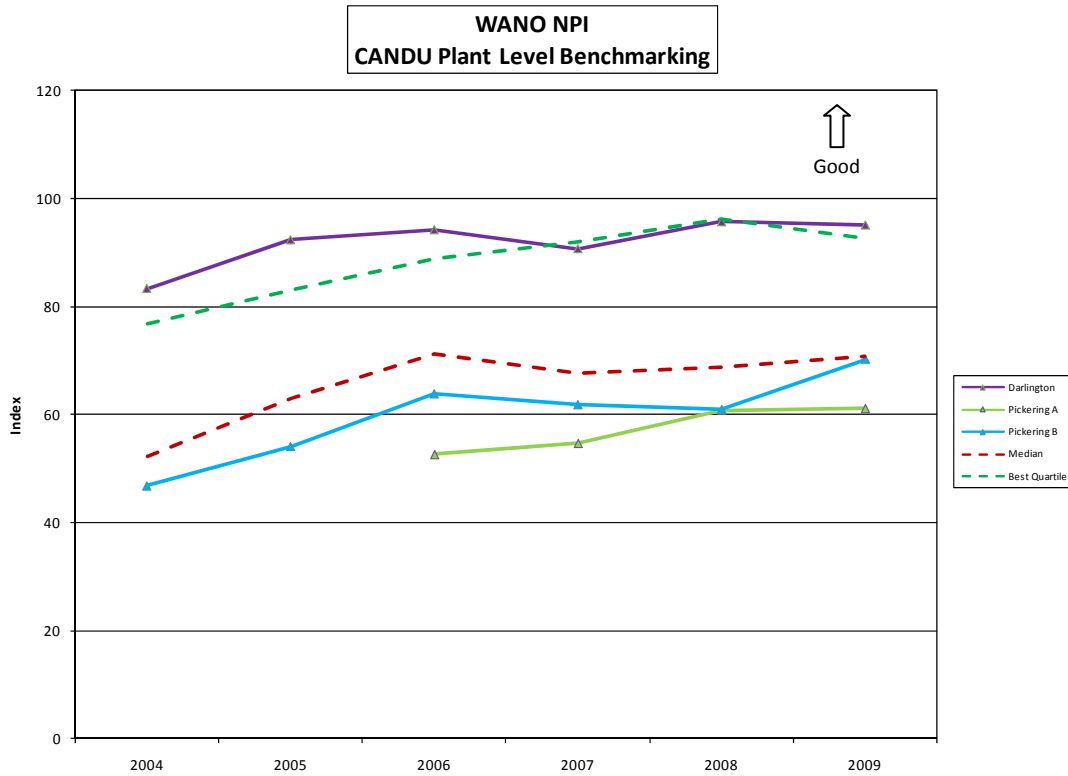
Observations – WANO NPI (CANDU)

2009
- The current best quartile at the plant level for WANO NPI is 92.6. The CANDU comparison panel has shown an upward trend since 2005.
- Darlington continued to demonstrate strong performance, achieving best quartile in 2009.
- The Pickering A Unit 1 and all Pickering B units showed improved performance during the year in absolute terms, but these gains were small compared to the CANDU panel, due to continued improvement in the performance of other units during the year.

Trend
- At the plant level, the median value for the panel had been on a decline since 2006, indicating that the performers outside of best quartile are performing worse. However, in 2009 this trend reversed and the median value rose slightly.
- Darlington is the strongest OPG performer achieving best quartile over most of the review period.
- Both Pickering A and Pickering B have performed consistently below median over the review period.
- Pickering A had shown the most improvement since 2005 achieving Pickering B levels by 2008. However this trend has reversed in 2009 with the continued poor performance of Pickering A Unit 4.
- Pickering B performance demonstrated improvement from 2004 through 2006. The declines in performance during 2007 and 2008 have been reversed in 2009, with considerable improvement.

Factors Contributing to Performance

- The WANO NPI is a composite index reflecting the weighted sum of the scores of 10 separate performance measures. A maximum score of 100 is possible. All of the sub-indicators in this index are reviewed separately in this benchmarking report.
- The methodology used to analyze the gap to top quartile is to indicate points gained or lost for each sub-indicator by station during the most recent period (2009).

Darlington
- For 2009, Darlington received maximum scores for 6 out of 10 NPI sub-indicators
- For each of the key safety system related metrics, high pressure injection, auxiliary feedwater, and emergency AC power, Darlington received 10 of 10 points.
- Darlington also received perfect scores for fuel reliability (10 of 10) and industrial safety accident rate (5 of 5), and a near perfect score for chemistry performance (4.9 of 5).
- Darlington received 12.5 out of a possible 15 points for unit capability factor; 14.4 out of a possible 15 points for forced loss rate; and 8.4 out of a possible 10 points for collective radiation exposure.

Factors Contributing to Performance (Cont'd)

Pickering A
- Pickering A received maximum scores for 5 out of 10 NPI sub-indicators.
- For each of the key safety system related metrics, high pressure injection, auxiliary feedwater, and emergency AC power, the station received 10 of 10 points.
- Pickering A earned 5 of 5 points for industrial safety accident rate and 6.1 out of a possible 10 points for collective radiation exposure.
- Pickering A earned 7.2 of 10 points for reactor trips; fuel reliability yielded 10 of 10 points, and chemistry performance yielded 2.8 of 5 points. Refer to reactor trips, fuel reliability, and chemistry performance for detailed information regarding performance of these indicators.
- Due to challenges with generation, Pickering A received 0 of 15 points for both unit capability factor and forced loss rate.

Pickering B
- Pickering B received maximum scores for 5 out of 10 NPI sub-indicators.
- For each of the key safety system related metrics, high pressure injection, auxiliary feedwater, and emergency AC power, Pickering B received 10 of 10 points.
- Pickering B earned 5 of 5 points for industrial safety accident rate.
- Pickering B earned 9.7 of 10 points for reactor trips.
- Pickering B achieved scores of 10 of 10 points for fuel reliability, 2.4 of 5 points for chemistry performance, and 7.8 out of a possible 10 points for collective radiation exposure. Refer to fuel reliability, chemistry performance, and collective radiation exposure sections for detailed information regarding performance on these indicators.
- Due to challenges with generation, Pickering B received 2.4 of 15 points for unit capability factor and 2.8 of 15 points for forced loss rate.

Please refer to Table 12 of the Appendix for an NPI plant level performance summary of OPG stations against the North American panel.

2-Year Forced Loss Rate

2009 2-Year Forced Loss Rate
CANDU Plant Level Benchmarking

2009 2-Year Forced Loss Rate
CANDU Unit Level Benchmarking

2-Year Forced Loss Rate
CANDU Plant Level Benchmarking
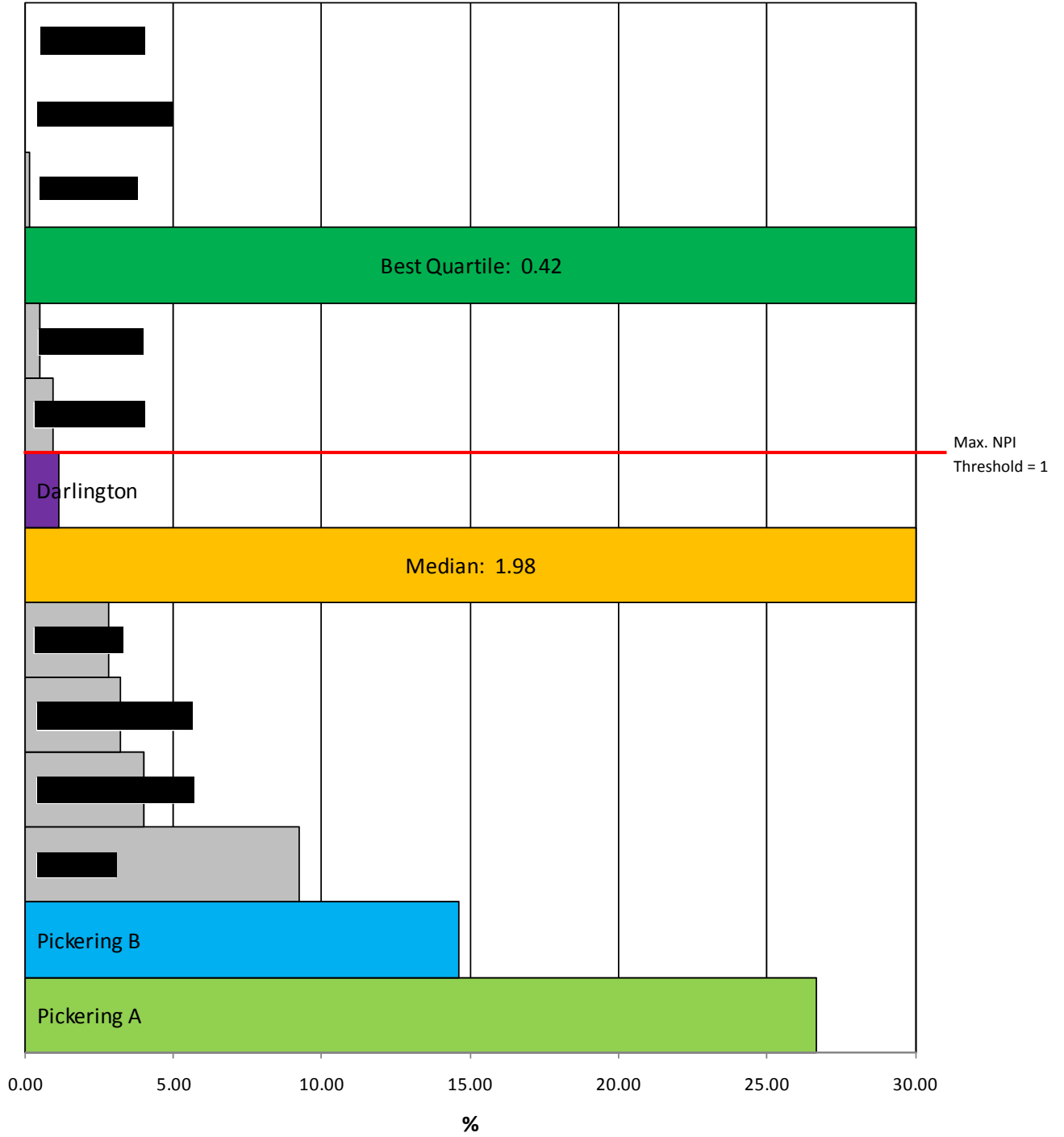
2-Year Forced Loss Rate
CANDU Unit Level Benchmarking
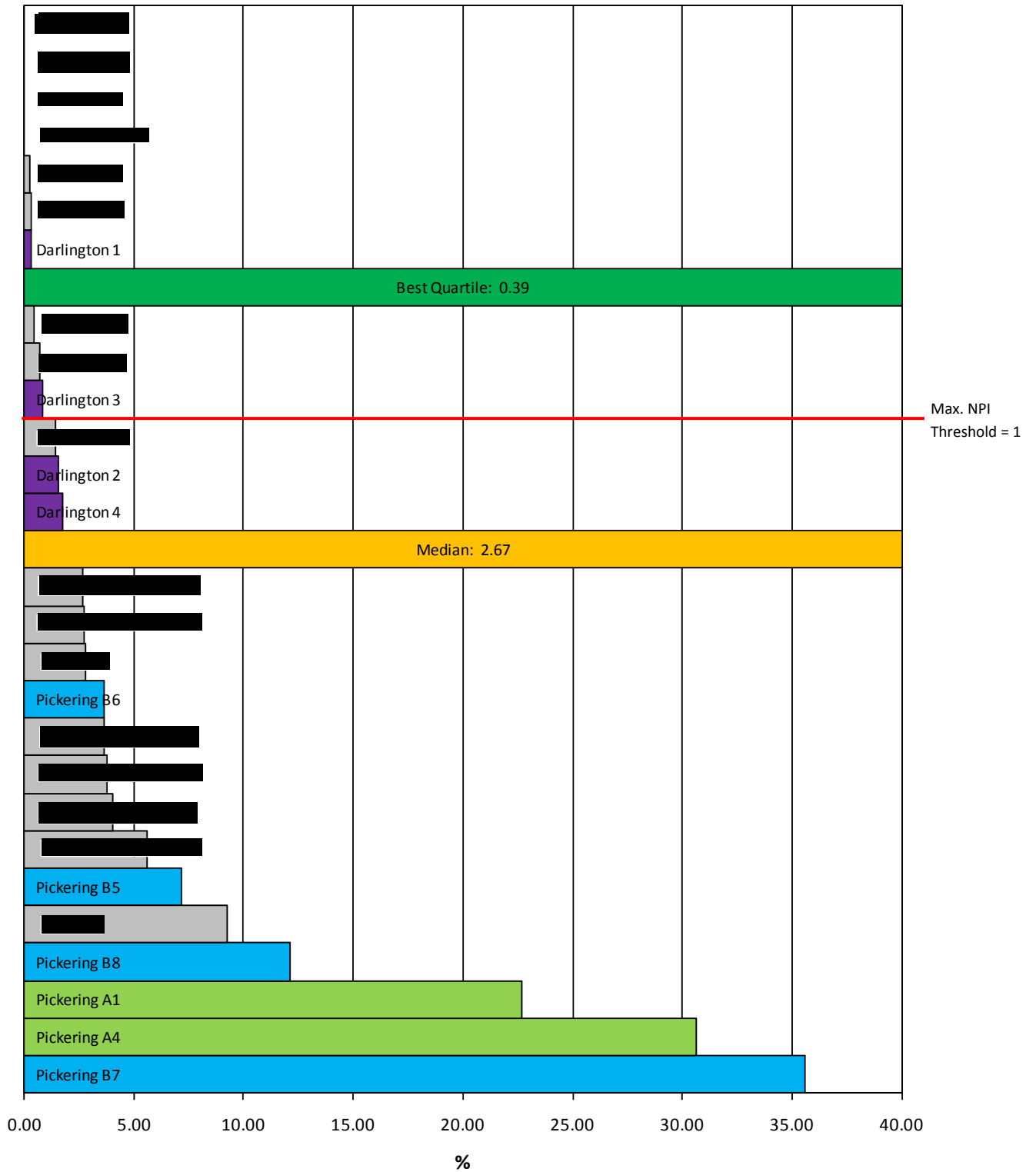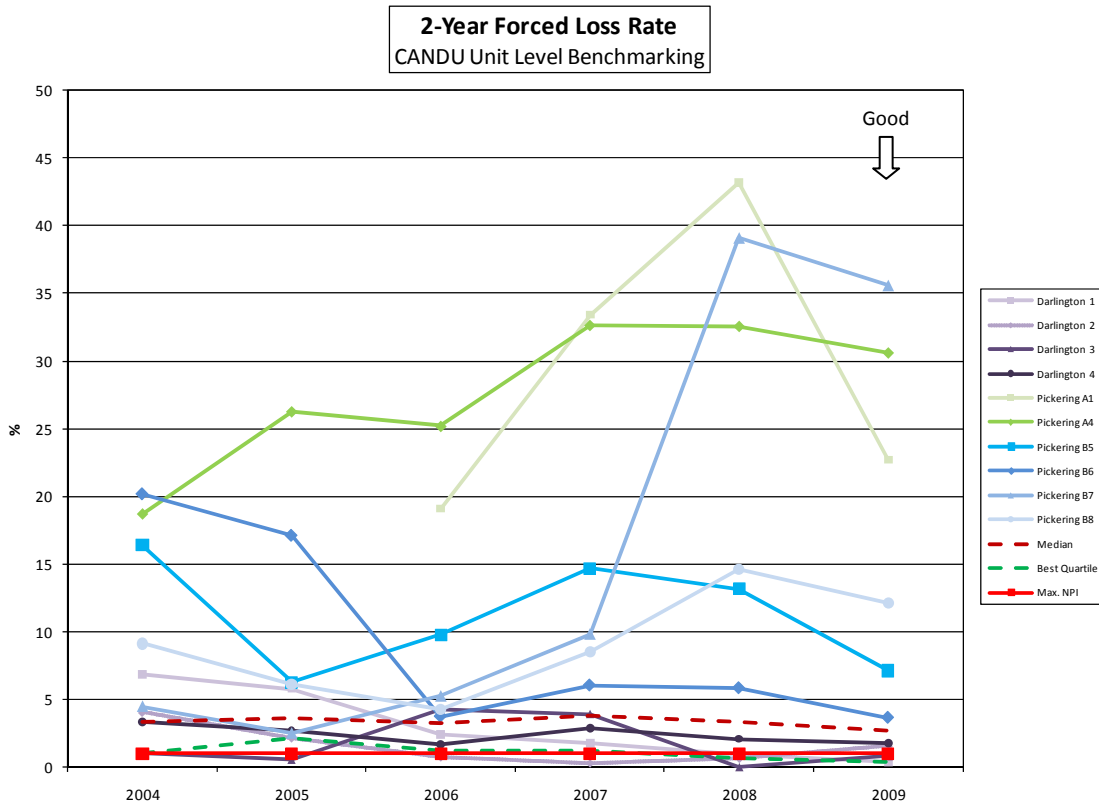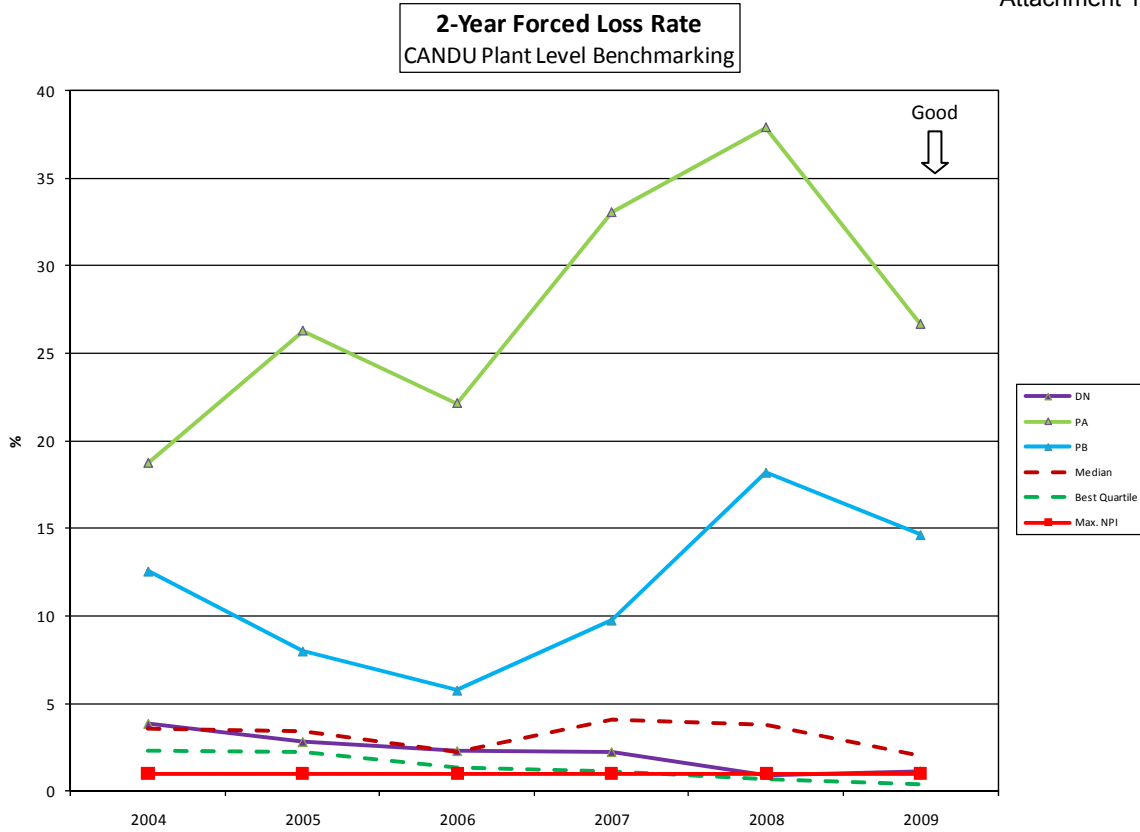
Observations – 2-Year Forced Loss Rate (CANDU)

2009 (2-Year Rolling Average)
- Forced loss rate (FLR) best quartile performance for the CANDU panel was 0.42% at the plant level and 0.39% at the unit level.
- The Darlington station performed better than median but worse than best quartile with all units performing better than median, and one unit performing better than best quartile.
- The Darlington gap to best quartile was 0. 7% against the CANDU panel for 2009.
- Pickering A and B performed below median at both the plant and unit level.
- The Pickering A and B gaps to best quartile were 26.2% and 14.2% against the CANDU panel for 2009, respectively.

Trend
- Best quartile and median performance improved slightly for the review period at both the unit and plant level.
- Darlington performance overall improved from just worse than median performance at the start of the review period to just worse than top quartile for the most recent time period.
- Pickering A had a limited time period compared to the other stations due to the restart of Unit 4 in September 2003 and unit 1 in November 2005.
- Pickering A's FLR performance worsened significantly, almost doubling from a FLR just under 20% to 37.90% in 2008, but improved to 26.7% in 2009.
- Pickering B FLR performance over the review period also worsened, almost doubling from an FLR just under 10% to 18.19% in 2008, but improved to 14.6% in 2009.

Factors Contributing to Performance

- Equipment Reliability incidents contributing to FLR included a Calandria Tube failure, a heat transport system leak, a faulty feeder cabinet door latch, and pipe elbow inspections due to new information on feeder thinning rates.
- Design Basis incidents contributing to FLR included an inter-station transfer bus (ISTB) problem, inadequate pipe seal design, and a system configuration problem.
- Human Performance incidents contributing to FLR included resin ingress to the system caused by a contractor error, a voltage transient caused during the execution of routine steps, and a troubleshooting error while resolving a leakage problem.

2-Year Unit Capability Factor

2009 2-Year Unit Capability Factor
CANDU Plant Level Benchmarking

Max. NPI
Threshold = 92

Best Quartile: 91.25

Darlington

Median: 85.25

Pickering B

Pickering A

%

2009 2-Year Unit Capability Factor
CANDU Unit Level Benchmarking

2-Year Unit Capability Factor
CANDU Plant Level Benchmarking
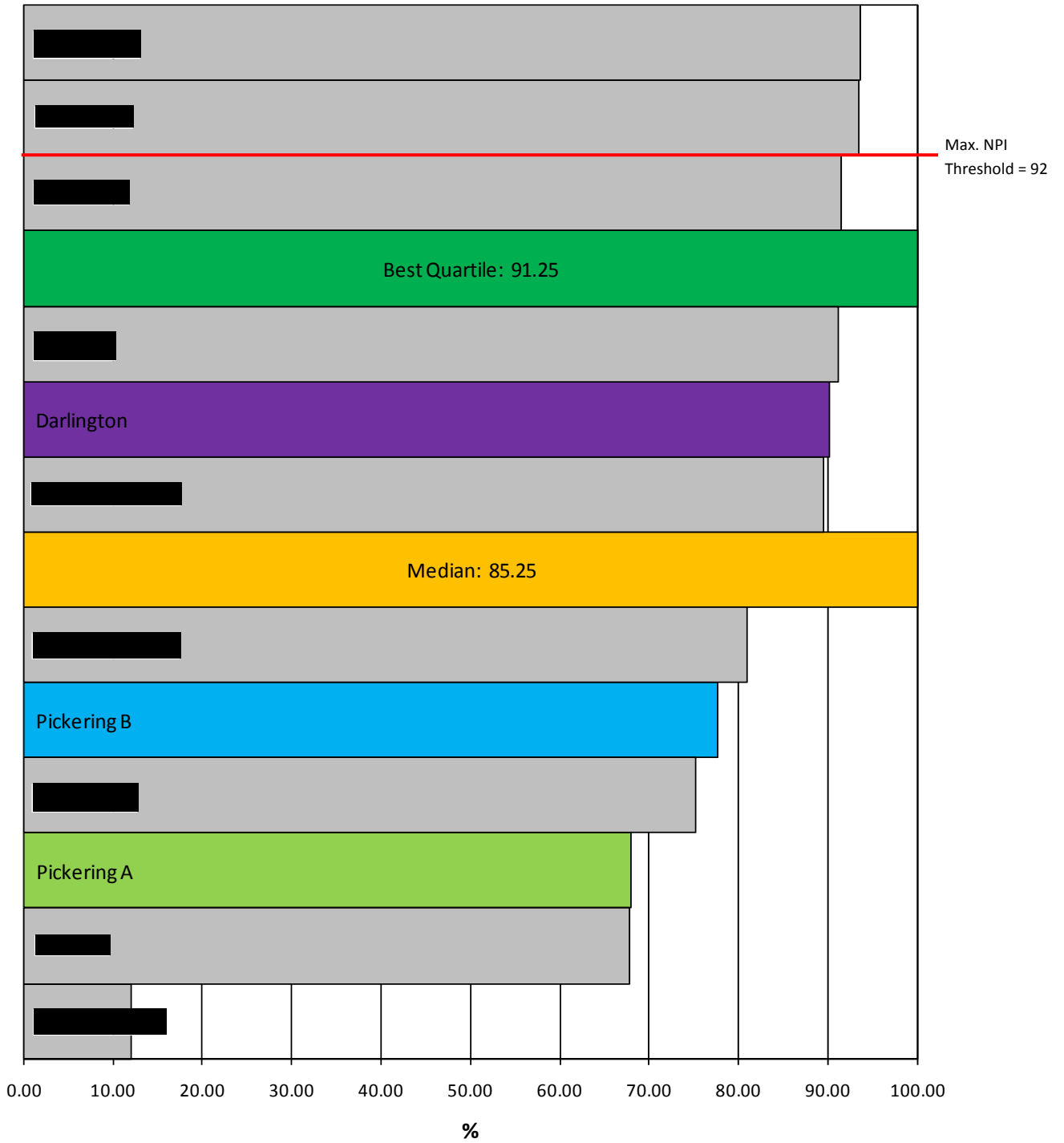
2-Year Unit Capability Factor
CANDU Unit Level Benchmarking
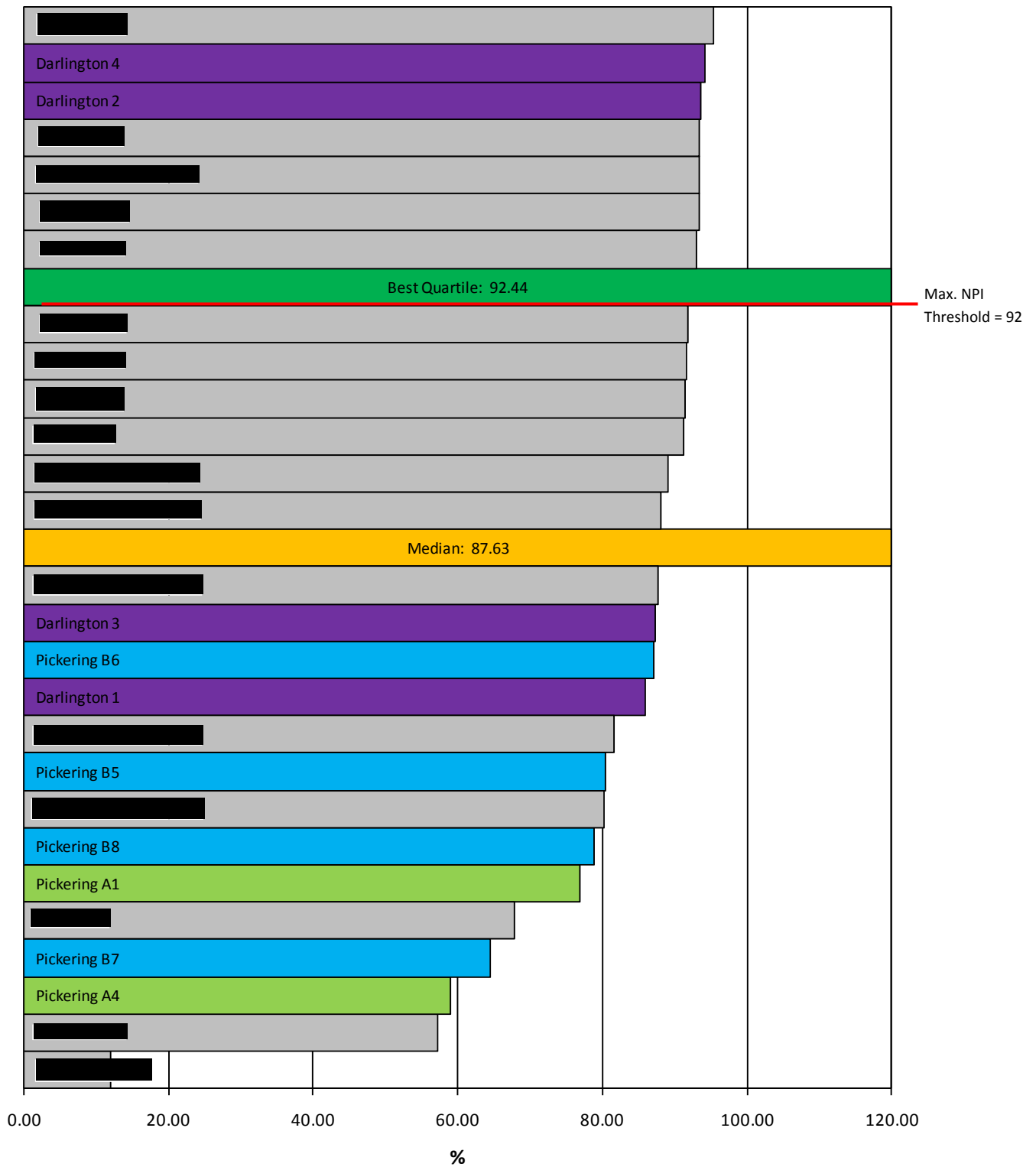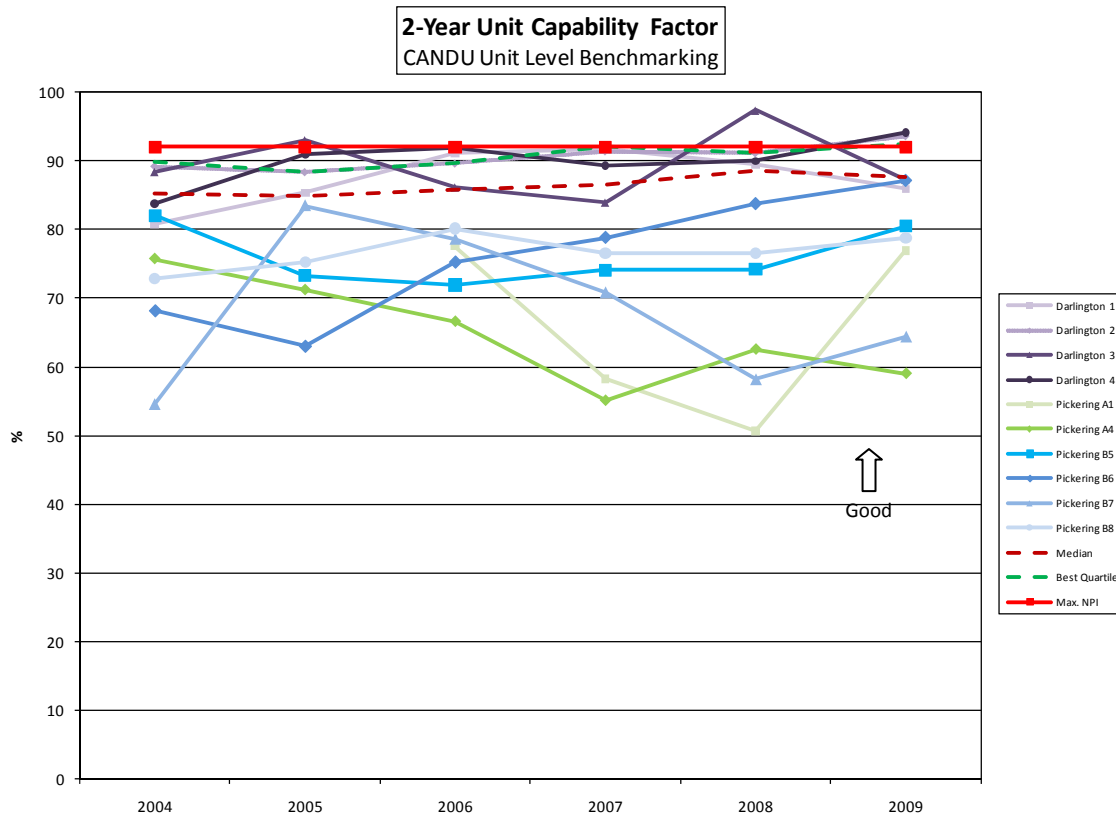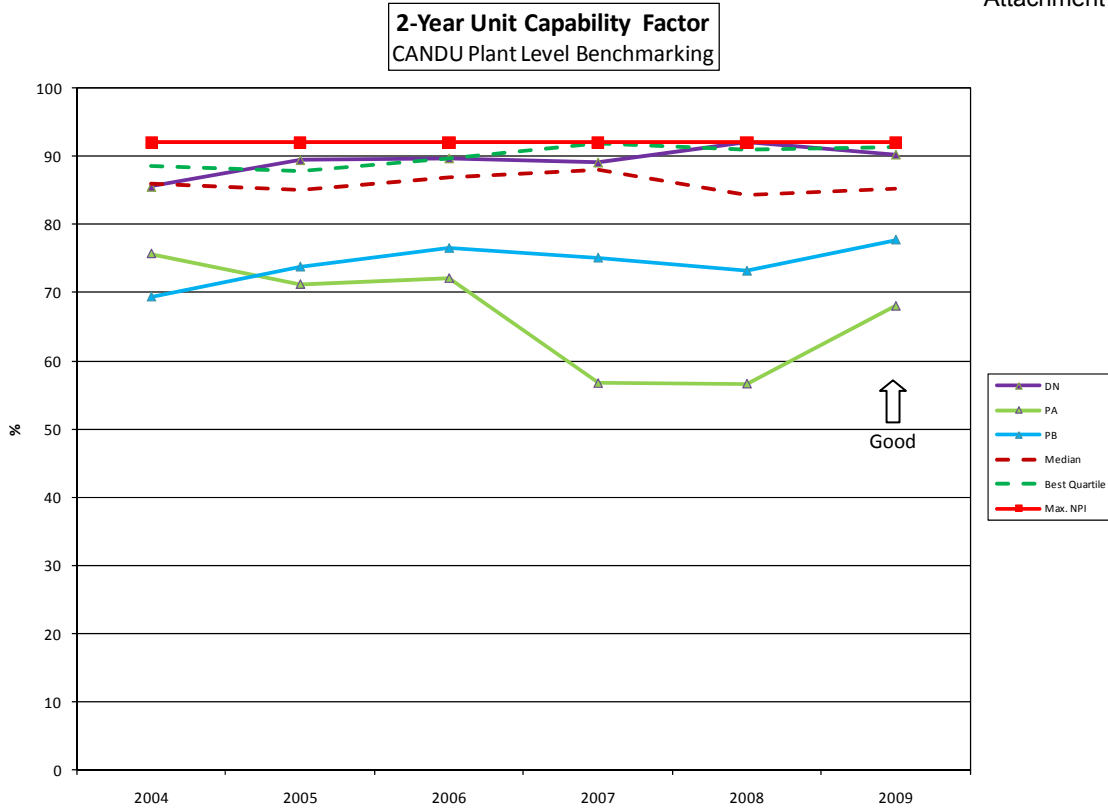
Observations – 2-Year Unit Capability Factor (CANDU)

2009 (2-Year Rolling Average)
- Unit Capability Factor best quartile performance for the CANDU panel was 91.25% at the plant level and 92.44% at the unit level.
- Darlington performed below best quartile as a station with two units performing better than best quartile and two below median at the unit level.
- Darlington gap to best quartile performance in UCF was 1.0% in 2009.
- Pickering A and B performed below median at both the plant and unit level.
- Pickering A and B gaps to best quartile were 23.3% and 13.6% for 2009, respectively.

Trend
- Best quartile and median for both plant average and unit performance have remained relatively flat over the review period.
- Darlington performance overall has remained above median for the review period. Pickering A had a limited time period compared to the other stations due to the restart of Unit 4 in September 2003 and Unit 1 in November 2005.
- Pickering A performance declined significantly in 2007 and 2008 with no individual or plant average data points at median level for the review period. However, Pickering A's UCF recovered significantly in 2009.
- Pickering B performance remained relatively stable over the review period but all data points at the unit level and plant level are below the median.

2-Year Chemistry Performance Indicator (CPI)

**2009 2-Year Chemistry Performance Indicator
CANDU Plant Level Benchmarking**
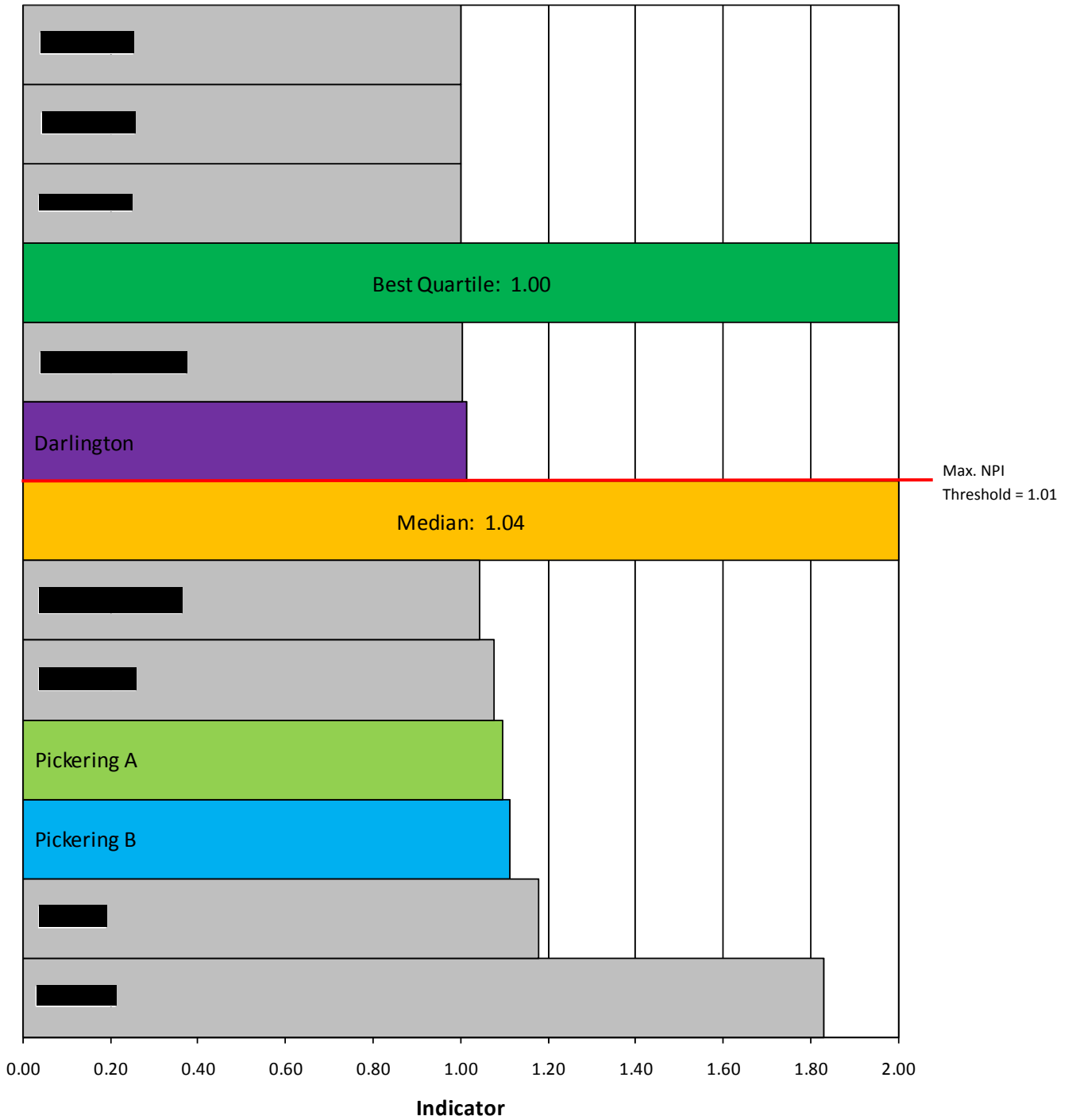
2009 2-Year Chemistry Performance (CPI)
CANDU Unit Level Benchmarking

2-Year Chemistry Performance (CPI)
CANDU Plant Level Benchmarking

2-Year Chemistry Performance Indicator
CANDU Unit Level Benchmarking
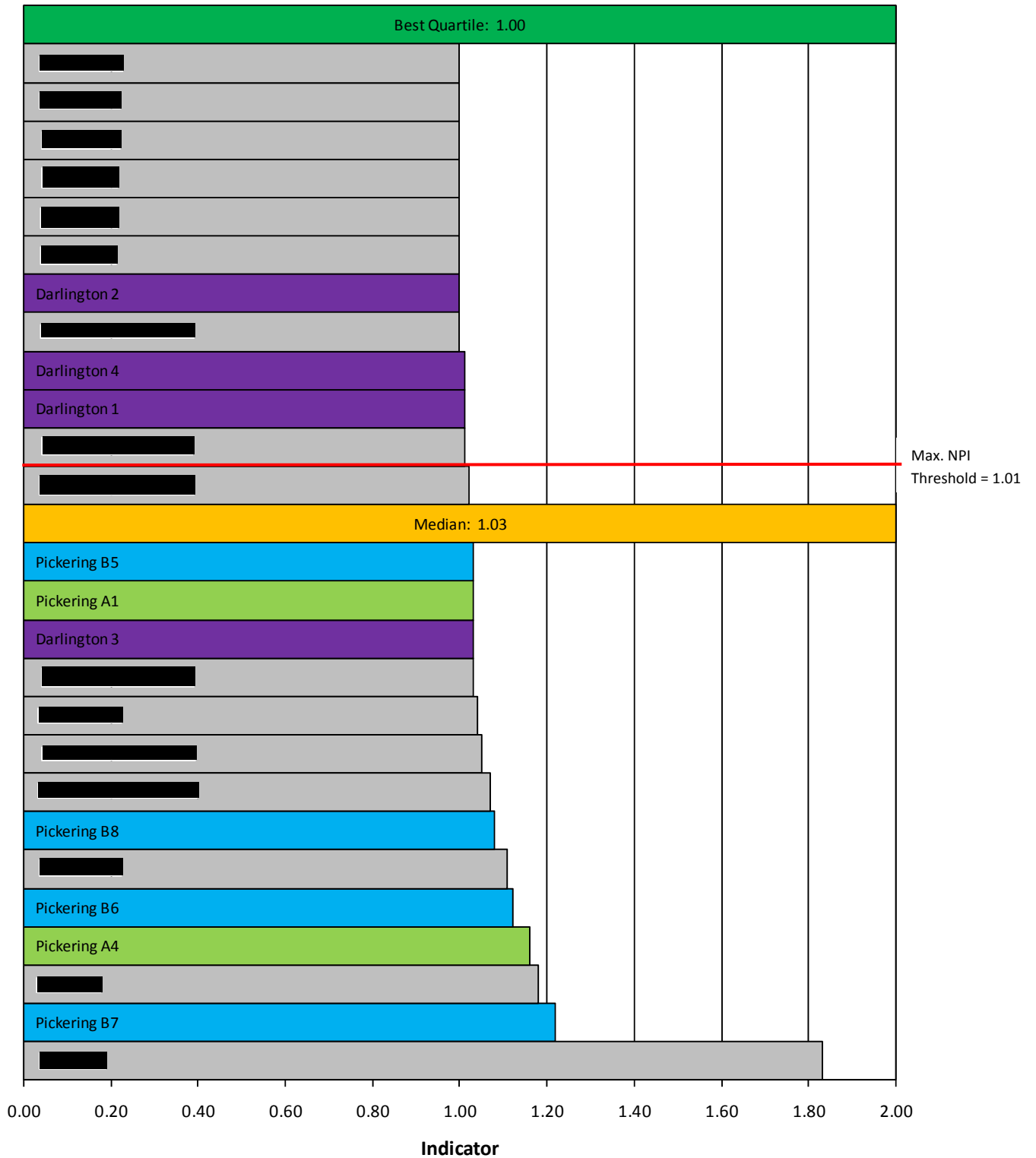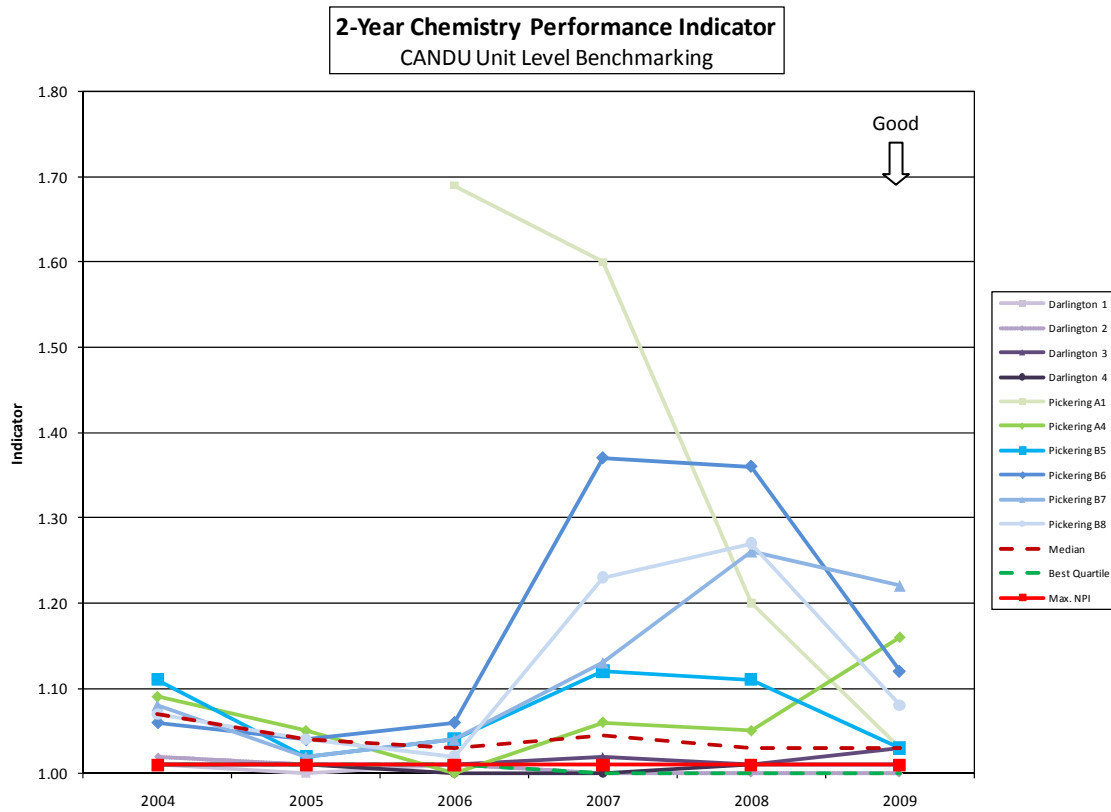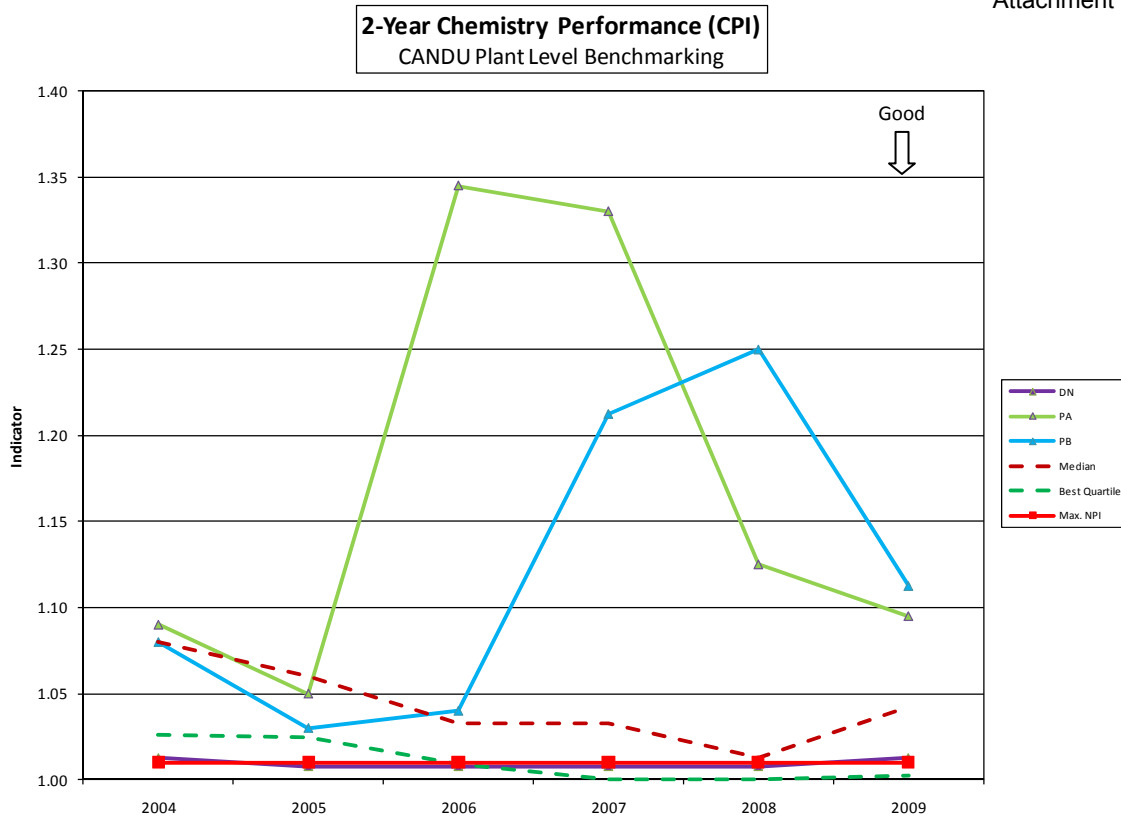
Observations – 2-Year Chemistry Performance Indicator (CANDU)

2009 (2-Year Rolling Average)
- The CANDU plant level median is 1.04, while the unit level median is 1.03.
- The plant level best quartile of the CANDU panel is 1.00. Darlington is above median at the plant level with a WANO CPI of less than 1.04, with Units 1, 2 and 4 performing above the unit level median of 1.03. Pickering A units are below the plant level median, with the Unit 1 CPI trending towards the median.
- Pickering B units are below the plant level median, with the Unit 5 CPI trending towards the median.

Trend
- Since 2004, Darlington has shown consistent improvement towards achieving the maximum NPI score.
- Pickering A plant level performance has improved since 2006.
- Pickering B plant level performance was close to the median prior to 2006, but declined in 2007 and 2008 before showing significant improvement in 2009.
- Since 2004, the top quartile and median scores across the CANDU plants, already close to the maximum, have converged even closer to the maximum 1.00 score.
- Relative ranking may be dramatically changed by just a few tenths of a part per billion (ppb) for a single chemical species. For example, for a Pickering unit an increase of 1 ppb sulphate, (e.g., from 1.7 ppb to 2.7 ppb) could move performance from top quartile (1.00) to bottom quartile (1.08). Similarly, an increase of 0.2 ppb in sodium could move performance from top quartile to median (1.03).

Factors Contributing to Performance

- Unit start-ups negatively impact the indicator by causing chemistry transients e.g., increased feedwater iron, which typically occur during these periods. Therefore, sustained periods of continued operation will assist in maximizing, i.e., lowering the WANO indicator score.
- There have been examples of defective blowdown valves requiring blowdown of individual boilers to be taken out of service. This causes boiler impurity concentrations to temporarily rise impacting the indicator score negatively (lower is better).

Darlington
- Darlington was very close to reaching best quartile performance in 2009. Improved Unit 3 performance can help improve overall plant performance. Forced outages resulting in unplanned unit start-ups have negatively impacted this indicator for the 2008-2009 period.

Pickering A
- Pickering A performance has been impacted by the unit re-start following a long period out of service and the effects of start-up chemistry impacted the indicator negatively. P4 was relatively stable during the reporting period but the return to service of P1 negatively impacted the overall Pickering A score.

Pickering B
- Pickering B units were moving toward median and best quartile prior to 2006. In December 2006 significant quantities of cation form resin entered the feedwater and boilers from the water treatment plant, releasing sulphate (one of the chemical species that makes up the indicator). The worst affected units were P6 and P8. Despite improved performance recently, the effect is still reflected in the score for the two-year rolling average.

1-Year On-line Elective Maintenance Backlog

2009 Elective Maintenance Backlog
All Participating Plants (AP-928 Working Group)

Elective Maintenance Backlog Work Orders per Unit

2006-2009 Elective Maintenance Backlog
All Participating Plants (AP-928 Working Group)
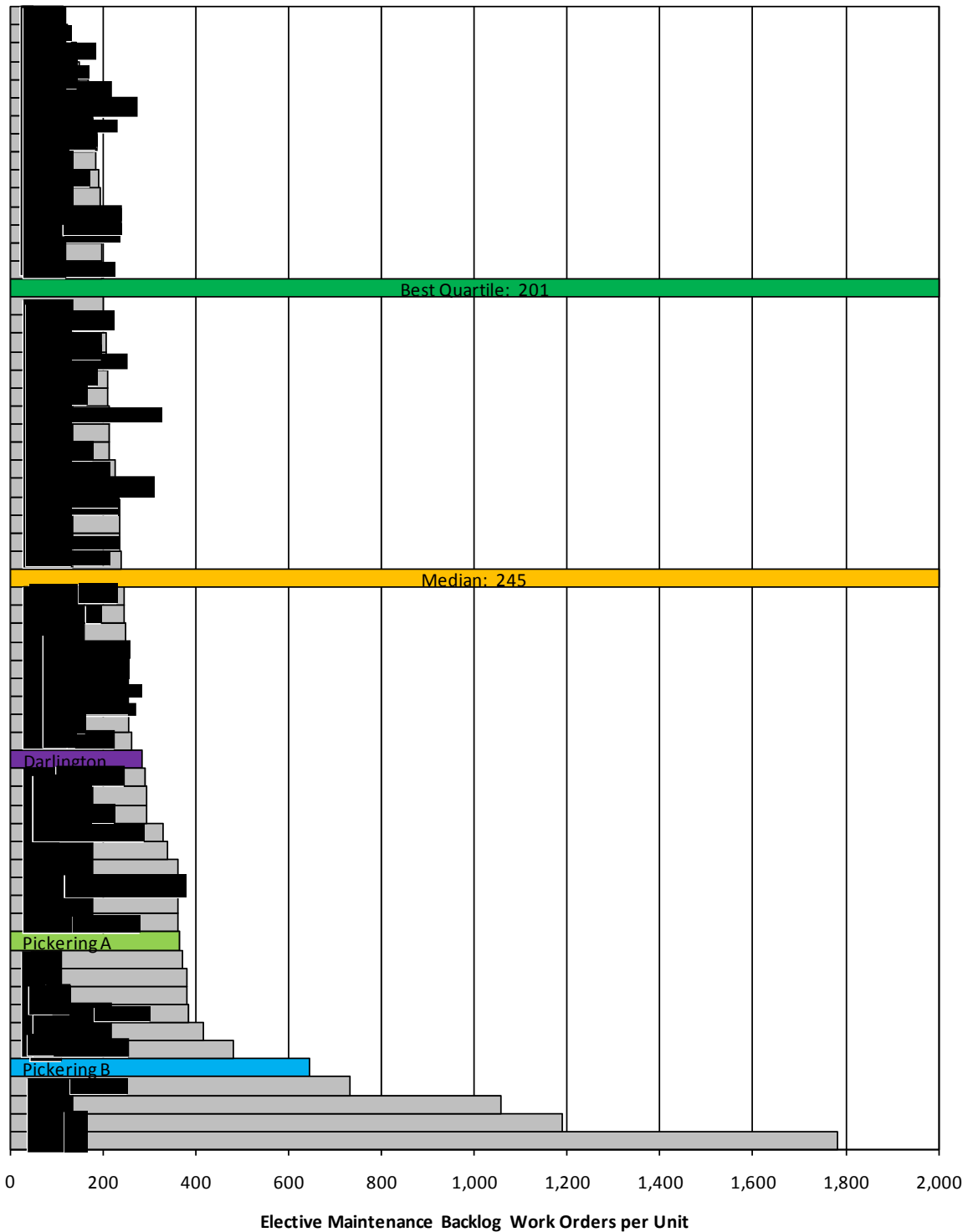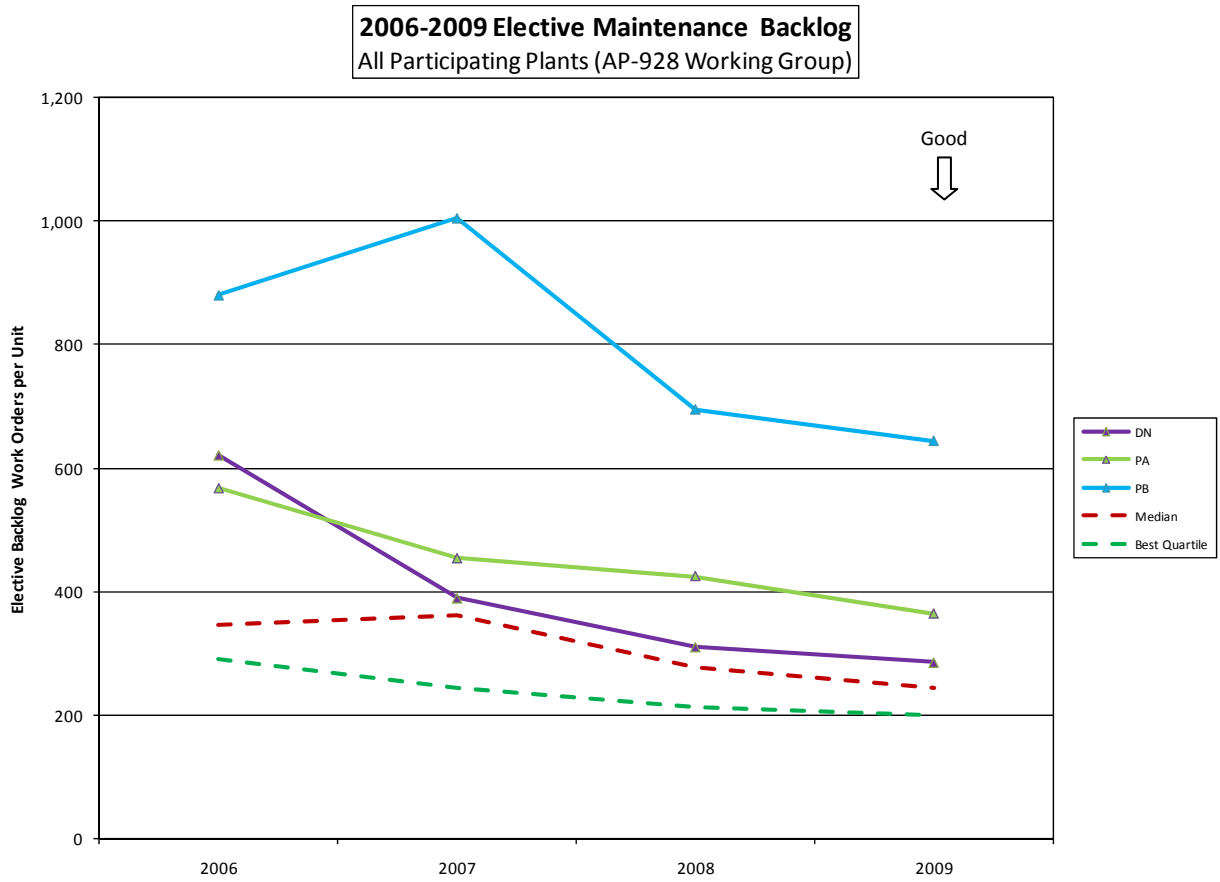
Observations – Elective Maintenance Backlog (INPO AP-928 Workgroup)

- Although all common services backlogs at Pickering are ascribed to Pickering A for purposes of internal reporting, when reporting externally, such backlogs are divided up between Pickering A and B based on operating units. Therefore 33% of common services backlogs reside at Pickering A, the remaining with Pickering B. This adjustment is reflected in the Pickering A and B backlog numbers presented below.

2009

- The data in this panel is gathered by an independent industry group of peers through an INPO AIP-928 group.
- Best quartile for the panel is 201 elective work orders.
- All three plants are currently performing worse than median.

Trend

- The overall industry best quartile has improved steadily over the review period.
- Darlington is the closest station in the OPG fleet to achieve median performance as indicated in industry performance metrics. Although Darlington has been focused on its elective maintenance backlogs for some time, an entire site focus made in 2006 allowed them to drive their backlogs down. Considerable work still remains to reach top quartile, but the infrastructure is in place.
- Pickering B was an outlier with the industry in 2004 and 2005, far above the nearest reporting utility. Significant gains have been made but they remain in the fourth quartile group, with a significant gap to top quartile remaining.
- Pickering A elective maintenance backlog has shown consistent improvement for the 2006-2009 review period.

Factors Contributing to Performance

- Key performance drivers for this metric include: parts obsolescence, bottle necks, and engineering holds.

Darlington

- Darlington broke the 300 plane in 2009 putting them within reach of median status. In order to bridge the gap in attaining top quartile, a 30% further reduction in backlogs is required. An additional challenge Darlington faces is related to the speed in which the industry is advancing in this area. It is projected that the actual gap they are facing is closer to a 40% reduction. Issues challenging Darlington include timely engineering holds resolution and parts obsolescence.

Pickering A

- A reduction of approximately 45% of their backlog is required to attain top quartile. Challenges affecting Pickering A include forced loss rate, work assessment, and parts obsolescence.

Pickering B

- Pickering B elective maintenance backlog was at 644 at December 1, 2009. To attain top quartile, a 70% reduction in backlogs will be required. Performance for the year has been flat with two units in a planned outage. Challenges affecting Pickering B include extended planned outages resulting in resource availability issues for operating units backlogs; assessing work, engineering holds resolution, and parts obsolescence.

1-Year Corrective Maintenance Backlog

2009 Corrective Maintenance Backlog
All Participating Plants (AP-928 Working Group)
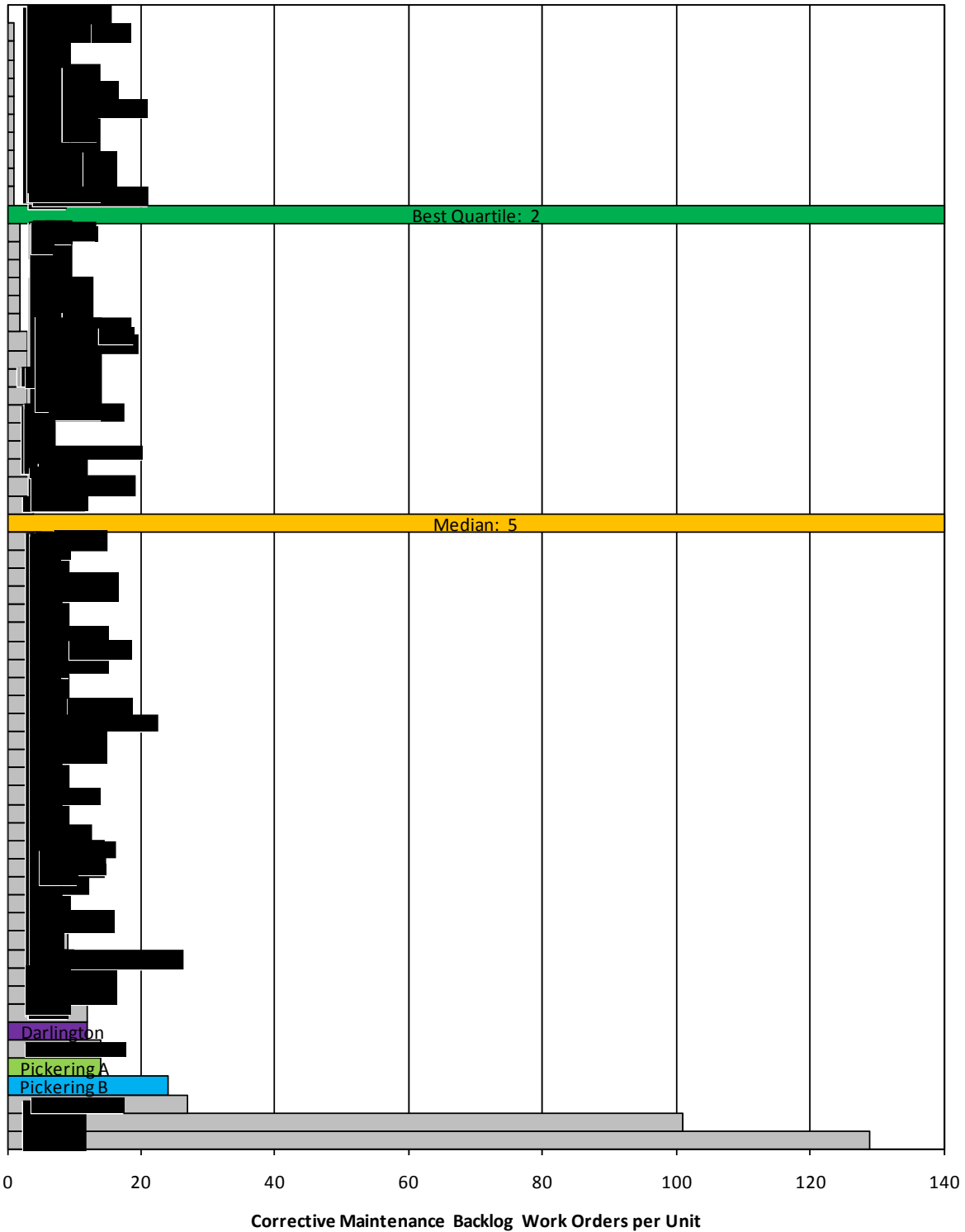
2006-2009 Corrective Maintenance Backlog
All Participating Plants (AP-928 Working Group)
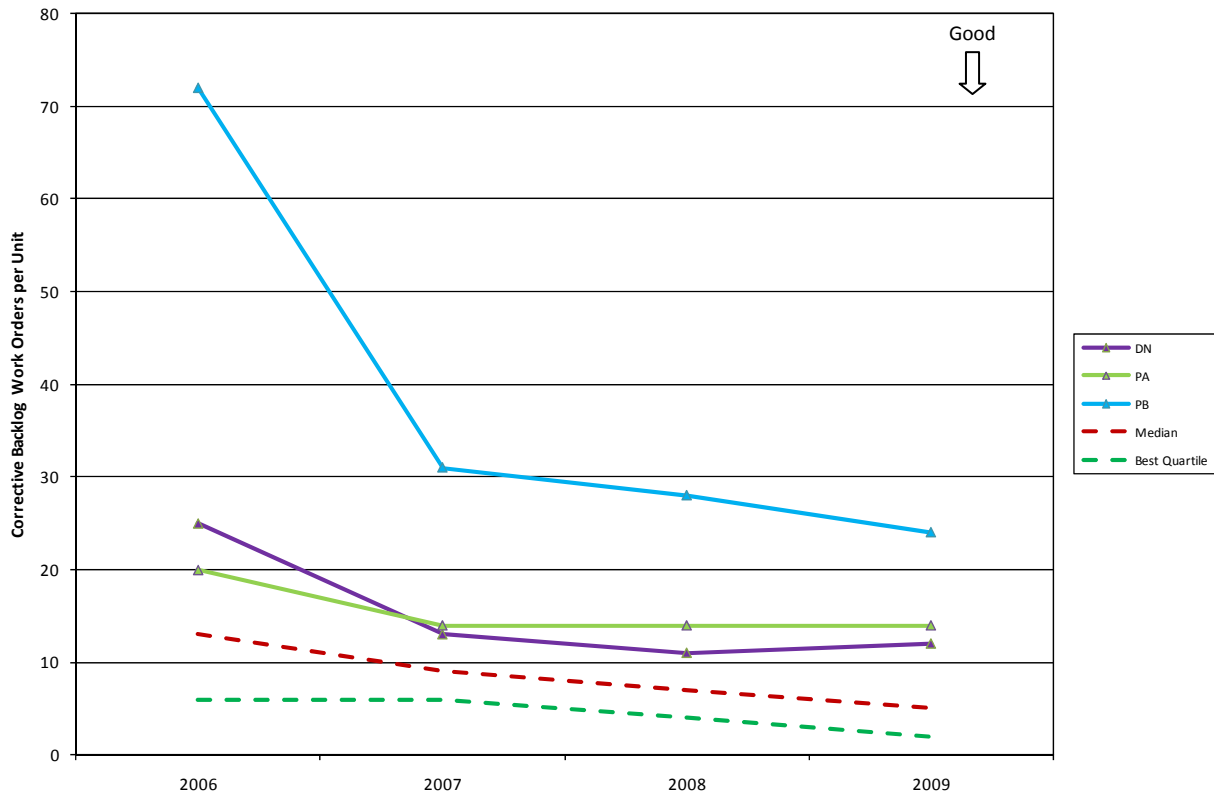
Observations – Corrective Maintenance Backlog (INPO AP928 Workgroup)

2009
- Best quartile for the panel is two work orders per unit.
- Currently all OPG sites are performing worse than median.
- Darlington is at 12, Pickering A is at 14 and Pickering B is at 24. A 60% reduction by Pickering A corrective maintenance backlog and an 80% by Pickering B corrective maintenance backlog are required to bring them to median performance in the industry.

Trend
- Best quartile has remained fairly constant and a low value for the review period while the median has improved, revealing an overall trend in the industry to single-digit corrective maintenance backlog results.
- All OPG sites have shown consistent improvement over the review period but remain worse than median. All stations were in excess of single-digit corrective maintenance values over the review period.

Factors Contributing to Performance

- Both the best quartile and median are single-digit values. Achieving single-digit corrective maintenance backlogs (i.e. nine or lower) is considered desirable performance. Further reductions may not be prudent from a cost/benefit perspective and would need to be evaluated.

Darlington
- Darlington has maintained the current performance level for the better part of 2009. Their program and process rigor are able to maintain corrective maintenance backlogs at this level.

Pickering A
- Pickering A has remained flat with the same challenges mentioned in the elective maintenance analysis.

Pickering B
- Pickering B has also remained flat with parts obsolescence and subsequent engineering issues with corrective maintenance backlogs.

General Comments
- The general comments on elective maintenance backlog (previous section) are also applicable for this section.

4.0 VALUE FOR MONEY

Methodology and Sources of Data

Costs indicators were retrieved from EUCG in June of 2010. Data was collected for three-year rolling averages for all financial metrics covering the review period from 2006-2009. Zero values for cost indicators are excluded from all calculations. All data pulled from the EUCG by OPG is converted and reported in Canadian dollars.

Effective January 2009 (but applied retroactively to EUCG historical data), EUCG automatically applies a purchasing power parity (PPP) value to adjust for all values across national borders. The primary function of the PPP value is to adjust for currency exchange rate fluctuations and take into account additional cross-border factors which may impact purchasing power of companies in different jurisdictions. As a result, cost variation between plants is limited, as much as possible, to real differences and not 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 in this panel. The remaining plants are BWRs or PWRs.

All cost metrics are normalized by some factor (MWh or MW DER) to allow for more accurate comparison across plants of different sizes and numbers of units.

Discussion

Four "value for money" metrics are benchmarked: Total Generating Costs per MWh, Non-Fuel Operating Costs per MWh, Fuel Cost per MWh and Capital Costs per MW DER. The metrics roll up as shown in the illustration below. Total generating cost is the sum of non-fuel operating cost, fuel cost, and capital cost. Given differences between OPG and most North American plants the best overall financial comparison metric for OPG facilities is Total Generating Cost per MWh.

Diagram of Summary Relationship of Value for Money Metrics
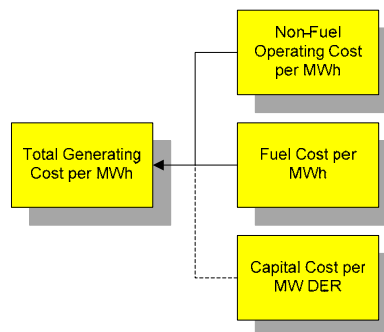
3-Year Total Generating Costs per MWh

2009 3 Year Total Generating Costs per MWh
EUCG Benchmarking All North America
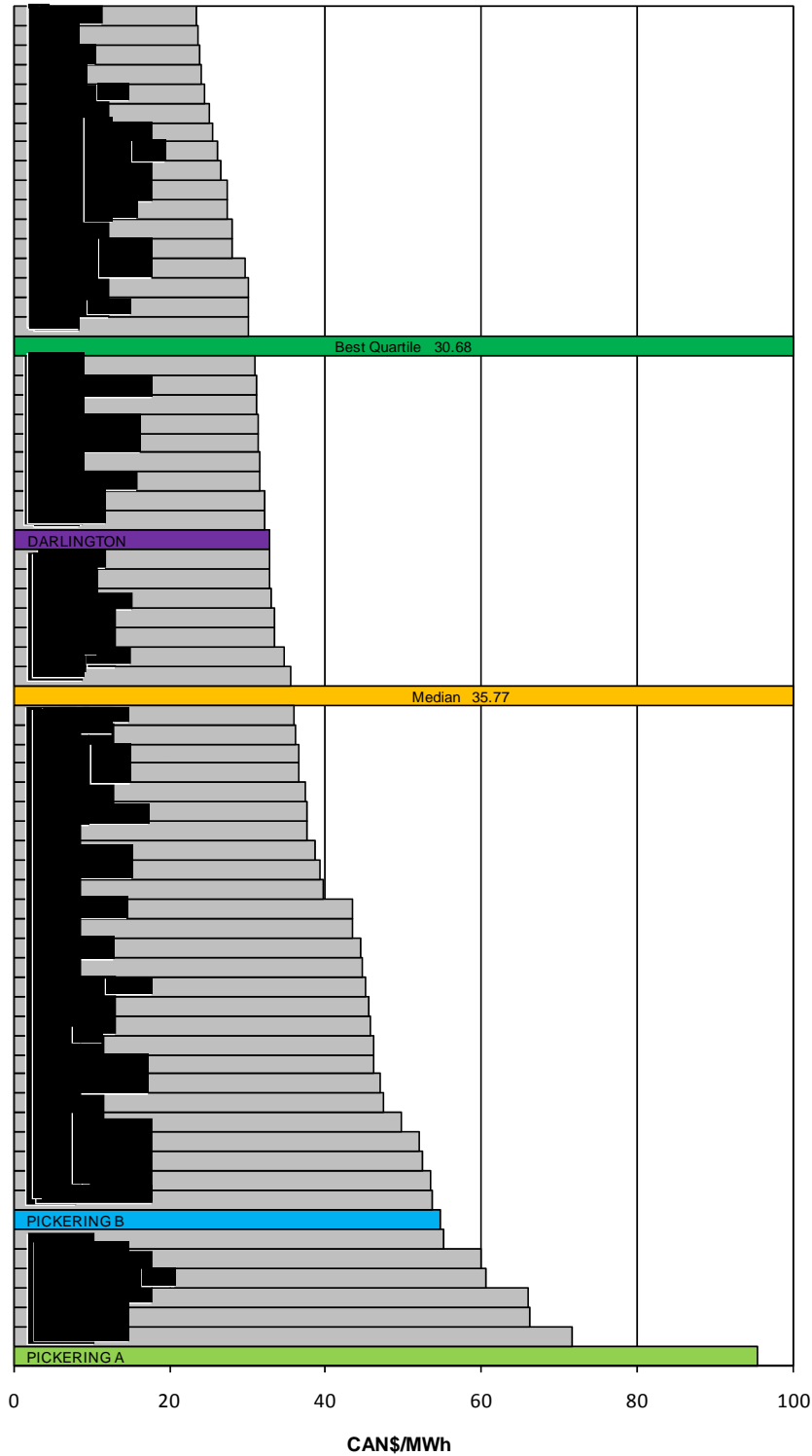
CAN$/MWh

3-Year Total Generating Costs per MWh
EUCG Benchmarking All North America
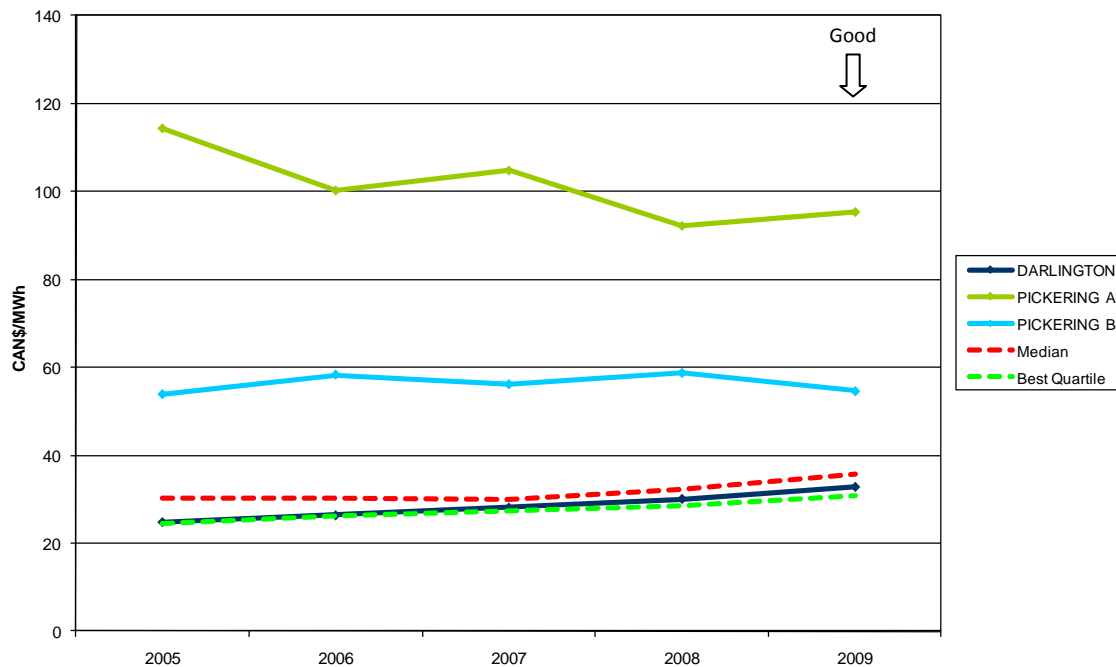
Observations – 3-Year Total Generating Cost per MWh (All North American)

2009 (3-Year Rolling Average)
- The best quartile level for total generating costs per MWh among North American EUCG participants was $30.68/MWh while the median level was $35.77/MWh.
- Darlington was the only CANDU plant in the panel to achieve total costs better than the industry median but they did not achieve best quartile.
- Pickering A's total generating cost was $95.41/MWh, well worse than the median of $35.77/MWh.
- Pickering B's total generating cost was $54.64/MWh, also well worse than the median of $35.77/MWh.

Trend
- Both best quartile and median total generating costs per MWh have increased over the 2005 to 2009 period – in effect, lowering the bar. The best quartile costs rose by $6.23/MWh while the median cost rose by $5.57/MWh.
- Darlington's costs trended upward over the review period. In 2005, they were at best quartile level but by 2009 they were between best quartile and median levels. The growth during this period was $7.88/MWh.
- Pickering A's total generation cost per MWh was the highest cost of any station reporting and was $59.64/MWh above the 2009 median, although costs have decreased over the period by $19/MWh.
- Pickering B's costs have consistently trended above the median.

Factors Contributing to Performance

- Total generating cost per MWh is the sum of non-fuel operating cost per MWh, fuel cost per MWh and capital cost per MWh. The benchmark metric is capital cost per MW DER. To include capital cost impact in total generating cost, station capital costs are divided by net MWh produced – same as for fuel/ non-fuel operating costs.
- For technological reasons, fuel per MWh is an advantage for all CANDUs and the OPG plants performed within the best quartile.
- Non-fuel operating cost per MWh for all OPG plants yielded results of worse than median for the most recent data point compared to the North American EUCG panel.

Darlington
- As stated above, fuel cost per MWh and capital cost per MW DER performed within the best quartile for Darlington while the non-fuel operating cost per MWh performed worse than median.
- The largest drivers of performance gap for Darlington are CANDU technology, corporate support costs and potential controllable costs.
- Due to strong generation performance at Darlington, capability factor does not contribute negatively to performance.
- Station size provides an overall advantage for Darlington (due to 4 relatively large units

Pickering A
- As stated above, fuel cost per MWh performed within the best quartile for Pickering A and capital cost per MW DER performed better than median while the non-fuel operating cost per MWh performed worse than median.
- The overall largest driver of cost per MWh for Pickering A during the review period is capability factor.
- Station size also negatively impacts cost per MWh for Pickering A (primarily driven by relatively small units).
- The remaining large drivers of cost performance at Pickering A include CANDU technology, corporate cost allocations, and potential controllable costs.

Pickering B
- As stated above, fuel cost per MWh and capital cost per MW DER performed within the best quartile for Pickering B while the non-fuel operating cost per MWh performed worse than median.
- Like Pickering A, the overall largest driver of cost per MWh for Pickering B over the review period is capability factor.
- Station size also negatively impacts cost per MWh for Pickering (primarily driven by relatively small units).
- The remaining large drivers of cost performance at Pickering B include CANDU technology, corporate cost allocations, and potential controllable costs.

3-Year Non-Fuel Operating Costs per MWh

2009 3 Year Non-fuel Operating Costs per MWh
EUCG Benchmarking All North America
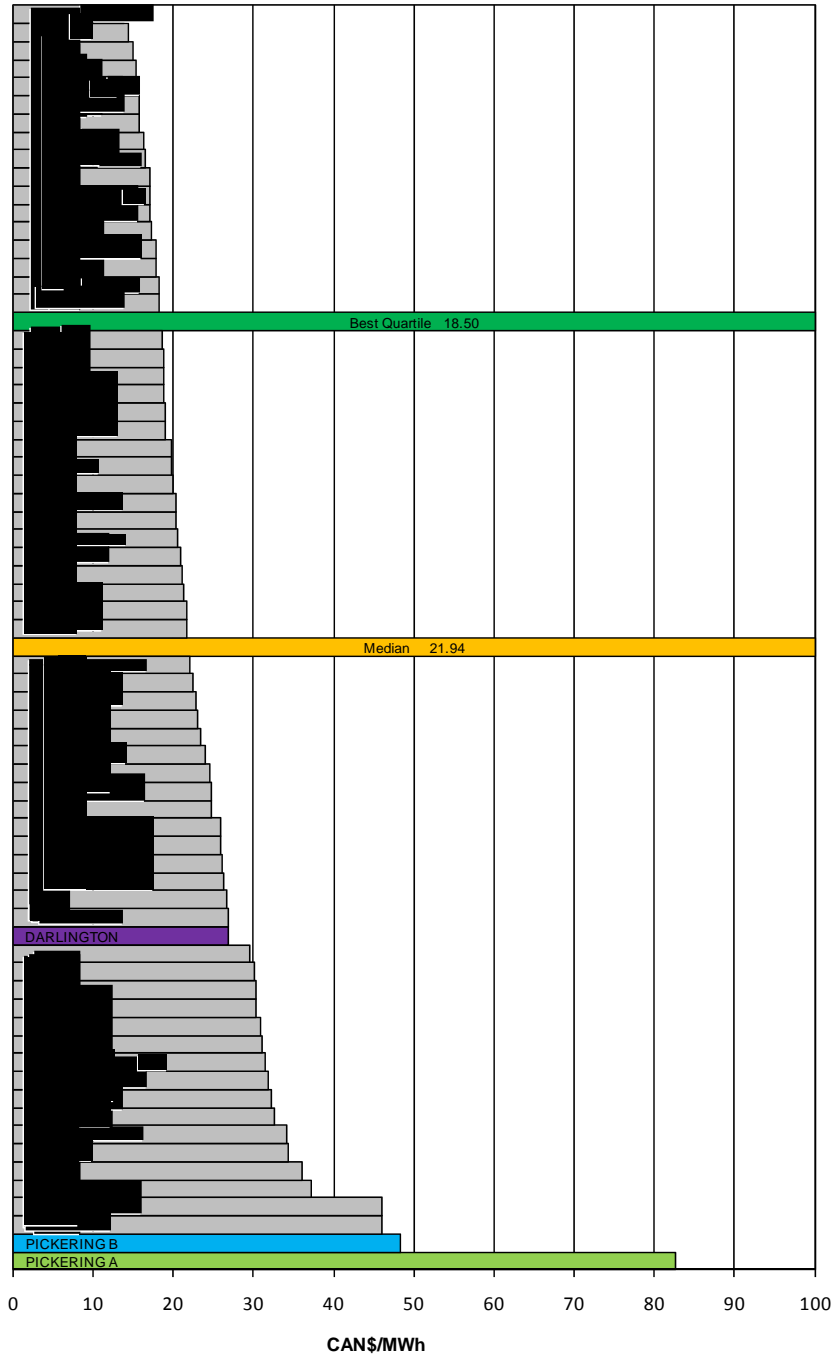
CAN$/MWh

3-Year Non-Fuel Operating Costs per MWh
EUCG Benchmarking All North America
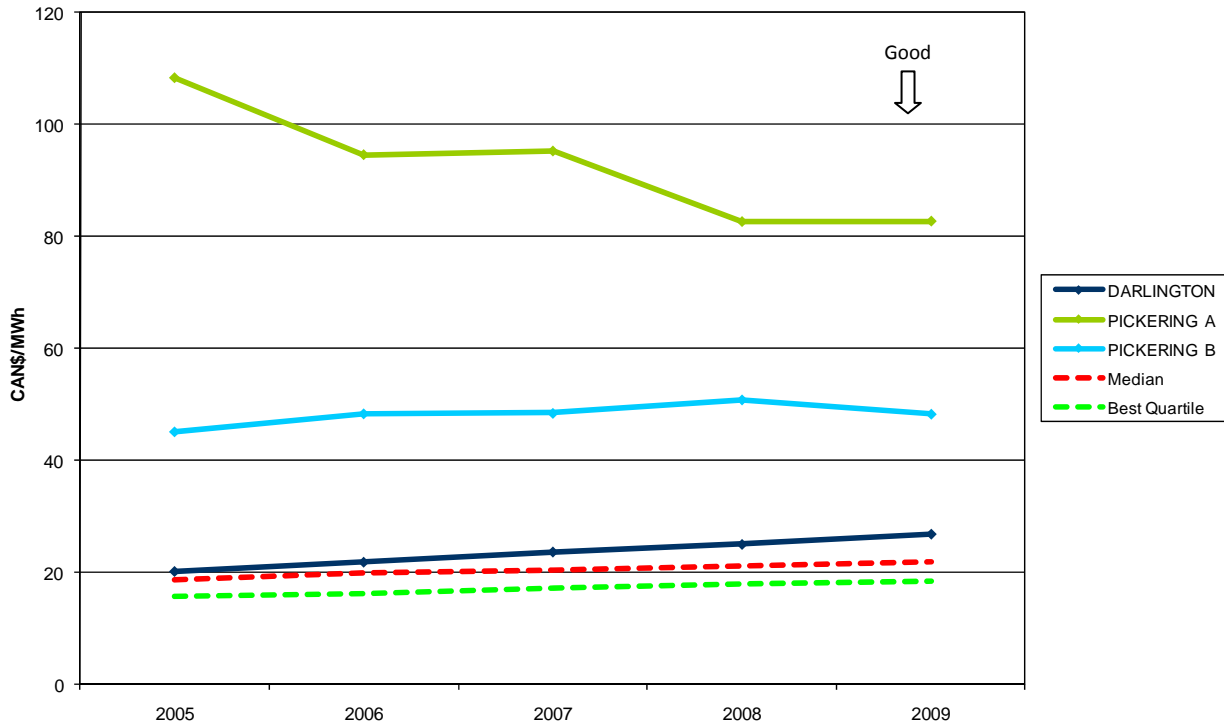
Observations – 3-Year Non-Fuel Operating Costs per MWh (All North American)

2009 (3-Year Rolling Average)
- Best quartile Plants had non-fuel operating costs of better than $18.50/MWh.
- Median Plants were better than $21.94/MWh.
- Compared to North American EUCG plants, the non-fuel operating costs per MWh of all participating Canadian CANDU plants are far worse than median performance.
- Darlington's costs, at $26.94/MWh, were $8.44/MWh higher than best quartile and $5/MWh higher than the median.
- Pickering B, at $48.37/MWh, was $29.87/MWh higher than best quartile and $ 26.43/MWh higher than median.
- Pickering A, at $82.70/MWh, was $64.2/MWh above best quartile and $60.76/MWh higher than the median.

Trend

- Both best quartile and median levels increased over the review period with annual percentages increases between 4% and 2% thus lowering the bar.
- Darlington non-fuel operating costs per MWh trended upward at a rate of increase nearly double that of the industry as a whole thus lowering their overall standing on this metric.
- Pickering A non-fuel operating costs per MWh showed a dramatic decrease since 2005 – a significant improvement.
- Pickering B non-fuel operating costs per MWh decrease slightly over 2005 and were approximately three times higher than best quartile for the North American EUCG panel.

Factors Contributing to Performance

- Performance in non-fuel operating cost per MWh drives the majority of OPG financial performance. Removing OPG's advantages in fuel costs and capital costs reveals relatively poor financial performance at all three OPG facilities with respect to non-fuel operating cost per MWh. Overall, the biggest drivers are: capability factor, station size, CANDU technology, corporate cost allocation and potential controllable costs. The biggest drivers are as stated below.
- The 'capability factor' driver is related specifically to generation performance of the station in relation to the overall potential for the station (results are discussed within the Reliability section within the 2-Year Unit Capability Factor metric).
- The 'station size' driver is the combined effect of number of units and size of units. The number of units and size of those units can have significant impacts on plant cost performance and review of the benchmarking data reveals a link between the two.
- The 'CANDU technology' driver relates specifically to the concept that CANDU technology results in some specific cost disadvantages related to the overall engineering and maintenance costs. In addition, this factor is influenced by the fact that CANDU plants have less well-developed user groups to share and adopt competitive advantage information, than do longer-established user groups for PWRs and BWRs. Quantification of CANDU technology impact to cost remains most difficult of all drivers.
- The 'corporate cost allocations' driver relates directly to the allocated corporate support costs charged to the nuclear group.
- The 'potential controllable costs' driver relate to the remaining costs which are not attributable to other specific cost drivers – and provide a potential improvement opportunity for further analysis.

Darlington

- The major contributing factors for Darlington performance for non-fuel operating cost per MWh were reviewed within the total generating cost per MWh section.
- The only additional contributing factor which appears within non-fuel operating cost is capitalization policy.
- The impact of differing capitalization policies is removed when looking at total generating cost per MWh (i.e. the sum of non-fuel operating cost, fuel cost, and capital cost).

Pickering A

- The major contributing factors for Pickering A performance for non-fuel operating cost per MWh were reviewed within the total generating cost per MWh section.
- The only additional contributing factor which appears within non-fuel operating cost is capitalization policy.
- The impact of differing capitalization policies is removed when looking at total generating cost per MWh (i.e. the sum of non-fuel operating cost, fuel cost, and capital cost).

Pickering B

- The major contributing factors for Pickering B performance for non-fuel operating cost per MWh were reviewed within the total generating cost per MWh section.
- The only additional contributing factor which appears within non-fuel operating cost is capitalization policy.
- The impact of differing capitalization policies is removed when looking at total generating cost per MWh (i.e. the sum of non-fuel operating cost, fuel cost, and capital cost).

3-Year Fuel Costs per MWh

2009 3 Year Fuel Costs per MWh
EUCG Benchmarking All North America
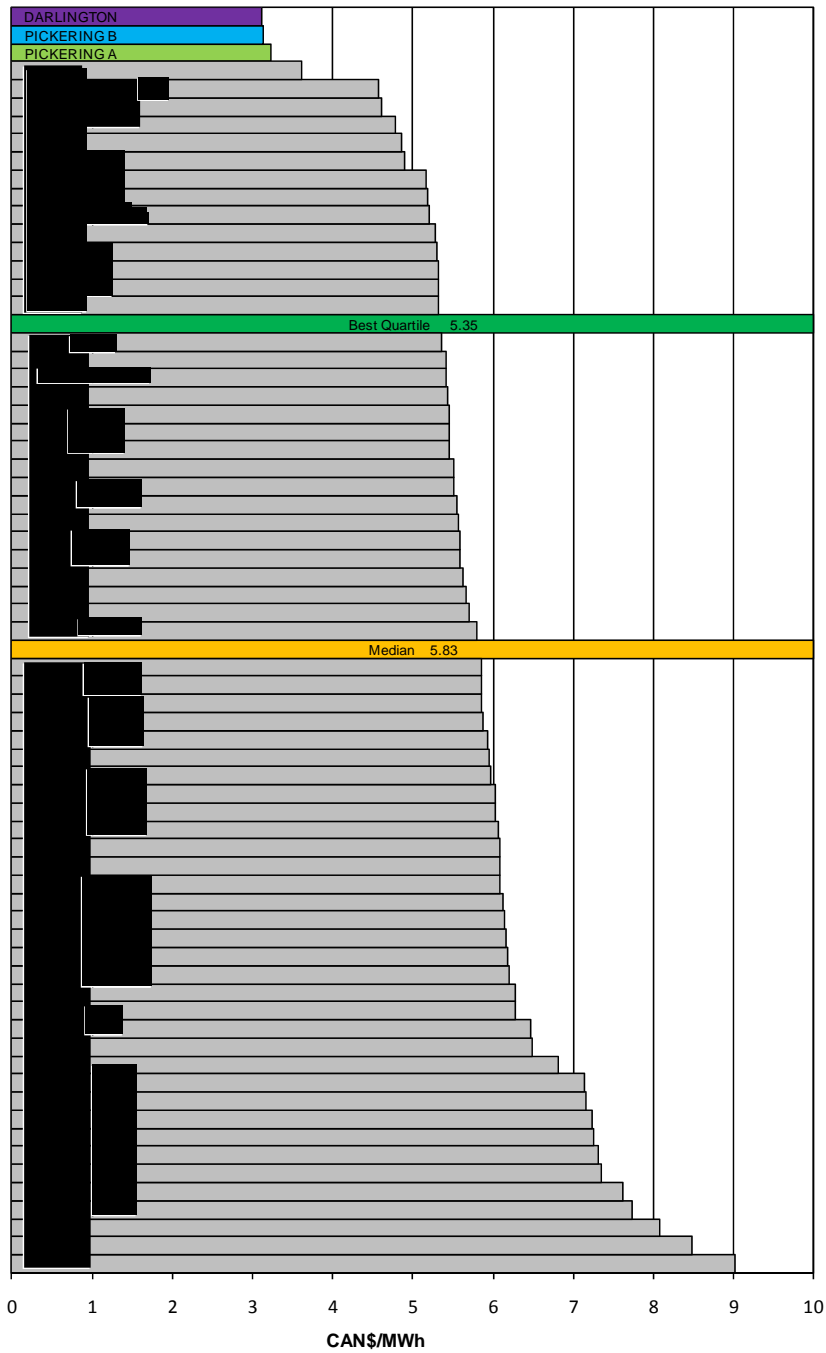
3-Year Fuel Costs per MWh
EUCG Benchmarking All North America
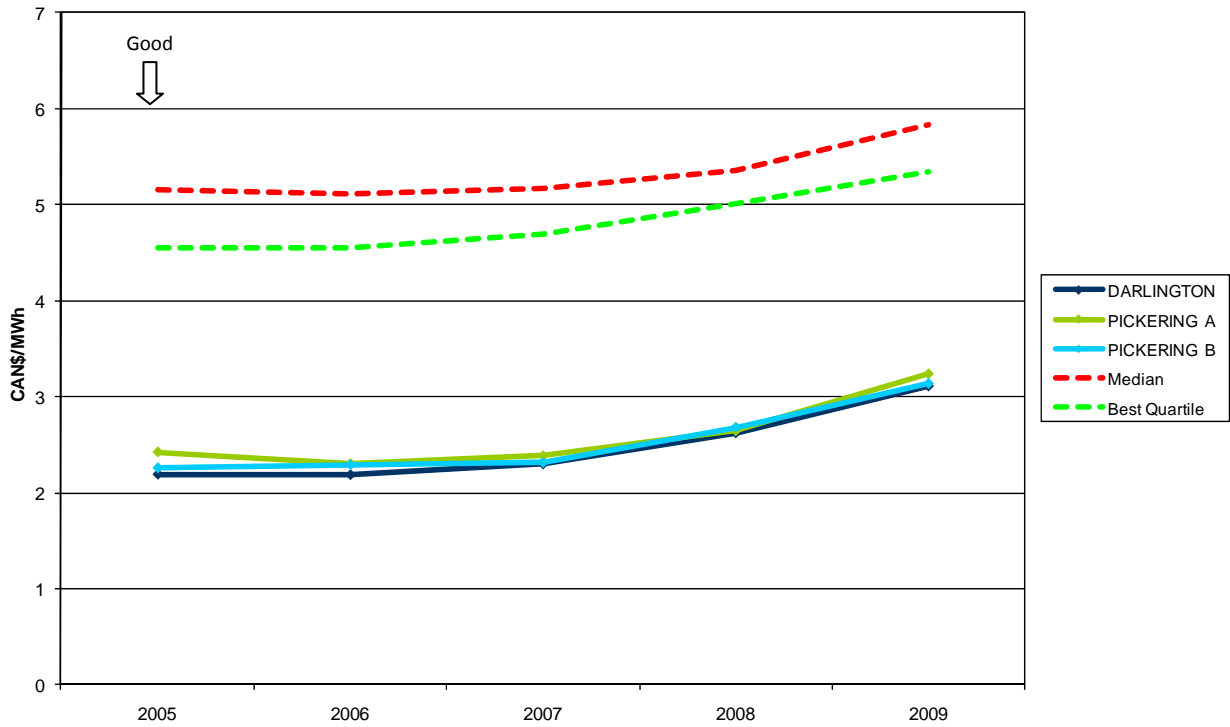
Observations – 3-Year Fuel Costs per MWh (All North American)

2009 (3-Year Rolling Average)

- Fuel costs per MWh for Canadian CANDU plants are over $1.73/MWh better than of the best quartile threshold for the panel of North American EUCG plants.
- ██

Trend

- The best quartile 3-year fuel costs per MWh have been slowing rising since 2005 with the greatest increase in 2009.
- Since 2006 fuel costs per MWh for all three OPG plants have been rising with the greatest increase in 2009.
- Fuel costs per MWh at the three OPG plants have been converging and currently are very similar to one another.

Factors Contributing to Performance

- Fuel cost, primarily driven by the technological differences in CANDU technology, are lower for OPG than for most North American PWR/BWR reactors. CANDUs do not require enriched uranium like BWRs and PWRs and, as a result, experience lower fuel costs. This provides a significant advantage for OPG in this cost category.

Best quartile fuel cost performance noted above is due to three significant factors:

- Uranium fuel costs: Raw uranium is processed directly into uranium dioxide to make fuel pellets, without the cost and process complexity of enriching the fuel as required in light water reactors. The advantage due to fuel costs also includes transportation, handling and shipping costs.
- Reactor core efficiency: CANDU is the most efficient of all reactors in using uranium, requiring about 15% less uranium than a pressurized water reactor for each megawatt of electricity produced.
- Fuel assembly manufacturing costs: Manufacturing costs for light water reactor fuel assemblies are significantly higher than CANDU fuel bundles, due to physical design complexity and increased amount of materials.

3-Year Capital Costs per MW DER

2009 3 Year Capital Costs per MW DER
EUCG Benchmarking All North America
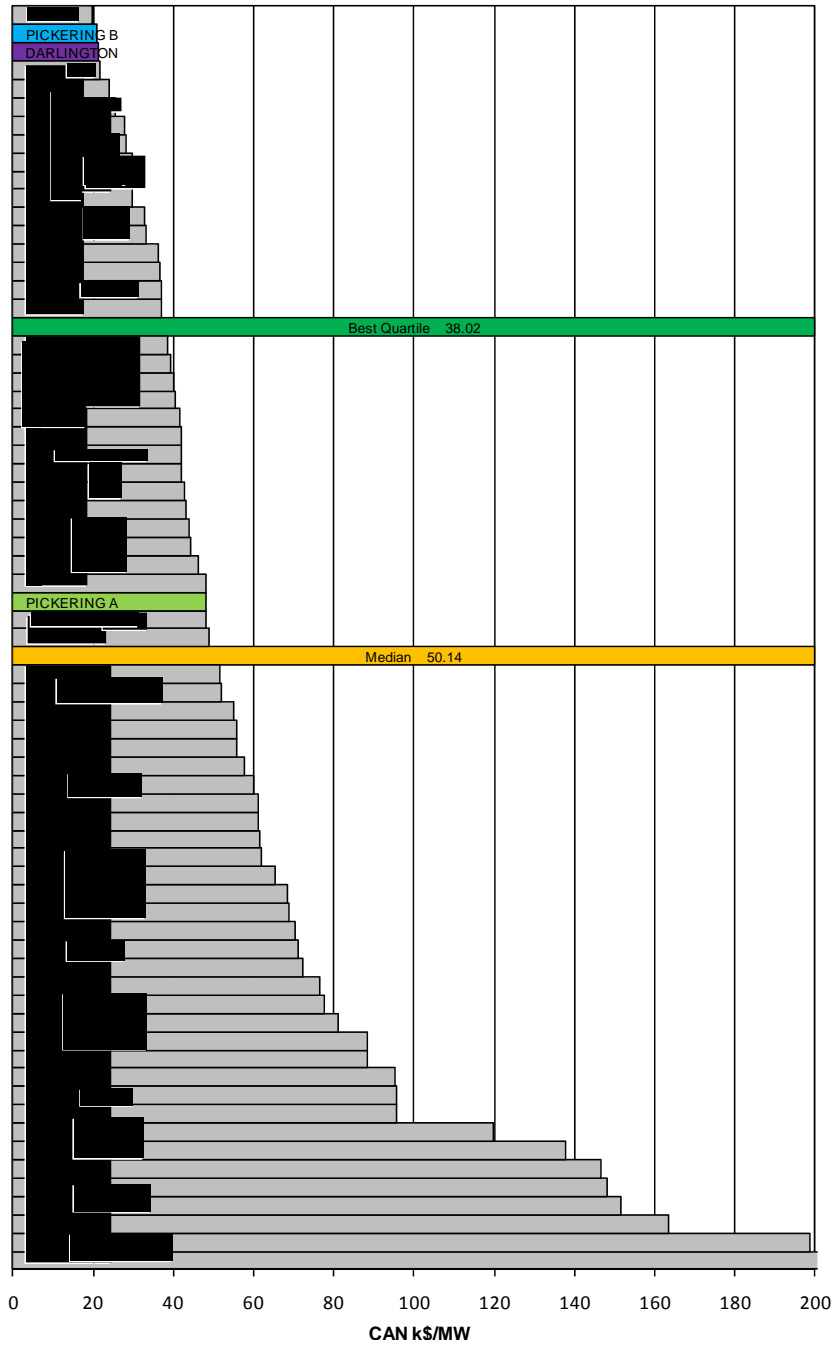
3-Year Capital Costs per MW DER
EUCG Benchmarking All North America
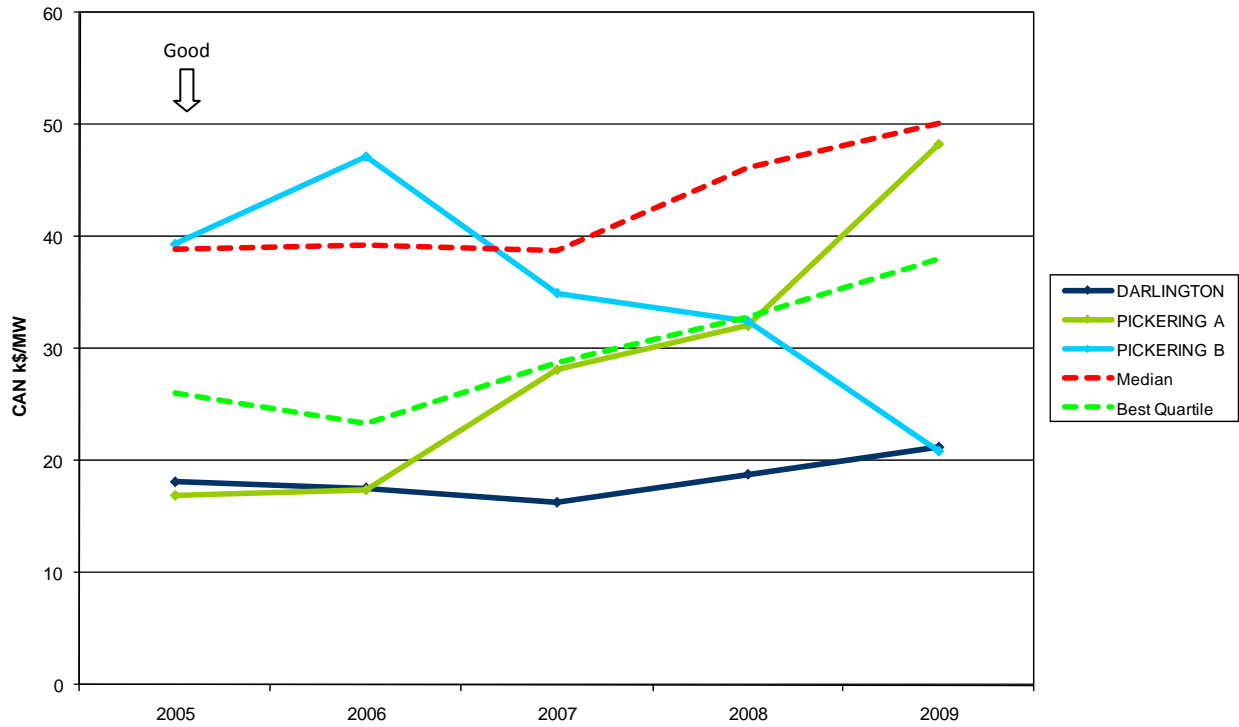
Observations – 3-Year Capital Costs per MW DER (All North American)

2009 (3-Year Rolling Average)
- Best quartile threshold for capital costs per MW DER across the North American EUCG peer panel plants was $38.02/MW DER.
- Median cost for the panel was $50.14/MW DER.
- Pickering B and Darlington had the second/third lowest capital costs/MW DER of any plant in the peer group.
- Pickering A was better than the median.

Trend
- Best quartile capital costs per MW DER have increased since 2006.
- Median levels for capital costs held steady from 2005 to 2007 and then escalated for both 2008 and 2009.
- Darlington's capital cost per MW DER decreased moderately between 2005 and 2007 and escalated for 2008 and 2009.
- Pickering A's capital costs per MW DER rose from 2005 to 2009 and was better than the median in 2009.
- Pickering B's capital costs per MW DER rose from 2005 to 2006 and have decreased through 2009.

Factors Contributing to Performance

- Darlington is performing within the best quartile for the panel while Pickering B and Pickering A are better than the median.
- One contributing factor for OPG appears to be the capitalization threshold. The minimum expenditure threshold for capitalization at OPG for generating assets is $200k per unit whereas the majority of the companies in the industry have adopted minimum capitalization thresholds that are significantly lower.

5.0 HUMAN PERFORMANCE

Methodology and Sources of Data

The Human Performance Error Rate metric has been selected 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 by comparing OPG Nuclear stations to industry quartiles through the use of consistent, comparable data. Since this is a new metric being piloted; only one year's worth of data was available through INPO when this report was produced.

2009 Human Performance Error Rate
North American PWR & PHWR Plant Level Benchmarking
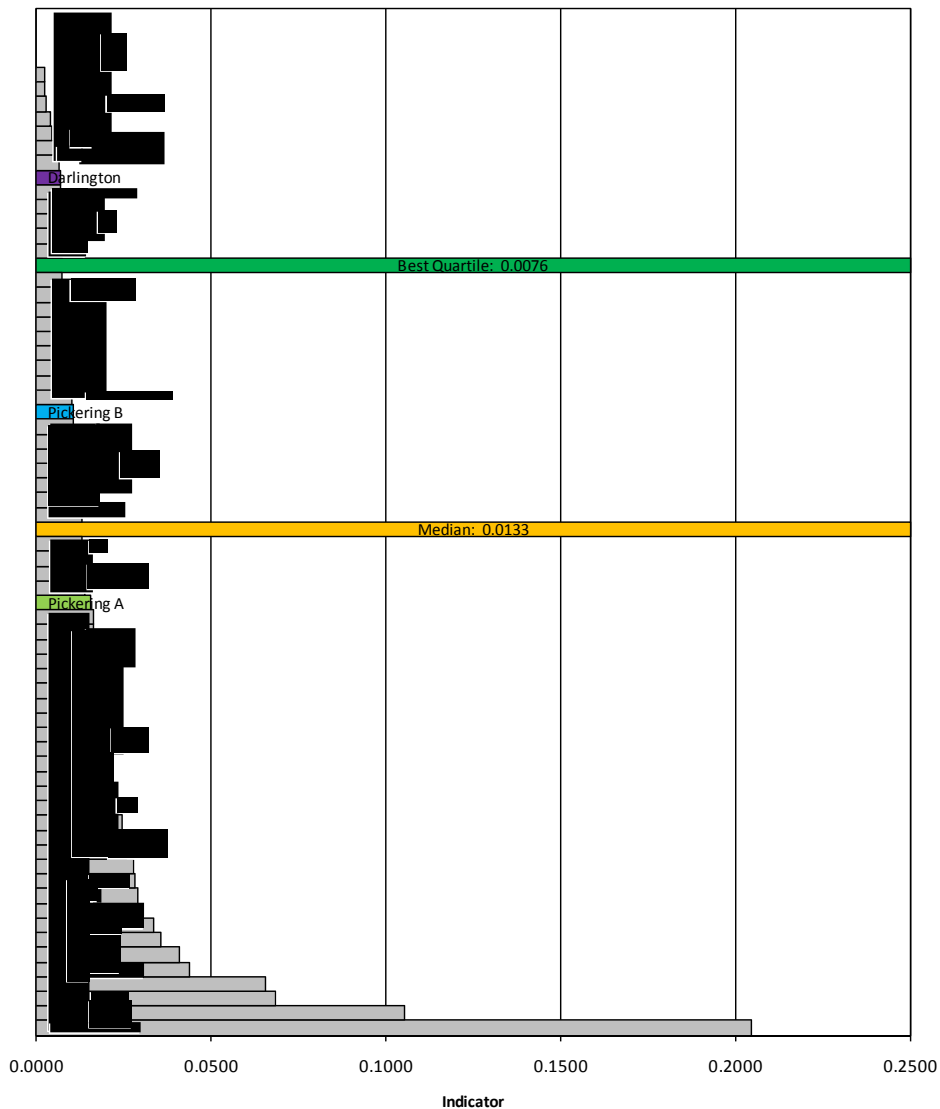
Human Performance Error Rate

Observations – Human Performance Error Rate (All North American Plants)

2009
- Best quartile threshold for Human Performance Error Rate across the North American plants was 0.0076
- Median rate was 0.0133
- Darlington exhibited top quartile performance compared to the peer group
- Pickering A and B have not yet achieve top quartile performance

Factors Contributing to Performance

- Pickering A's performance has been negatively impacted by 3 events in 2009.
- Pickering B's performance has been trending in the right direction over the last year, finishing the year with 4 events and above median against the INPO panel.
- Top performance was achieved at Darlington for 2009.

6.0 MAJOR OPERATOR SUMMARY

Purpose

This section supplements the Executive Summary, providing more detailed comparison of the major operators of nuclear plants for three key metrics: WANO NPI, Unit Capacity Factor (UCF) and Total Generating Costs (TGC). Although our benchmarking study has been primarily focused on operational performance comparison to COG CANDUs, this section of the report contemplates the larger industry by capturing OPG Nuclear's performance against North American PWR and PHWR operators. 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 all of the detailed data in the previous sections provide the more complete picture of plant by plant performance. WANO NPI and UCF are calculated as the mean of all unit performance for a specific operator. TGC is the mean of plant level data because costs are not allocated to specific units within EUCG.

A table of plants and their operators for WANO NPI and for UCF is provided in Table 7 of the Appendix and, for TGC see Table 8 in the Appendix.

WANO NPI Analysis

The WANO NPI results for the operators in 2009 are illustrated in the graph below. WANO method four was used for these calculations.

2009 WANO NPI for Major Operators*
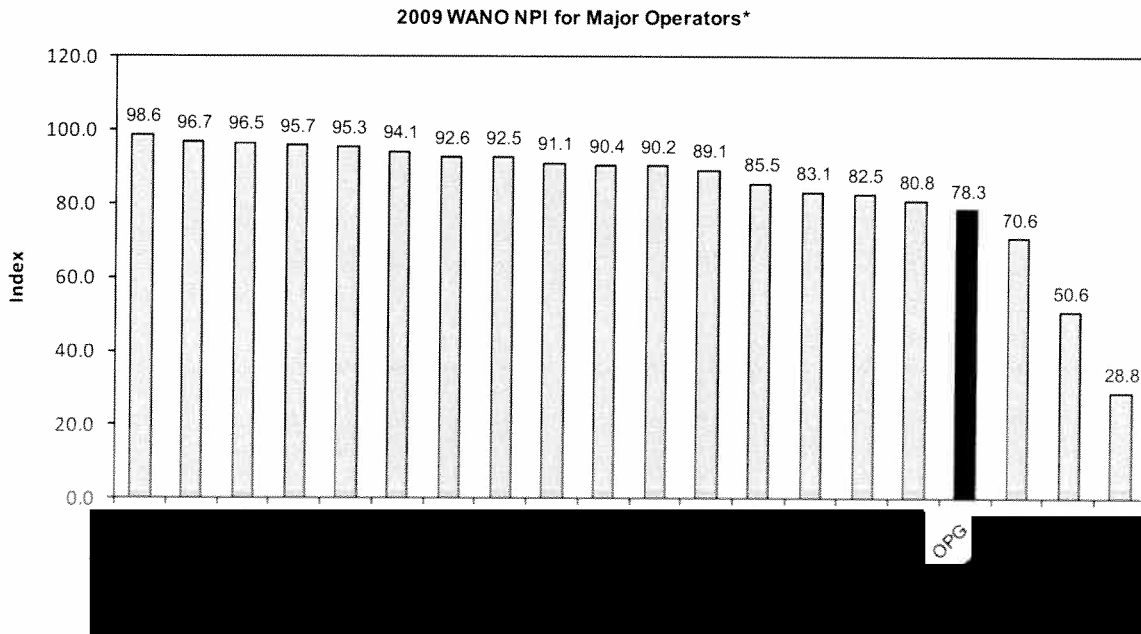
*See Table 7 in the Appendix for listing of operators and plants.
**OPG unit values averaging to a WANO NPI of 78.3 in 2009 are shown below:

Unit	2009 WANO NPI
Darlington 1	95.40
Darlington 2	97.60
Darlington 3	92.50
Darlington 4	95.00
Pickering A1	69.50
Pickering A4	52.80
Pickering B5	71.00
Pickering B6	83.30
Pickering B7	60.60
Pickering B8	65.70

In 2009, ▮▮▮▮ led all the operators in this data set with an NPI of 98.56. OPG ranked 17th, with an NPI of 78.34. Darlington performed significantly better overall than Pickering A and Pickering B, achieving best quartile for most of the review period. Refer to Section 3 for further information.

The NPI rankings of the major operators from 2006 to 2009 are listed in Table 3.

Table 3: Average WANO NPI Rankings

Operator	2006	2007	2008	2009
▮▮▮	1	2	13	1
▮▮▮▮▮▮	4	5	2	2
▮▮	19	17	5	3
▮▮▮	2	1	3	4
▮▮▮▮▮	6	10	9	5
▮▮▮▮▮	9	8	1	6
▮▮	11	6	10	7
▮▮▮▮▮▮	5	9	7	8
▮▮▮	10	7	12	9
▮▮▮▮	8	11	11	10
▮▮▮▮▮	15	15	16	11
▮▮▮	7	3	4	12
▮▮▮▮▮▮	3	4	8	13
▮▮	14	14	15	14
▮▮▮▮▮	12	13	6	15
▮▮▮	13	12	14	16
OPG	17	16	17	17
▮▮▮▮▮	20	19	18	18
▮▮▮▮▮	16	20	19	19
▮▮▮▮▮	18	18	20	20

Unit Capability Factor (UCF) Analysis

Unit Capability Factor is the ratio of available energy generation over a given time period to the reference energy generation of the same time period. Reference energy generation is the energy that could be produced if the unit were operating continuously at full power under normal

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Filed: 2010-12-27
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Attachment 1

conditions. Since nuclear generation plants are large fixed assets, the extent to which these assets generate reliable power is the key to both their operating and financial performance. For this reason, this NPI indicator has been examined more closely below.

A comparison of UCF values for major nuclear operators is presented in the graph below. UCF is expressed as a two-year average. OPG achieved a two-year average unit capacity factor of 80.8% and ranked 17 out of 20 major operators in the WANO data set. The two operators reporting the lowest UCF values are all CANDU operators. The range of values reported for these operators, however, varies greatly.

2009 2-Year Unit Capability Factor Ranking for Major Operators*
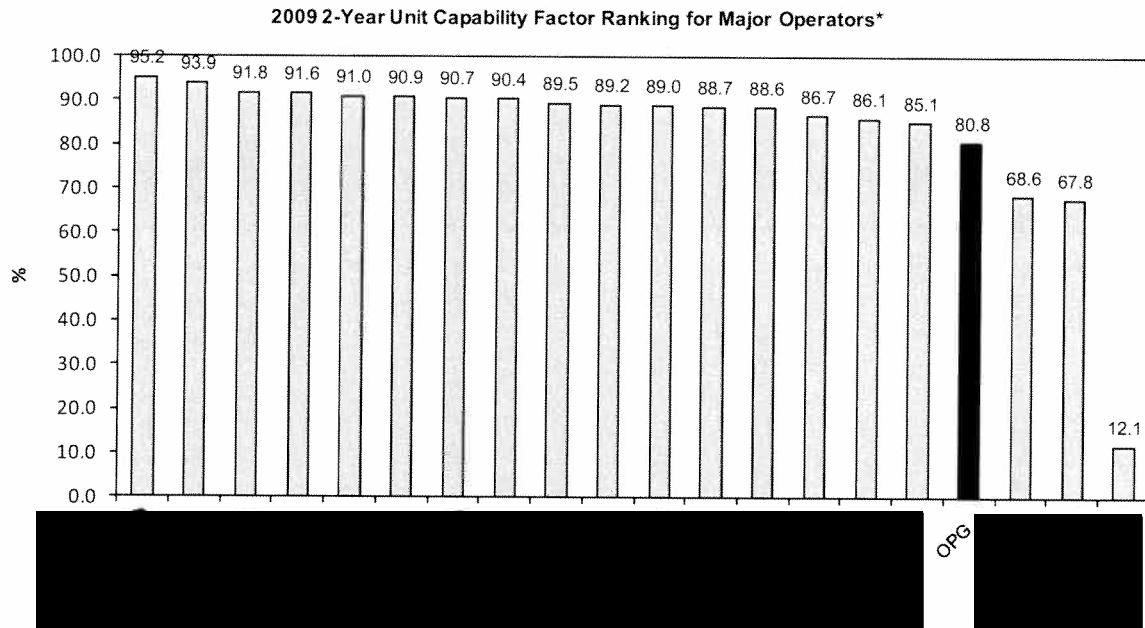
*OPG unit values averaging to a 2-Year UCF in 2009 of 80.8 are shown below:

Unit	2009 2-Year UCF
Darlington 1	85.91
Darlington 2	93.63
Darlington 3	87.27
Darlington 4	94.10
Pickering A1	76.97
Pickering A4	59.03
Pickering B5	80.51
Pickering B6	87.08
Pickering B7	64.41
Pickering B8	78.77

Based on reviewing individual unit results, Darlington performed the best overall, followed by Pickering B and then Pickering A. Rankings for the major operators for UCF over the past four years are provided in Table 4 below.

Table 4: Two-Year Unit Capability Factor Rankings

Operator	2005	2006	2007	2008	2009
	1	2	4	1	1
	2	1	2	2	2
	7	6	8	12	3
	4	5	3	4	4
	10	9	6	7	5
	15	3	1	10	6
	6	10	9	3	7
	9	7	10	13	8
	12	8	11	6	9
	17	14	13	15	10
	5	4	5	8	11
	13	19	19	5	12
	14	13	7	14	13
	19	16	15	17	14
	3	20	17	9	15
	8	12	12	11	16
OPG	20	18	20	18	17
	11	17	14	16	18
	16	15	18	19	19
	18	11	16	20	20

Total Generating Costs/MWh Analysis

The 3-year total generating costs results for the major operators in 2009 are displayed in the graph below. Total generating costs are defined as total operating costs plus capital costs. This value is divided by the total net generation for the year and provided as a three-year average. The top performer for 2009 was ███. OPG Nuclear ranked 16th with a 3-year total generation cost of $60.94 per MWh. Rankings for the major operators for TGC over the past five years are provided in Table 5 below.

2009 3 Year Total Generating Costs per MWh*
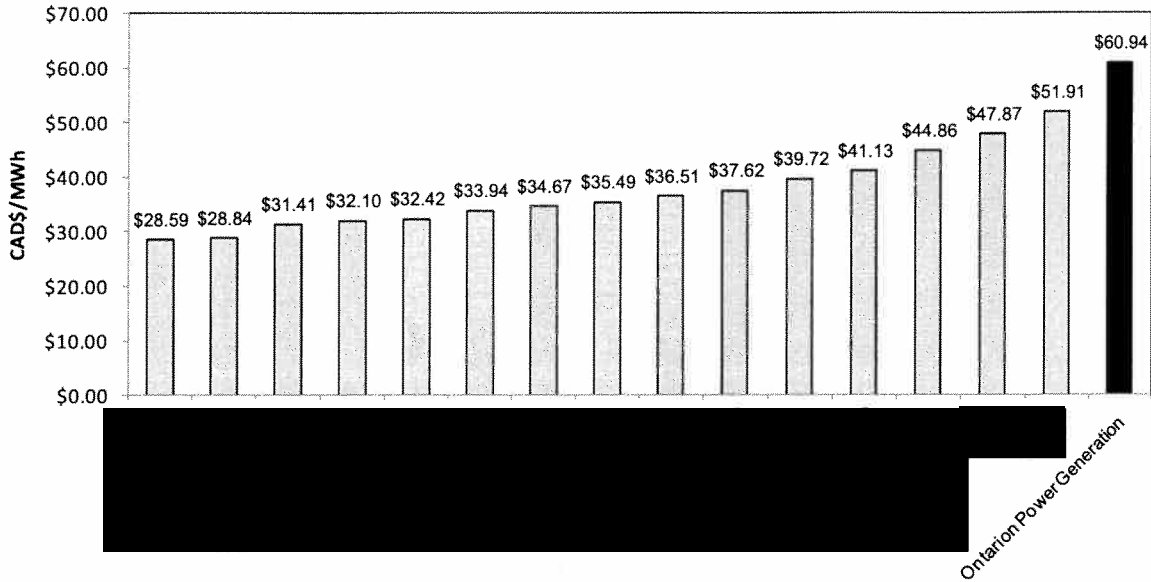
*OPG plant values averaging to 3 Year TGC of $60.94/MWh are shown below:

Unit	2009 3 Year TGC
Darlington	$32.77/MWh
Pickering A	$95.41/MWh
Pickering B	$54.64/MWh

Table 5: Three-Year Total Generating Costs per MWh Rankings

	2005	2006	2007	2008	2009
	3	2	4	4	1
	1	1	1	1	2
	4	4	2	2	3
	2	3	5	5	4
	9	11	10	10	5
	6	5	3	3	6
	7	12	13	13	7
	8	8	8	9	8
	10	10	9	11	9
	11	9	12	12	10
	5	6	7	8	11
	13	7	6	7	12
	14	15	15	15	13
	12	13	14	14	14
	15	14	11	6	15
Ontario Power Generation	16	16	16	16	16

Total Generating Cost is comprised of: (a) Non-Fuel Operating Costs, plus (b) Fuel Costs, plus (c) Capital Costs. Table 6 below shows the relative contribution of these cost components to Total Generating Cost and compares OPG's costs to those of all EUCG operators. As stated in Section 4, OPG Nuclear's advantages in Fuel Costs and Capital Costs are offset by relatively poor financial performance at all three OPG facilities with respect to Non-Fuel Operating Cost. Low Fuel Costs are attributable to the use of CANDU technology while low Capital Costs may reflect OPG's policies regarding capitalization. Additionally, by reviewing individual plant results, Darlington performed by far the best overall, followed by Pickering B and then by Pickering A.

Table 6: EUCG Indicator Results Summary (Operator Level)

EUCG Indicator Results Summary	OPG Average	All EUCG Operators*		Units
		Median	Best Quartile	
Value for Money Performance				
3-Yr. Non-Fuel Operating Costs per MWh	$ 52.67	$ 21.94	$ 18.50	CAD $/MWh
3-Yr. Fuel Costs per MWh	$ 3.16	$ 5.83	$ 5.35	CAD $/MWh
3-Yr. Capital Costs per MW DER	$ 30.09	$ 50.14	$ 38.02	CAD $/MWh
3-Yr. Total Generating Costs per MWh	$ 60.94	$ 35.77	$ 30.68	CAD $/MWh

*See Table 11 in the appendix for list of operators included.

Note: This summary contains the average of all plant results per operator.

7.0 APPENDIX

<u>Acronyms</u>

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
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

<u>Safety and Reliability Definitions</u>

The following definitions are summaries extracted from the *November 2003 WANO PERFORMANCE INDICATOR PROGRAMME REFERENCE MANUAL.*

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. For BWRs and most PWRs, these limiting values are the medians for each parameter, based on data collected in 1993, thereby reflecting recent actual performance levels. For other plants, they reflect challenging targets. 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.

- PWRs with recirculating steam generators and VVERs
  - Steam generator blowdown chloride
  - Steam generator blowdown cation conductivity (only applicable to VVER and PWRs with I-800 steam generator tubes)
  - Steam generator blowdown sulfate
  - Steam generator blowdown sodium

- Final feedwater iron
- Final feedwater copper (not applicable to PWRs with I-800 steam generator tubes)
- Condensate dissolved oxygen (only applicable to PWRs with I-800 steam generator tubes)
- Steam generator molar ratio target range (by reporting the upper and lower range limits (as "from" and "to" values when using molar ratio control)
- Steam generator actual molar ratio (if reporting molar ratio control data)

- PWRs with once through steam generators
    - Final feedwater chloride
    - Final feedwater sulfate
    - Final feedwater sodium
    - Final feedwater iron
    - Final feedwater copper

- Pressurized heavy water reactors (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

- PHWRs on molar ratio control
    - Steam generator blowdown chloride
    - Steam generator blowdown sulfate
    - Final feedwater iron
    - Final feedwater copper
    - Feedwater dissolved oxygen
    - Steam generator molar ratio target range (by reporting the upper and lower range limits (as "from" and "to" values)
    - Steam generator actual molar ratio

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.

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.

Fuel reliability is inferred from fission product activities present in the reactor coolant. Due to design differences, this indicator is calculated differently for different reactor types. 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.

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 or per 1,000,000 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.

Plant capacity factor is defined as the ratio of the net electricity generated, for the time considered, to the energy that could have been generated at continuous full-power operation during the same period. (Note: this is a generic definition as no definition was provided by EUCG).

The **safety system performance indicator** is defined for the many different types of nuclear reactors within the WANO membership. To facilitate better understanding of the indicator and applicable system scope for these different type reactors a separate section has been developed for each reactor type.

Also, because some members have chosen to report all data on a system train basis versus the "standard" overall system approach, special sections have also been developed for those reactor types where train reporting has been chosen. (The resulting indicator values resulting from these methods are essentially the same.)

Each section is written specifically for that reactor type and reporting method. If a member desires to understand how a different member is reporting or wishes to better understand that member's indicator, it should consult the applicable section.

The safety systems monitored by this indicator are the following:

PHWRs

Although the PHWR safety philosophy considers other special safety systems to be paramount to public safety, the following PHWR safety and safety-related systems were chosen to be monitored in order to maintain a consistent international application of the safety system performance indicators:

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

These systems were selected for the safety system performance indicator based on their importance in preventing reactor core damage or extended plant outage. Not every risk important system is monitored. Rather, those that are generally important across the broad nuclear industry are included within the scope of this indicator. 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.)

Except as specifically stated in the definition and reporting guidance, no attempt is made to monitor or give credit in the indicator results for the presence of other systems at a given plant that add diversity to the mitigation or prevention of accidents. For example, no credit is given for additional power sources that add to the reliability of the electrical grid supplying a plant because the purpose of the indicator is to monitor the effectiveness of the plant's response once the grid is lost.

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.

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 setpoint 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 (keff) 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 following definitions are taken from the AP-928 Rev 2 issued November 2007.

Corrective maintenance is any work on a **power block** system, structure, or component (SSC) that has failed or is significantly degraded such that failure is imminent (within its operating

cycle/preventive maintenance interval) and the SSC no longer conforms to or performs its design function. An SSC should be considered failed or significantly degraded if the deficiency is similar to any of the following:

- Is removed from service because of actual or incipient failure
- Significant component degradation that affects system operability – The SSC may be determined operable by engineering assessment, but the degradation is significant and requires immediate corrective action. This normally includes any deficiency that requires a basis for continued operation as defined in NRC Regulatory Issue Summary (RIS) 2005-20, *NRC Inspection Manual*, Part 9900, Technical Guidance.
- Creates the potential for rapidly increasing component degradation (for example, borated water leaks or steam leaks where cutting degradation is possible)
- Releases fluids that create significant exposure or contamination concerns (or has the potential to do so under postulated accident conditions) – Minor leaks that can be controlled and managed by simple drip catch containments would not be included here
- Adversely affects controls or process indications that impair operator ability to operate the plant or that reduce the redundancy of important equipment
- Significant component degradation identified from the conduct of predictive, periodic, or preventive maintenance which, if not resolved, could result in equipment failure or significant additional damage prior to its next scheduled preventive maintenance period

Elective maintenance is any work on **power block equipment** for which identified potential or actual degradation is minor and does not threaten the component's design function or performance criteria. This category of maintenance is intended to be performed in the future, but the nature of the degradation is such that scheduling flexibility exists. Examples are as follows:

- Minor leaks that are simply controlled and that do not justify immediate action to repair
- Minor degradation, identified by predictive, periodic, or planned preventive maintenance activities, that warrants attention to maintain the long-term reliability of the equipment, but that is not expected to result in failure prior to its next scheduled preventive maintenance period
- Other minor plant equipment deficiencies that do not impede plant operation, nuclear or plant reliability, or operator ability to properly respond to normal, off-normal, or accident transients or conditions. Examples are as follows:
  - Damaged or broken local indication gauges that are informational only and that are not required for operator control of systems for normal or emergency response
  - Indications of internal valve leakage that do not hinder system operation or the ability to provide maintenance isolation

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

Power block equipment includes all SSCs required for the safe and reliable operation of the station. It will include all safety-related and balance-of-plant systems and components required for operation, including radioactive waste processing and storage and switchyard equipment maintained by the station. Systems, structures, or components required to maintain federal or state/provincial regulatory compliance should be included in this grouping. It will not include buildings or structures that support station staff, such as offices or storage structures, or the HVAC and support systems focused only on habitability of those structures. This distinction may vary among stations.

Value for Money Definitions

The following definition summaries are taken from the *January 2006 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, mobile equipment, and vehicles should also be included. These costs should be fully burdened with indirect costs, but exclude AFUDC.

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

Generation (Gigawatt Hours)
Per NRC monthly operating report definition for net electrical energy: The gross electrical output of the unit measured at the output terminals of the turbine-generator minus the normal station service loads during the gross hours of the reporting period, expressed in Gigawatt hours (GWh). Negative quantities should not be used.

Design Electrical Rating (DER)
Per Energy Information Administration, the definition for design electrical rating: The nominal net electrical output of a unit, specified by the utility and used for plant design.

Operating Costs ($)
The data provided should reflect the full cost for operating and maintaining the nuclear plant. This should include all costs from the senior nuclear corporate officer down. These costs should reflect the share of payroll taxes and benefits and corporate administrative and general costs applicable to the nuclear plant. Costs that would be applicable if the plant were considered a separate business unit should be included.

Total Generating Costs ($)
The sum of total operating costs and capital costs as above.

Total Operating Costs ($)
The sum of operating costs and fuel costs as above.

Note: Capital costs, fuel costs, operating costs and total generating costs are divided by net generation as above to obtain per MWh results. Non-fuel operating costs and capital costs are also divided by MW DER to obtain 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 Hours)
The number of Site Event Free Day Resets per 10,000 hours worked averaged over 18 months for 2009. Since this is a new metric being piloted; only one year's worth of data was available through INPO at the time the benchmark study was completed.

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. However, the definition may differ slightly due to adaptation resulting from technological differences.

Panels

Table 7: WANO Panel

Operator	Plant	Operator	Plant
Bruce Power	BRUCE NUCLEAR A	Strategic Teaming And Resource Sharing (STARS)	CALLAWAY
	BRUCE NUCLEAR B		COMANCHE PEAK
Constellation	CALVERT CLIFFS		DIABLO CANYON
	GINNA		PALO VERDE
Dominion	KEWAUNEE		SOUTH TEXAS
	MILLSTONE	Tennessee Valley Authority (TVA)	WATTS BAR
	NORTH ANNA	Utilities Service Alliance (USA)	COOK
	SURRY		FORT CALHOUN
Duke Power	CATAWBA		
	MCGUIRE		
	OCONEE		
Entergy	ANO		
	INDIAN POINT		
	WATERFORD		
Exelon	BRAIDWOOD		
	BYRON		
	THREE MILE ISLAND		
FirstEnergy	BEAVER VALLEY		
	DAVID-BESSE		
Florida Power & Light (FPL)	POINT BEACH		
	SEABROOK		
	ST. LUCIE		
	TURKEY POINT		
Hydro Quebec	GENTILLY		
Independents	SAN ONOFRE		
	SEQUOYAH		
	SUMMER		
	WOLF CREEK		
Int'l CANDU	CERNAVODA		
	EMBALSE		
	QINSHAN 3		
	WOLSONG A		
	WOLSONG B		
NB Power	POINT LEPREAU		
Nuclear Management Company (NMC)	PALISADES		
	PRAIRIE ISLAND		
Ontario Power Generation (OPG)	DARLINGTON		
	PICKERING A		
	PICKERING B		
Progress Energy	CRYSTAL RIVER		
	HARRIS		
	ROBINSON		
Public Service Enterprise Group (PSEG)	SALEM UNIT		
Southern Energy	FARLEY		
	VOGTLE		

Table 8: EUCG Panel

Operator	Plant	Operator	Plant
Bruce	BRUCE	Strategic Teaming And Resource Sharing (STARS)	CALLAWAY
Constellation	CALVERT CLIFFS		COMANCHE PEAK
	NINE MILE		DIABLO CANYON
	R.E. GINNA		PALO VERDE
Dominion Resources	KEWAUNEE		SOUTH TEXAS
	MILLSTONE	Tennessee Valley Authority (TVA)	BROWNS FERRY
	NORTH ANNA		SEQUOYAH
	SURRY		WATTS BAR
Duke	CATAWBA	Utilities Service Alliance (USA)	COLUMBIA
	MCGUIRE		COOK
	OCONEE		COOPER
Entergy	ARKANSAS ONE		FERMI
	FITZPATRICK		FORT CALHOUN
	GRAND GULF		SAN ONOFRE
	PALISADES		SUSQUEHANNA
	PILGRIM		WOLF CREEK
	RIVER BEND	Xcel Energy	MONTICELLO
	VERMONT YANKEE		PRAIRIE ISLAND
	WATERFORD		
Exelon	BRAIDWOOD		
	BYRON		
	CLINTON		
	DRESDEN		
	LASALLE		
	LIMERICK		
	OYSTER CREEK		
	PEACH BOTTOM		
	QUAD CITIES		
	THREE MILE ISLAND		
First Energy	BEAVER VALLEY		
	DAVID-BESSE		
	PERRY		
Ontario Power Generation (OPG)	DARLINGTON		
	PICKERING A		
	PICKERING B		
Progress Energy	BRUNSWICK		
	CRYSTAL RIVER		
	HARRIS		
	ROBINSON		
Public Service Enterprise Group (PSEG)	HOPE CREEK		
	SALEM		
South Carolina Power and Gas	SUMMER		
Southern	FARLEY		
	HATCH		
	VOGTLE		

Table 9: COG CANDUs

Operator	Plant
Bruce Power	BRUCE NUCLEAR A
	BRUCE NUCLEAR B
China	QINSHAN 3
CNEA	EMBALSE
Hydro Quebec	GENTILLY
Korea	WOLSONG A
	WOLSONG B
NB Power	POINT LEPREAU
OPG	DARLINGTON
	PICKERING A
	PICKERING B
Romania	CERNAVODA

Table 10: CEA Members

Companies
AltaLink
ATCO Electric
ATCO Power
BC Hydro
Brookfield Renewable Power
ENMAX
EPCOR
FortisAlberta
FortisBC
Horizon Utilities Corp
Hydro One
Hydro Ottawa
HydroQuebec Distribution
Hydro Quebec TransEnergie
Manitoba Hydro
New Brunswick Power
Newfoundland Power
Nova Scotia Power
OPG
SaskPower
The Hydro Group (Newfoundland)
Toronto Hydro
TransAlta

Table 11: INPO Members for Human Performance Error Rate

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

Table 12: NPI Plant Level Performance Summary (North American Panel)

Indicator	NPI Max	Median	Best Quartile	2009 Actuals		
				Pickering A	Pickering B	Darlington
2-Year Industrial Safety Accident Rate (#/200k hours worked)	0.20	0.07	0.03	0.21	0.11	0.06
2-Year Collective Radiation Exposure (man-rem per unit)	80.00	65.63	56.05	78.01	93.10	61.44
Fuel Reliability (microcuries per gram)	0.000500	0.000006	0.000001	0.000041	0.000056	0.000247
2-Year Reactor Trip Rate (# per 7,000 hours)	0.50	0.22	0.00	0.74	0.27	0.00
3-Year Auxiliary Feedwater System Unavailability (#)	0.0200	0.0044	0.0033	0.0063	0.0043	0.0000
3-Year Emergency AC Power Unavailability (#)	0.0250	0.0134	0.0100	0.0106	0.0107	0.0059
3-Year High Pressure Safety Injection Unavailability (#)	0.0200	0.0033	0.0021	0.0011	0.0001	0.0001
2-Year Forced Loss Rate (%)	1.00	1.92	0.80	26.66	14.63	1.13
2-Year Unit Capability Factor (%)	92.0	90.3	91.7	68.0	77.7	90.2
2-Year Chemistry Performance Indicator (Index)	1.01	1.01	1.00	1.09	1.11	1.01
WANO NPI (Index)	Not Applicable	92.1	95.3	61.1	70.2	95.1