NUCLEAR FUEL COSTS

1.0 PURPOSE

This evidence presents the forecast of nuclear fuel costs including the key cost drivers and assumptions.

2.0 OVERVIEW

OPG is requesting approval of nuclear fuel costs of $219.9M in 2017, $222.0M in 2018, $233.1M in 2019, $228.2M in 2020 and $212.7M in 2021. Nuclear fuel costs for 2013-2021 are provided in Ex. F2-5-1 Table 1.

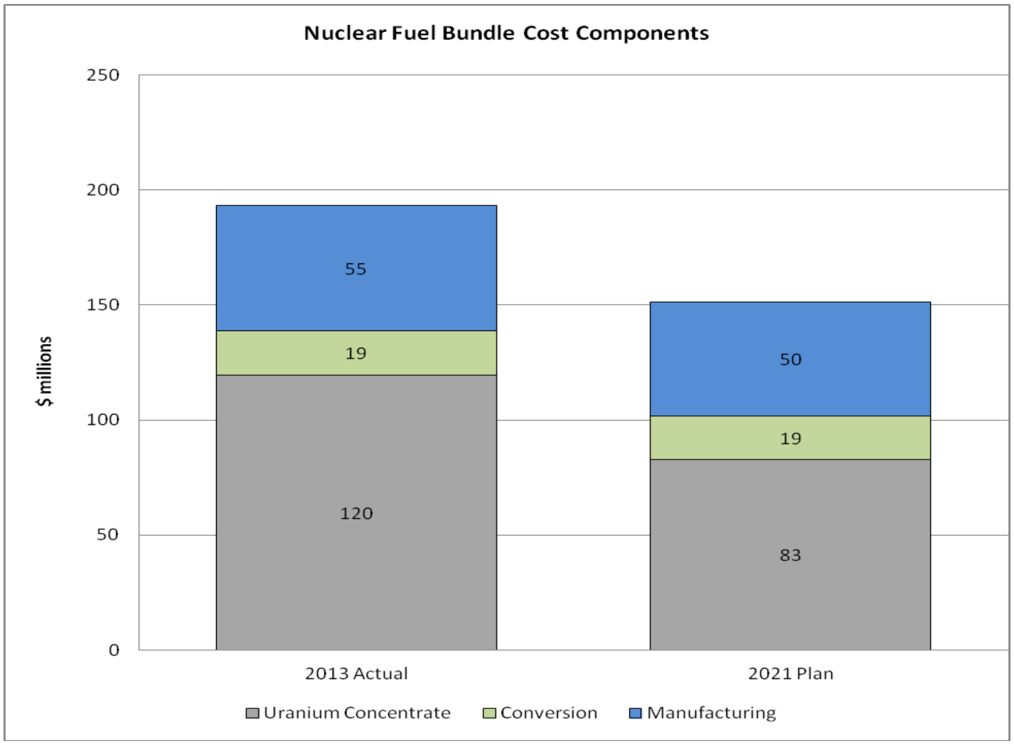
Nuclear fuel costs consist of the following:

- The weighted average cost of manufactured uranium fuel bundles loaded into a reactor (“nuclear fuel bundle cost”).
- Used nuclear fuel storage and disposal, which is discussed in Ex. C2-1-1.
- Fuel oil, which is used to run stand-by generators at OPG’s nuclear stations.

The nuclear fuel bundle cost for OPG’s nuclear facilities is forecast to decrease by $41.8M from 2013 to 2021, reflecting changes in the individual component costs that make up the cost of a fuel bundle (uranium concentrate, uranium conversion and fuel bundle manufacturing costs) and the impact of changes in production on fuel useage (including a requirement for a load of new fuel to be included in the reactor core of Unit 2 prior to start-up after refurbishment). Chart 1 below shows the the amount of change by each component on total fuel bundle cost.

Chart 1

Total Fuel Bundle Cost by Component



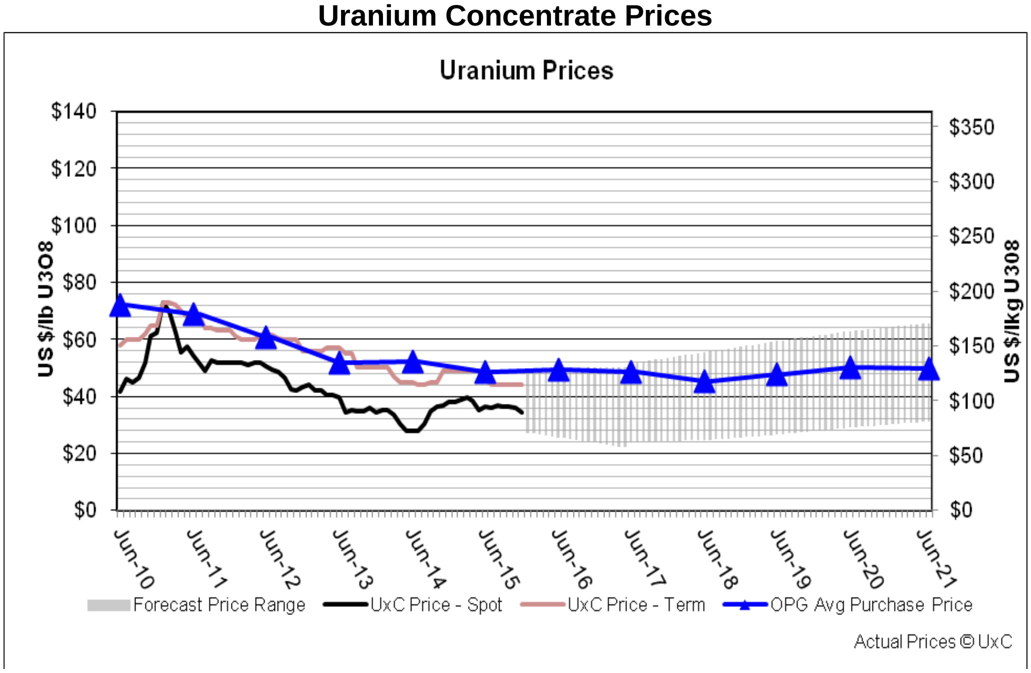
The change in each component is driven by changes in price and volume. Specifically:

- Uranium Concentrate: OPG's average price of uranium concentrate in a fuel bundle loaded into a reactor is forecast to decrease from CDN $162.2/Kilogram Uranium (KgU) to CDN$141.71/KgU) by the end of the test period, as shown in Chart 2 below. The impact of the change in the price of uranium concentrate on total fuel bundle cost from 2013 to 2021 is a decrease of $12M.
- Conversion Services and Nuclear Fuel Bundle Manufacturing Costs: OPG is forecasting an increase in the contract prices paid for uranium conversion services. Under the existing contract, the conversion price will increase from CDN $25.82/KgU in 2013 to a forecast price in 2021 of CDN $32.26/KgU. The nuclear fuel bundle manufacturing contract price is forecast to increase from CDN $72.87/KgU in 2013 to CDN $84.10/KgU in 2021. The impact of the price changes of these two services on total fuel bundle cost from 2013 to 2021 is an increase of $10M.

- Production: Nuclear fuel cost over the test period is impacted by variations in generation which drive fuel useage, including lower generation due to the refurbishment of Darlington units. Generation in 2021 at Darlington is forecast to be 16.6 TWh as compared to actual generation of 25.1 TWh in 2013. Offsetting lower generation is the one time impact of a requirement for a load of new fuel to be included in the reactor core of Unit 2 prior to start-up. One-half of the cost of the new fuel load will be capitalized in 2019 when the new fuel is loaded into the reactor and after the refurbished unit is declared in service in 2020, depreciated over the station's remaining life. This is consistent with the concept that half of the fuel in the fuel channels will be unused at the end of the station life. The other half of the cost of the new fuel load for Unit 2 will be expensed in 2020 when Unit 2 is declared in-service. The impact of changes in production from 2013 to 2021 on total fuel bundle cost is a decrease of $40M.

Chart 2

Uranium Concentrate Prices

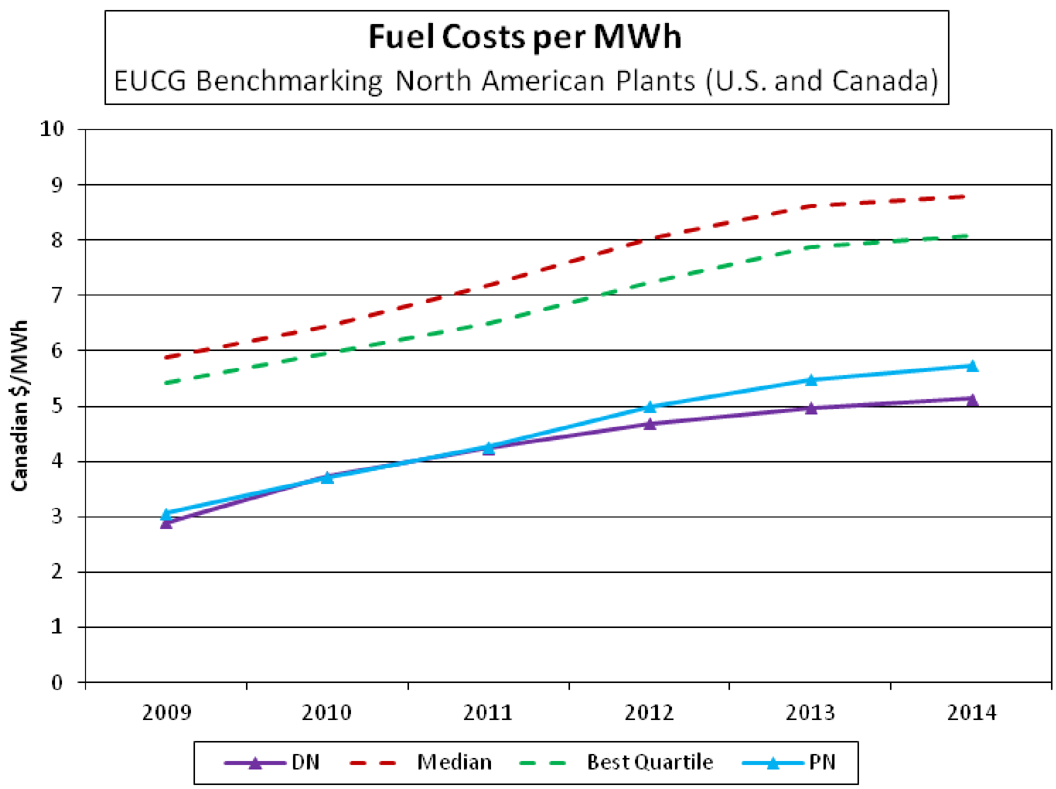


More detailed explanations of nuclear fuel cost variances over the period 2013-2021 are provided in Ex. F2-5-2.

3.0 BENCHMARKING OF NUCLEAR FUEL COSTS

Darlington and Pickering continue to rank among the top North American EUCG plants in terms of fuel costs mainly due to the use of natural uranium by CANDU reactors. The escalation trends in OPG's fuel bundle costs are also consistent with other North American nuclear operators, based on EUCG data (which includes CANDU, PWR ("Pressurized Water Reactors") and BWR ("Boiling Water Reactors") units) as per the 2015 Benchmark Report (Ex. F2-1-1 Attachment 1, p. 75) and per Chart 3 below.

Chart 3



4.0 NUCLEAR FUEL SUPPLY

The following evidence is substantially unchanged from that filed in EB-2013-0321.

4.1 General

OPG's nuclear fuel supply strategies and procurement plans are reviewed and approved by OPG's senior management, including consideration of nuclear fuel quality, because the supply and quality of nuclear fuel are extremely important factors in maintaining nuclear safety.

To ensure high quality nuclear fuel supplies, OPG requires its fuel bundle manufacturer to maintain a quality program which conforms to a rigorous Canadian quality standard (CAN3-Z299.1). This ensures that all phases, including design, procurement, manufacturing and inspection, are appropriately controlled. OPG performs surveillance of all manufacturing processes to monitor conformance to design requirements and to verify conformance to OPG's quality standard requirements. Potential vulnerabilities in the supply chain need to be carefully managed by OPG as only two vendors have been qualified by OPG and licensed by the CNSC to manufacture the fuel bundle designs required by OPG units.

The OPG nuclear fuel supply objectives are to:

- Ensure security of supply: OPG must reduce the risk of its reactors being shut down due to lack of fuel bundles, including the risk that any step in the supply chain is substantially delayed due to lack of materials from an earlier step.
- Minimize cost: OPG seeks to obtain its fuel supply at the lowest cost, consistent with its fuel quality requirements.

OPG's nuclear fuel procurement supply chain is made up of the following three stages:

- The purchase of uranium concentrates.
- The purchase of services for the conversion of uranium concentrate to uranium dioxide pellets.
- The purchase of services for the manufacture of nuclear fuel bundles containing the uranium dioxide pellets.

OPG's fuel procurement planning for the test period begins with a five-year forecast of the required number of manufactured fuel bundles to be loaded into OPG's reactors. OPG's production forecast from the approved Nuclear Generation Plan (see Ex. E2-1-1) determines the forecast of fuel bundles required for fueling, adjusted by forecasts of fuel burn-up and reactor thermal efficiency rates. From this forecast and considering existing inventories, OPG determines its need for purchasing additional manufactured fuel bundles. This determines the need for uranium dioxide conversion services and the need to procure and deliver new supplies of uranium concentrates.

OPG currently purchases each of these components separately and maintains ownership of the uranium at each stage of the nuclear supply chain. OPG does this because its fuel bundle manufacturing service providers are not willing to accept the supply risk associated with the uranium concentrates and uranium conversion services portions of the supply chain. OPG therefore arranges each stage to protect itself from possible supply disruptions.

OPG maintains a 12 month supply of fuel bundles to allow continued fueling in the event of a disruption in the supply of fuel bundles or uranium conversion due to production issues or labour unrest. A three month supply of uranium dioxide is targeted to feed the fuel bundle manufacturing process. In addition, the uranium conversion supplier is also contractually required to maintain an inventory of certified uranium dioxide for OPG's use in the event of a supply interruption at the supplier's facilities. In 2013, OPG reduced its minimum uranium concentrate inventory target to 288,000 KgU, representing a four month supply to feed the production of uranium dioxide. OPG's prior inventory target of 385,000 KgU, or approximately 5.5 months supply, was put into place at a time when there was more uncertainty with respect to the supply of uranium. The target inventory level was reduced based on recommendations from the Longenecker Report (see section 5.0 below).

OPG's projected closing year-end nuclear fuel inventories are expected to reach this target level by the end of 2019. Inventory levels levels in 2016 and 2017 exceed the target due to the spill over effect of lower than budgeted production in 2014 and 2015. Inventory levels exceed target in 2018 because of the need to ensure sufficient quantities of uranium concentrate are available prior to the restart of Darlilngton Unit 2, as there will be a full load of new fuel required in 2019 to load into the reactor core prior to start-up. Nuclear fuel inventories are discussed in Ex. B1-1-1, section 3.2.3.

4.2 Uranium Concentrate Procurement

4.2.1 Objectives

The primary objectives of OPG's uranium concentrate procurement program are to ensure an adequate supply of uranium is available to meet the operational requirements of OPG's nuclear units, while minimizing the price, market and credit risks associated with this supply. In addition, OPG also must ensure quality standards are met. As discussed in section 5.0 below, Longenecker & Associates ("Longnecker"), external consultants, concluded that OPG's uranium procurement program is appropriate and fully inclusive of the various factors that should be considered.

The procurement program has the following requirements:

- **Purchase within pre-established physical coverage limits.** OPG uses a quantitative risk management model to establish long-term physical coverage limits. These limits establish the maximum and minimum percentages of future uranium requirements that can be under contract. The minimum limit ensures security of supply by requiring a certain amount of OPG's future requirements be under contract or in inventory. The maximum limit ensures more regular entry by OPG into the market, thereby encouraging a diversity of suppliers which reduces the impact of individual supply source disruptions.
- **Purchase within pre-established financial coverage limits**. OPG's risk management methodology also establishes financial coverage limits. Financial coverage limits specify the maximum and minimum portion of supply to be under "fixed" price arrangements, expressed as a percentage of OPG's aggregate amount under contract. This mitigates near term cost uncertainty and encourages a diversity of contract pricing mechanisms.

- **Maintain, as market conditions dictate, a strategic target inventory of uranium.** This further mitigates the impact of supply disruptions and ensures continuous reactor operations.
- **Employ competitive and fair procurement practices**. The use of these practices provides value for money. OPG's standard procurement practice is to employ competitive processes where available, using pre-determined evaluation criteria that include quality, security of supply and costs.

OPG completed an internal review of its physical and financial coverage limits in November 2014. Based on this review, no changes were deemed necessary to the existing market risk limit framework for both physical coverage ratios and financial coverage ratios.

4.2.2 Uranium concentrate pricing provisions and fuel contracts

OPG's existing long term contracts for the supply of uranium concentrates contain a mix of pricing provisions, as shown in Chart 4 below. Under contracts with market-related pricing terms, quantities are priced at a market price established at or near the time of delivery. Contracts with fixed or indexed pricing include base prices, set at the time of contract signing, which escalate to the time of delivery by formula or by published, inflation-related, indexes. Combination, or hybrid contracts, provide for a combination of market-related pricing and fixed/indexed pricing. For spot market purchases, OPG generally enters into contracts priced for delivery within three months of contracting.

A summary of OPG's existing fuel contracts are shown in Chart 4 below:

Chart 4

Summary of Existing Fuel Contracts

Contract	Contract Award	Date of First Delivery	Delivery Period	Total Quantity (000 kgU)	Pricing: MR = Market related HYB = combination of MR and Indexed
A	2007 2nd half	2009	9 years	1,154	HYB
B	2010 2nd Q	2015	6 years	577	HYB

Contract	Contract Award	Date of First Delivery	Delivery Period	Total Quantity (000 kgU)	Pricing: MR = Market related HYB = combination of MR and Indexed
C	2013 3rd Q	2015	4 years	336	MR
D	2013 3rd Q	2015	4 years	432	Fixed
E	2014 3rd Q	2016	6 years	385	MR
F	2014 3rd Q	2016	6 years	385	Fixed
G	2015 3rd Q	2017	6 years	260	MR
H	2015 3rd Q	2017	6 years	220	Fixed

OPG ensures a continued presence in the uranium market by making purchases under long-term contracts, short-term spot market contracts, or a combination of both.

In forecasting nuclear fuel costs, OPG models its existing contracts using forecasts of cost escalators, foreign exchange rates, and market price indicators. For its uncontracted uranium requirements, OPG uses a forecast based on industry market participants, specifically the annual average of the Ux Consulting Company's spot forecast and the TradeTech Company spot forecast.

Uncertainty in the start up of new uranium production, the possible liquidation of additional inventories, the uncertainty of worldwide nuclear expansion, fluctuations in exchange rates, and political developments in uranium producing regions are expected to result in price volatility over the test period and account for the wide range of forecast market prices.

4.3 Uranium Conversion Services Procurement

To meet fuel quality requirements, OPG's uranium conversion suppliers must conform to CSA standard CAN3Z299.2-85, Quality Assurance Program. This standard ensures that all phases of production, including procurement, manufacturing and inspection, are appropriately controlled. OPG performs audit and surveillance of the conversion supplier and verifies conformance to the quality standard.

In 2011, OPG negotiated a new agreement for uranium conversion services for the period 2012-2021 inclusive. Under the new agreement, the price is indexed to inflation and is subject to adjustment for cost (or benefit) sharing if actual cost changes go beyond a threshold. OPG's test period forecast assumes no adjustment for cost or benefit sharing.

4.4 Manufactured Fuel Bundles Procurement

OPG currently has a supply contract with General Electric (one of the two domestic CANDU fuel bundle manufacturers) to supply OPG's requirements through 2018. The base price under this contract is subject to future adjustments for inflation and changes in zirconium costs, a key component in fuel bundles. As OPG has not negotiated pricing terms for a fuel bundle contract post 2018, similar escalated pricing as in the current contract was assumed to continue over the forecast period 2019-2021.

5.0 URANIUM PROCUREMENT PROGRAM ASSESSMENT

In its Decision with Reasons in EB-2010-0008, the OEB directed OPG to engage an external consultant to conduct a review of OPG's procurement program to determine whether the company is optimizing its contracting in order to minimize costs to ratepayers.

The review was undertaken by Longenecker, who are consultants with extensive experience in uranium procurement. Longenecker found that OPG's uranium procurements have been undertaken in a professional manner, using evaluation criteria that gives appropriate consideration to diversity of supply and the relative capabilities and performance risks of suppliers, and that it includes an appropriate mix of contracts (spot versus long-term, fixed price versus market-related, etc). They also found that OPG's procurement strategy is prudent in today's market. Longenecker concluded that OPG's uranium procurement program is appropriate and fully inclusive of the various factors that should be considered.

OPG filed the Uranium Procurement Program Assessment Study prepared by Longnecker in EB-2013-0321. In its Decision with Reasons in EB-2013-0321, the OEB accepted the findings in the Longnecker report. The OEB also acknowledged that three of four recommendations made in the report have been implemented. The fourth recommendation, which pertained to “off-market” transactions was not implemented as the recommendation is inconsistent with OPG’s policy and the government’s procurement guidelines to which OPG is subject.

OPG continues to follow the three recommendations made by Longnecker.

Numbers may not add due to rounding.

Table 1
Nuclear Fuel Costs ($M)

Line No.	Description	2013 Actual	2014 Actual	2015 Actual	2016 Budget	2017 Plan	2018 Plan	2019 Plan	2020 Plan	2021 Plan
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
	Uranium:									
1	**Darlington NGS**	107.3	114.6	98.5	112.5	82.6	82.5	82.4	85.5	71.9
2	**Pickering NGS**	86.0	84.2	87.7	86.0	79.9	79.9	79.5	81.8	79.6
3	**Total Fuel Bundle Cost**	193.3	198.8	186.2	198.6	162.6	162.3	161.9	167.3	151.4
4	**Total Fuel Bundle Cost[1] ($/MWh)**	4.32	4.14	4.18	4.24	4.27	4.22	4.15	4.48	4.28
5	**Used Fuel Storage & Disposal[2]**	49.0	53.6	53.1	62.0	53.0	55.2	66.7	56.3	56.5
6	**Fuel Oil**	2.4	2.3	5.1	4.2	4.3	4.4	4.5	4.6	4.7
7	**Total Nuclear Fuel Costs**	244.7	254.8	244.3	264.8	219.9	222.0	233.1	228.2	212.7

Notes:
1 Line 3 divided by nuclear production from Ex. E2-1-1 Table 1.
2 Used Fuel Storage & Disposal is discussed in Ex. C2-1-1.

COMPARISON OF NUCLEAR FUEL COSTS

1.0 PURPOSE

This evidence presents period-over-period comparisons for nuclear fuel bundle costs for 2013-2021 in support of the approvals sought for nuclear fuel costs. Nuclear fuel costs consist of Total Fuel Bundle Cost, Used Fuel Storage and Disposal cost, and Fuel Oil. This exhibit discusses period-over-period changes for Total Fuel Bundle Cost. Used Fuel Storage and Disposal is discussed in Ex. C2-1-1. Comparisons for Fuel Oil are not discussed because the period-over-period changes are not material.

2.0 OVERVIEW

Period-over-period variances are presented in Ex. F2-5-2 Table 1 and are explained below. See Ex. F2-5-1 for a discussion of key drivers associated with nuclear fuel bundle costs.

3.0 PERIOD-OVER-PERIOD CHANGES – TEST YEARS

2017 Plan versus 2016 Budget

The decrease of $36.0M in nuclear fuel bundle cost is due to lower energy production of -$37.3M and higher fuel utilization efficiency of -$1.2M, offset by higher unit prices for new fuel loaded at +$2.4M.

2018 Plan versus 2017 Plan

The decrease of $0.2M in nuclear fuel bundle cost is due to lower unit prices for new fuel loaded at -$1.9M, offset by higher energy production of +$1.3M and lower fuel utilization efficiency of +$0.4M.

2019 Plan versus 2018 Plan

The decrease of $0.5M in nuclear fuel bundle cost is due to lower unit prices for new fuel loaded at -$2.7M and higher fuel utilization efficiency of -$0.1M, offset by higher energy production of +$2.3M.

2020 Plan versus 2019 Plan

The increase of $5.4M in nuclear fuel bundle cost is due to higher unit prices for new fuel loaded at +$1.8M and the one time impact of +$15.3M related to the requirement for a load of new fuel to be included in the reactor core of Unit 2 prior to start-up, offset by lower energy production of -$6.8M and higher fuel utilization efficiency of -$4.9M.

2021 Plan versus 2020 Plan

The decrease of $15.8M in nuclear fuel bundle cost is due to lower energy production of -$9.2M and no repeat of the new fuel load in Unit 2 which occurred in 2020 (-$15.3M), offset by higher unit prices for new fuel loaded at +$3.2M and lower fuel utilization efficiency of +$5.5M.

4.0 PERIOD-OVER-PERIOD CHANGES – BRIDGE YEAR

2016 Budget versus 2015 Actual

The increase of $12.4M in nuclear fuel bundle cost is due to higher energy production of +$10M, higher unit prices for new fuel loaded at +$1.8M and lower fuel utilization efficiency of +$0.6M.

5.0 PERIOD-OVER-PERIOD CHANGES - HISTORICAL YEARS

2015 Actual versus 2015 OEB Approved[1]

The decrease of $15.6M in nuclear fuel bundle cost is due to lower energy production of -$8.7M and lower unit prices for new fuel loaded at -$8.5M, offset by lower fuel utilization efficiency of +$1.6M.

2015 Actual versus 2014 Actual

[1] Fuel Bundle Cost for OEB Approved adjusted to reflect nuclear production forecast adjustments per EB-2013-0321 Ex. N1, Ex. N2 and Decision with Reasons, pp. 39 and 49.

The decrease of $12.7M in nuclear fuel bundle cost is due to lower energy production of -$14.1M offset by higher unit prices for new fuel loaded at +$0.6M and lower fuel utilization efficiency of +$0.8M.

2014 Actual versus 2014 OEB Approved[1]

The decrease of $9.6M in nuclear fuel bundle cost is due to lower energy production of -$4.5M, lower unit prices for new fuel loaded at -$5.4M, offset by lower fuel utilization efficiency of +$0.3M.

2014 Actual versus 2013 Actual

The increase of $5.6M in nuclear fuel bundle cost is due to higher energy production of +$14.1M offset by lower unit prices for new fuel loaded at -$7.3M and higher fuel utilization efficiency of -$1.2M.

2013 Actual versus 2013 Budget

The decrease of $22.6M in nuclear fuel bundle cost is due to lower energy production of -$14.9M, lower unit prices for new fuel loaded at -$7.2M and higher fuel utilization efficiency of -$0.5M.

Table 1
Comparison of Nuclear Fuel Costs ($M)

Line No.	Business Unit	2013 Budget	(c)-(a) Change	2013 Actual	(g)-(c) Change	2014 OEB Approved[1]	(g)-(e) Change	2014 Actual	(k)-(g) Change	2015 OEB Approved[1]	(k)-(i) Change	2015 Actual
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)
	Uranium:											
1	**Darlington NGS**	119.7	(12.4)	107.3	7.3	118.1	(3.5)	114.6	(16.1)	109.0	(10.5)	98.5
2	**Pickering NGS**	96.2	(10.2)	86.0	(1.8)	90.3	(6.1)	84.2	3.5	92.8	(5.1)	87.7
3	**Total Fuel Bundle Cost**	215.9	(22.6)	193.3	5.6	208.4	(9.6)	198.8	(12.7)	201.8	(15.6)	186.2
4	**Used Fuel Storage & Disposal[2]**	52.7	(3.7)	49.0	4.6	56.1	(2.5)	53.6	(0.5)	56.7	(3.6)	53.1
5	**Fuel Oil**	4.0	(1.6)	2.4	(0.0)	4.1	(1.7)	2.3	2.8	4.2	0.9	5.1
6	**Total Nuclear Fuel Costs**	272.6	(27.9)	244.7	10.1	268.6	(13.8)	254.8	(10.4)	262.6	(18.3)	244.3

Line No.	Business Unit	2015 Actual	(c)-(a) Change	2016 Budget	(e)-(c) Change	2017 Plan	(g)-(e) Change	2018 Plan	(i)-(g) Change	2019 Plan	(k)-(i) Change	2020 Plan
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)
	Uranium:											
7	**Darlington NGS**	98.5	14.1	112.5	(29.9)	82.6	(0.1)	82.5	(0.1)	82.4	3.2	85.5
8	**Pickering NGS**	87.7	(1.7)	86.0	(6.1)	79.9	(0.1)	79.9	(0.3)	79.5	2.2	81.8
9	**Total Fuel Bundle Cost**	186.2	12.4	198.6	(36.0)	162.6	(0.2)	162.3	(0.5)	161.9	5.4	167.3
10	**Used Fuel Storage & Disposal[2]**	53.1	8.9	62.0	(8.9)	53.0	2.2	55.2	11.5	66.7	(10.4)	56.3
11	**Fuel Oil**	5.1	(0.9)	4.2	0.1	4.3	0.1	4.4	0.1	4.5	0.1	4.6
12	**Total Nuclear Fuel Costs**	244.3	20.4	264.8	(44.8)	219.9	2.1	222.0	11.1	233.1	(4.9)	228.2

Line No.	Business Unit	2020 Plan	(c)-(a) Change	2021 Plan
		(a)	(b)	(c)
	Uranium:			
13	**Darlington NGS**	85.5	(13.7)	71.9
14	**Pickering NGS**	81.8	(2.2)	79.6
15	**Total Fuel Bundle Cost**	167.3	(15.8)	151.4
16	**Used Fuel Storage & Disposal[2]**	56.3	0.2	56.5
17	**Fuel Oil**	4.6	0.1	4.7
18	**Total Nuclear Fuel Costs**	228.2	(15.5)	212.7

Notes:
1 Fuel Bundle Cost on lines 1, 2 and 3 adjusted to reflect nuclear production forecast adjustments per EB-2013-0321 Ex. N1, Ex. N2 and Decision with Reasons, pp. 39 and 49.
2 2013 Actual, 2014 Actual, 2015 Actual, 2016 Budget, 2017 Plan, 2018 Plan, 2019 Plan, 2020 Plan, and 2021 Plan from Ex. C2-1-1 Table 2, line 2. Used Fuel Storage & Disposal is discussed in Ex. C2-1-1.