NUCLEAR FUEL COSTS

1.0 PURPOSE

This evidence describes OPG’s nuclear fuel supply, sets out the forecast of nuclear fuel costs and identifies key cost drivers and assumptions.

2.0 OVERVIEW

The test period forecast for OM&A associated with nuclear fuel costs is $235.6M for 2011 and $261.7M for 2012, as set out in Ex. F2-T5-S1 Table 1. These costs form part of the requested nuclear revenue requirement.

This evidence also supports approvals related to the Nuclear Fuel Cost Variance Account which is described in Ex. H1-T1-S1.

Section 3.0 of this exhibit describes OPG’s fuel supply objectives, strategies and processes and section 4.0 sets out the cost forecast for the test period, including an analysis of underlying trends affecting uranium pricing.

3.0 NUCLEAR FUEL SUPPLY

3.1 General

The accountability for developing supply strategies, executing procurement processes and administering nuclear fuel supply contracts rests with the Nuclear Supply Chain. OPG’s nuclear fuel supply strategy is reviewed and approved by OPG senior management.

The nuclear fuel supply objectives and strategies are:

- High Quality: Fuel quality is assured by sourcing from suppliers that conform to the various Canadian Standards Association CAN3-Z299 quality standards. Supplier quality assurance program conformance is verified by OPG through source surveillance and audit.
• Security of Supply: OPG must ensure that its reactors are not shut down due to lack of fuel, and in that respect must ensure that each step in the supply chain is not substantially delayed due to lack of materials.

• Cost: OPG seeks to obtain supply at the lowest cost consistent with the above objectives.

OPG’s nuclear fuel procurement strategies take into account new fuel requirements, existing inventories, existing supply arrangements and fuel supply market conditions.

OPG’s standard procurement practice for nuclear fuel is to issue a request for proposals to a pre-determined group of suppliers, and to then evaluate proposals against pre-determined evaluation criteria that include quality, security of supply and costs. However, OPG may also review and accept unsolicited proposals on a case-by-case basis.

OPG’s nuclear fuel supply chain is made up of the following stages:

• The purchase of uranium concentrate
• The purchase of services for the conversion of uranium concentrates to uranium dioxide
• The purchase of services for the manufacture of fuel bundles containing the uranium dioxide

OPG currently purchases each of these components separately and maintains ownership of the uranium throughout the supply chain. Nuclear fuel inventories are discussed at Ex. B1-T1-S1, section 3.2.3.

The CANDU fuel bundle is an integral assembly of hermetically sealed, zirconium clad, cylindrical fuel elements containing ceramic uranium dioxide pellets. Each Pickering reactor uses fuel bundles that have a 28-element configuration. Each Pickering A reactor (Units 1 and 4) has 390 fuel channels containing 12 fuel bundles each (4,680 bundles per reactor). Each Pickering B reactor (Units 5 through 8) has 380 fuel channels containing 12 fuel bundles each (4,560 bundles per reactor). Each Darlington reactor uses fuel bundles that have a 37-element configuration. Each Darlington reactor has 480 fuel channels containing 13 fuel bundles each (6,240 bundles per reactor).
3.2 Fuel Planning

OPG’s fuel procurement planning begins with a forecast of fuel bundle reactor loading requirements. The quantity of fuel bundles required for normal fueling is determined by converting OPG’s forecast of electrical energy production, as referenced at Ex. E2-T1-S1, into a forecast of fuel bundles required for fueling (“usage”) using forecasts of fuel burn-up and reactor thermal efficiency rates (“fuel utilization efficiency”).

OPG maintains inventories at each stage of the nuclear fuel supply chain. An inventory of fuel bundles equivalent to 12 months of expected forward usage is maintained to allow continued fueling in the event of a disruption in the supply of fuel bundles or uranium conversion. A working inventory of uranium dioxide is maintained to feed the fuel manufacturing process and an inventory of uranium concentrates and recycled uranium dioxide scrap from the manufacturing process is maintained to feed the production of uranium dioxide.

From the forecast of fuel bundle requirements, and with consideration of existing inventories, OPG can then determine its need for delivery of new manufactured fuel bundles, which in turn determines the need for uranium dioxide conversion services and then the need to procure and deliver new supplies of uranium concentrates.

The annual purchase quantities required to meet expected usage and inventory requirements over the 2010 - 2012 period are shown in Chart 1:

**Chart 1**

**Annual Purchase Requirements for Usage and Inventory**

<table>
<thead>
<tr>
<th>Requirements (000's kgU)</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium Concentrates</td>
<td>720</td>
<td>786</td>
<td>813</td>
<td>2,319</td>
</tr>
<tr>
<td>Uranium Conversion</td>
<td>752</td>
<td>816</td>
<td>847</td>
<td>2,415</td>
</tr>
<tr>
<td>28-element Fuel Bundles</td>
<td>362</td>
<td>373</td>
<td>290</td>
<td>1,025</td>
</tr>
<tr>
<td>37-element Fuel Bundles</td>
<td>391</td>
<td>380</td>
<td>508</td>
<td>1,279</td>
</tr>
</tbody>
</table>
3.3 Fuel Bundle Manufacturing

A key objective in fuel bundle manufacturing is to ensure high quality. An improperly manufactured fuel bundle is at risk of failing within a reactor which would create additional costs to locate and remove the defective fuel bundle as well as to purify and decontaminate reactor systems. This could also potentially lead to reactor shutdown and an increased radiological risk. As such, OPG requires the fuel bundle manufacturer to maintain a quality program which conforms to the Canadian CAN3-Z299.1 to ensure that all phases, including design, procurement, manufacturing and inspection are appropriately controlled. OPG performs surveillance of all manufacturing processes and verifies conformance to quality standard CAN3-Z299.1.

OPG currently has a supply contract with one of the two domestic CANDU fuel bundle manufacturing suppliers which covers requirements through the test period. Most other countries using CANDU reactors have purchased or developed their own fuel bundle manufacturing capabilities. However these off-shore facilities are not qualified by OPG nor do they have capacity available to produce the 28-element and 37-element fuel designs required for OPG reactors. OPG’s supplier has a well developed quality program and OPG has not had a manufacturing-related defect from this supplier in over 16 years.

Pricing under this contract is volume dependant and indexed to such factors as inflation and foreign exchange rates.

3.4 Uranium Conversion

The supplier’s processes must conform to CAN3-Z299.2 to ensure that all phases, including procurement, manufacturing, and inspection, are appropriately controlled. OPG performs surveillance of the conversion process and verifies conformance to the quality standard.

OPG has a supply contract with the sole domestic supplier of uranium conversion services, which covers requirements through 2011. OPG expects that its new agreement for conversion services, beginning in 2012, will incorporate similar pricing as the existing agreement. OPG generally maintains a two to three month uranium dioxide working
inventory and the supplier is also contractually required to maintain an inventory of certified uranium dioxide for OPG's use in the event of a supply interruption. Pricing under this contract is volume dependant and indexed to inflation.

3.5 Uranium Concentrates

3.5.1 Overview

OPG’s strategy for ensuring a supply of uranium concentrates is to maintain a combination of supply contracts and inventory which provide a minimum of 100 per cent of delivery requirements for two years and a declining proportion of delivery requirements for ten years.

OPG maintains a portfolio of uranium concentrates supply contract arrangements, diversified by source, contract term, and pricing mechanism. This diversity provides supply security, by ensuring that a supply disruption from any single supplier would not impact OPG’s entire supply. Portfolio diversity also reduces cost volatility.

OPG’s uranium concentrates requirements of 2,319,000 kgU are expected to be met over 2010 - 2012 through deliveries of 1,712,000 kgU under four existing contracts with three suppliers (74 per cent), the drawdown of 286,000 kgU of existing inventory (12 per cent), and new purchases of 321,000 kgU (14 per cent). New purchases will be made under long-term contracts, short-term spot market contracts, or a combination of both.

OPG’s existing long term contracts for the supply of uranium concentrates contain a mix of pricing provisions. Under contracts with market-related pricing terms, quantities are priced at market price, established at or near the time of delivery. Contracts with indexed pricing include base prices, set at the time of contract signing, but which escalate to the time of delivery by formula or by published, inflation-related, indexes. The quantities of contract deliveries under the existing contracts are shown by year and by pricing category (market-related and indexed pricing) in Chart 2 below:
Chart 2
Existing Contracts by Pricing Category

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Related (000’s kgU)</td>
<td>346</td>
<td>354</td>
<td>378</td>
<td>1,078</td>
</tr>
<tr>
<td>Indexed (000’s kgU)</td>
<td>231</td>
<td>262</td>
<td>141</td>
<td>634</td>
</tr>
<tr>
<td>Total</td>
<td>577</td>
<td>616</td>
<td>519</td>
<td>1,712</td>
</tr>
</tbody>
</table>

The 321,000 kgU of new purchases (i.e., either under long-term or short-term spot market contracts) is priced at market prices forecast for 2010, 2011, and 2012.

3.5.2 Market Conditions

Starting in 2003, demand for uranium began to increase in response to a number of factors, including: supply disruption events which highlighted the production risks (e.g., floods in Saskatchewan and Australian mines and a fire at an Australian mill), a renaissance of nuclear programs worldwide, particularly in Asia, and recognition of the limits to inventory reductions. These factors stimulated increases in the price of uranium and, as the price continued to rise, encouraged the entry of non-traditional market participants, such as investment funds. Uranium spot market prices peaked in June 2007 at US$136 per pound. Term prices, which are the starting prices for indexed price contracts, increased in parallel with spot prices through the first quarter of 2007, reaching a plateau of US$95 per pound. The majority of worldwide uranium purchases are provided under term contracts. The remainder is traded on the spot market, defined as having delivery within one year.

Since this peak, spot prices declined through 2008 and 2009, initially, due to a lack of utility demand and the credit crisis which forced the sale of investor-held uranium, and most recently, due to soft utility demand and a higher than planned amount of production available for sale. Term prices declined as well but not as low as spot prices, reflecting the longer-term supply/demand market fundamentals and the expected cost of new production. On the supply side, the price run-up initially stimulated significant exploration, investment in mine expansion and new uranium mining projects around the world. Recently, the drop in uranium...
prices and the credit crisis (i.e., reduced access to project funding) have meant that marginal
mining projects have been dropped or deferred.

Historical spot market prices and term prices are shown in Figure 1.0.

**Figure 1.0**

Uranium Price Indicators

Based on industry forecasts, spot and term prices in the range of US$45 to US$80 per pound
are expected over the test period. OPG used a mid price forecast of US$48 per pound in
2010 rising to US$61 per pound in 2012 in forecasting fuel costs. However, uncertainty in the
schedules for new uranium production, liquidation of additional inventories, the pace of
worldwide nuclear expansion, and political developments in uranium producing regions are
expected to result in price volatility over the test period and account for a wide range of
potential market prices.
4.0 NUCLEAR FUEL COST FORECAST

The nuclear fuel cost forecast for the calendar years 2011 and 2012 is shown in Ex. F2-T5-S1 Table 1 along with comparable figures for 2008, 2009 and 2010. The nuclear fuel costs as shown in Ex. F2-T5-S1 Table 1 represent the total cost of each finished fuel bundle in aggregate as it is loaded into a reactor.

The total cost of a finished fuel bundle as it is loaded into a reactor includes the cost of each of the three components (i.e., uranium concentrate, uranium conversion, and fuel bundle manufacturing). The relative weighting of the cost of the uranium concentrate to the total cost of the finished fuel bundle is expected to vary over time reflecting the underlying price volatility of uranium concentrates as discussed in section 3.5.2 above. This price volatility adds a great deal of uncertainty to forecasting future nuclear fuel costs. Given the expected volatility, OPG is proposing to continue the Nuclear Fuel Cost Variance Account. Over 2008 and 2009, uranium market prices were lower than those forecast by OPG in EB-2007-0905, resulting in a credit in the Nuclear Fuel Cost Variance Account (see Ex. H1 T1 S1 Table 1). OPG is forecasting a debit amount for 2010, such that overall there will be a net debit balance in this account owing to OPG from ratepayers for the period 2008 - 2010.

Exhibit F2-T5-S1 Table 1 also includes costs related to nuclear used fuel management services as discussed at Ex. C2-T1-S2, and fuel oil which is used to run stand-by generators.

As shown in Ex. F2-T5-S1 Table 1, OPG’s nuclear fuel costs are trending higher over the period 2007 - 2012, despite uranium market (spot and term) prices having leveled off after spiking in 2007 (Figure 1.0). This disconnect between the trend in uranium market prices and the trend in nuclear fuel costs is primarily a reflection of the timing of OPG’s negotiation of uranium concentrate contract prices, the expiry of previously negotiated supply contracts, fuel inventory management, and inventory accounting.

- Timing of OPG contract negotiations: There is a time lag between the time when uranium concentrate indexed contracts are negotiated (which reflect market conditions at the time of negotiation) and the time when the uranium concentrate is delivered into OPG’s
inventory. OPG’s indexed priced contracts have base prices, set at the time of contract negotiation, which escalate to the time of delivery by formula or by published, inflation-related, indexes. Hence prices at time of delivery under such indexed price contracts do not reflect market prices at time of delivery, but rather market prices at the time the contract was entered into, plus escalation. For example, prices for indexed contracts negotiated in 2006 that are delivered in 2011 will reflect market prices in 2006, plus escalation, not 2011 spot or term market prices.

Chart 3 shows a summary of existing uranium concentrate supply contracts.

### Chart 3
Summary of Existing Fuel Contracts (as of Dec 31, 2009)

<table>
<thead>
<tr>
<th>Contract</th>
<th>Contract Negotiation</th>
<th>Date of First Delivery</th>
<th>Delivery Period</th>
<th>Total Quantity (000 kgU)</th>
<th>Pricing:</th>
<th>MR = Market related</th>
<th>COMB = combination of MR and Indexed</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2006 1st half</td>
<td>2007</td>
<td>7 years</td>
<td>1,462</td>
<td>MR</td>
<td>MR</td>
<td>COMB</td>
</tr>
<tr>
<td>B</td>
<td>2006 1st half</td>
<td>2010</td>
<td>6 years</td>
<td>1,154</td>
<td>COMB</td>
<td>COMB</td>
<td>COMB</td>
</tr>
<tr>
<td>C</td>
<td>2006 1st half</td>
<td>2011</td>
<td>5 years</td>
<td>385</td>
<td>COMB</td>
<td>COMB</td>
<td>COMB</td>
</tr>
<tr>
<td>D</td>
<td>2007 2nd half</td>
<td>2009</td>
<td>9 years</td>
<td>1,154</td>
<td>COMB</td>
<td>COMB</td>
<td>COMB</td>
</tr>
</tbody>
</table>

- Expiry of Existing Contracts. Fuel inventory during the period 2010 - 2012 includes uranium delivered prior to 2010 under contracts entered into by OPG during periods of lower uranium prices. While deliveries under these contracts will terminate prior to the test period, these deliveries being in inventory will beneficially impact nuclear fuel costs during the test period.

- Fuel Inventory Management: OPG maintains inventories at each stage of the nuclear fuel supply chain to ensure that supply disruptions do not impact on generation capability. OPG must ensure that its reactors are not shut down due to lack of fuel, and in that respect must ensure that each step in the supply chain is not substantially delayed due to lack of materials. As noted earlier, OPG’s strategy for ensuring an available supply of uranium concentrates is to maintain a combination of supply contracts and inventory which provide a minimum of 100 per cent of delivery requirements for two years and a
declining proportion of delivery requirements for ten years. For purposes of inventory management, OPG must regularly enter the uranium market for a portion of its supply needs regardless of prevailing uranium market prices.

- Average Cost Accounting: OPG uses average cost methodology for inventory accounting, which tends to smooth the impact of uranium concentrate price changes on nuclear fuel costs. There are lags between the time when uranium concentrate is delivered into OPG inventory, converted to uranium dioxide, placed into fuel bundles and loaded into a reactor. With average cost accounting, the price of uranium concentrate within a manufactured fuel bundle will lag changes in uranium market prices, e.g., average fuel costs may increase in a period when the market price of the uranium concentrate input is decreasing.

Attachment 1 shows a visual relationship between uranium concentrate market prices, OPG’s contract prices at delivery and fuel bundle prices in inventory.

The key cost drivers impacting the year-over-year variances in nuclear fuel costs as shown in Ex. F2-T5-S1 Table 1 are:

- Uranium concentrate price changes under market priced and indexed contracts
- Escalation of uranium conversion service and fuel bundle manufacturing contract prices at general inflation rates
- Changes in the level of OPG energy production
- Changes in fuel utilization efficiency

Explanations of nuclear fuel cost variances over the period 2007 - 2012 are more fully described at Ex. F2-T5-S2.
LIST OF ATTACHMENTS

1

2

3  Attachment 1: Uranium Market Prices, Uranium Contract Prices and Fuel Costs
Note: OPG Average Purchase Price (US $/lb) relates to purchases within a given year.