ONTARIO POWER GENERATION

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Uranium Market Risk Limits

Internal Review

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Uranium Market Risk Limits

Internal Review and Recommendations

1. Executive Summary

OPG has an annual uranium fuel U_3O_8 requirement of approximately 1.5 Mlbs. to support the company's nuclear generation. To mitigate the risks of supply disruption and price volatility, OPG has developed uranium procurement policies and practices. The initial study conducted in September 2012 was a result of the recommendations contained in an evaluation submitted by the external consultant, Longenecker and Associates, who advised upon the regular review of inventory levels and risk limits – this report is the fourth in a series intended to reassess OPG's procurement policies. The primary goal of the 2016 review was to determine if OPG's policies for uranium procurement were appropriate. The review resulted in a minor update to the financial coverage ratio, given the downward pressure on uranium prices at that time.

This document re-examines the limits and exception reporting policies, consistent with the recommendations in the previous report, in light of the industry trends that have developed over the last two years.

The Credit and Market Risk (CMR) group's recommendations from this updated review are:

- Maintain the current Market Risk Limit framework for Physical Coverage Ratios.
- Maintain the Financial Coverage Ratios (i.e. percentage of fixed priced volume).
- Maintain the current exception reporting structure.
- Review risk limits every two years.

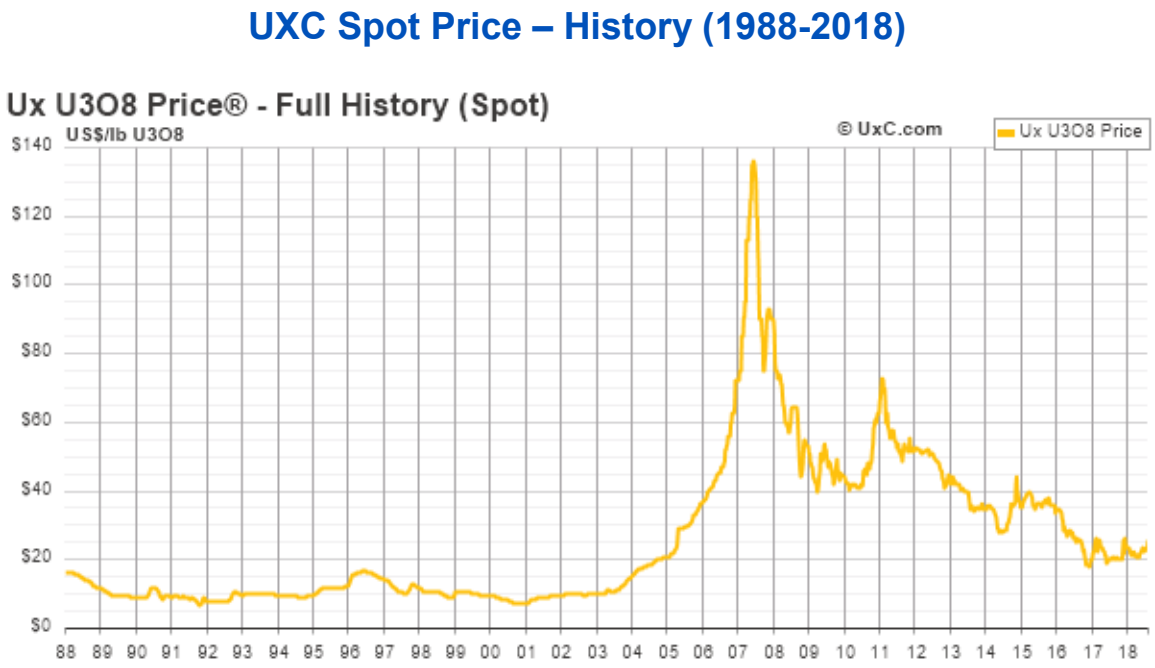
2. Scope of Review

2.1 Overview

The objective of this study was to evaluate whether the Market Risk Limits that OPG have for purchasing uranium, as currently mandated (see Appendix A), are appropriate or require any adjustments. This document reviews the current industry practices and trends in the uranium market and OPG's exception reporting since the last review was done in 2016.

Uranium prices have fluctuated widely since 2005 after remaining relatively low (under $20/lb.) for an extended period of time. Prices increased dramatically beginning in 2005 (see Figure 1) to over $140/lb. in 2008. The financial crisis of 2008-09 brought uranium prices back down to $40/lb. by 2010. Over the last 5 years, prices have continued to drift downwards. This price drop has been further stimulated by the aftermath of the 2011 Fukushima accident, as politically-inspired constraints on nuclear development have become increasingly popular. Since 2016, prices had dropped to a 15-year low – inflation adjusted. However, since March of this year, prices have begun to recover, with spot prices approaching US$28/lb.

Figure 1 UXC Spot Price



UxC Hstorical Data September, 2018

2.2 Market Risk Limits

OPG currently has an annual uranium fuel requirement of approximately 1.5 Mlbs. Nuclear is the largest component of OPG's overall generation at approximately 40 TWhs per year.

OPG has exposure to the supply and price of uranium and thus has a significant risk to operations. There are numerous external factors that can impact the supply and price of uranium. Therefore, Market Risk Limits have been implemented to hedge some of the risk related to market prices and align with industry practices. Appendix A – Current Risk Limits, outlines both the rationale for establishing limits and the current limits that govern OPG's procurement program in detail.

In general, there are two types of risk limits, Physical Coverage Limits and Financial Coverage Limits (defined in Appendix A). For each type of limit, there are 10 yearly limits (the current year and forward 9 years).

The issue to address is whether OPG's Market Risk Limits are appropriate in light of current industry practices and OPG specific needs. CMR has reviewed a number of industry studies (see Resources Section) to develop the conclusions found in this report.

2.3 Exception Reporting

Current Financial and Physical Coverage Exception Structure

Metric	Relative to Min/Max Limit
Target	Within Min/Max*
Warning	Within 10% of Min/Max
Exception	Greater than 10% of Min/Max

*As currently defined; see Table A3 and A4.

The issue to address is whether OPG's exception reporting is appropriate given current industry practices and OPG specific needs. CMR has also reviewed the level of exceptions reported since Q1/17 and has provided recommendations.

3. Review of Market Risk Limits

3.1 Physical Limits

The Physical Risk Limits were developed to ensure security of supply of uranium for the current year and future years by requiring firm contracts for a certain percentage of required future generation. There are Physical Risk Limits for 10 years, the current year and forward 9 years. These limits are structured on a declining scale, i.e. a greater proportion of current year and near term expected needs are required to be contracted and less contracted further outward (Table A3).

The nuclear industry has faced a number of challenges over the last number of years. The Fukushima accident had far reaching consequences on nuclear generation resulting in slowdowns in development plans and a change in public perception towards nuclear power. Some of the challenges facing the nuclear industry include:

- Reactors being permanently shut down in the US due to competition from lower cost or highly subsidized generation technologies such as wind and solar.
- The trend of deregulation of power prices, coupled with subsidized green technologies, does not bode well with the construction of new nuclear reactors which are capital intensive and provide returns over a longer period of time.
- A number of current operating reactors are facing earlier closures than previously anticipated, especially those in Europe due to increasing public pressure.
- Public and political opinions have become more vocal in favor of Green Energy which has led to a reduction of investment.
- The price of uranium (U3O8) has fallen as a result of oversupply from mines in Canada, Kazakhstan and Australia, coupled with stagnant demand in many markets.

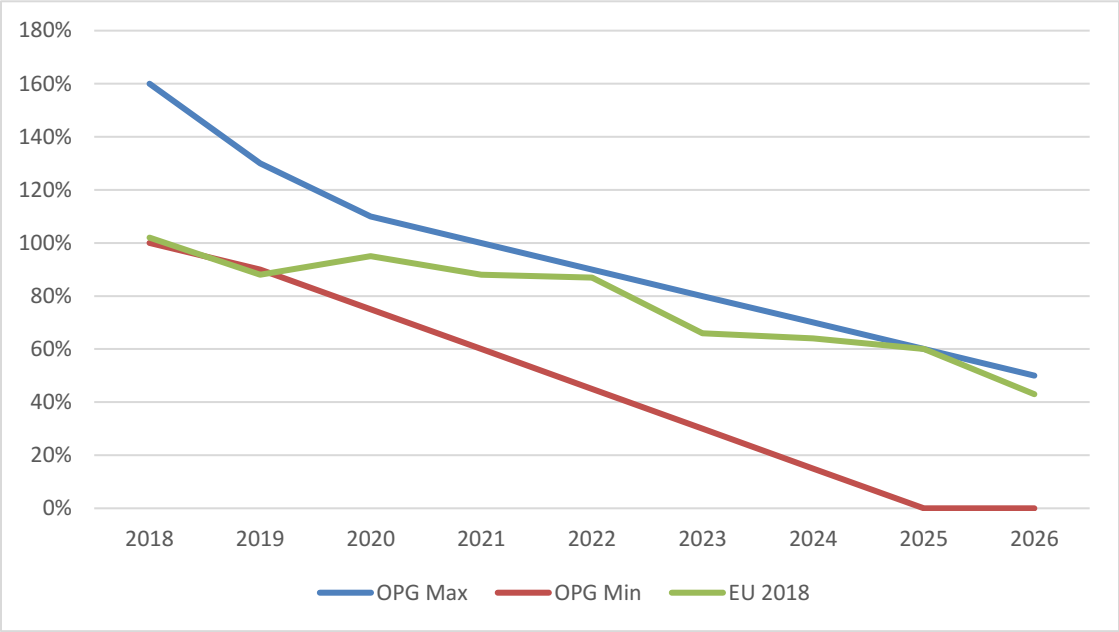
The World Nuclear Association (WNA) reported that in September 2018, globally, there were 453 operable reactors with another 55 under construction. New plants coming online have been largely balanced by old plants being retired. Over 1996-2016, 80 reactors were retired as 96 started operation. The 2017 WNA Market Report reference scenario has 140 reactors closing by 2035, and 224 new ones coming on line. Should this outlook materialize, nuclear generation would grow by 25% by 2035.

In summary, recent events have slowed the projected use of nuclear generation, but growth in developing markets is still anticipated out to 2035 and beyond.

3.1.1 European Utilities Uranium Hedging

A review of the hedging practices of European nuclear generators as outlined in the Euratom Supply Agency Annual Report 2017 (released June 2018) presented the following picture:

EU Uranium Coverage Rate vs. OPG Physical Coverage Limits

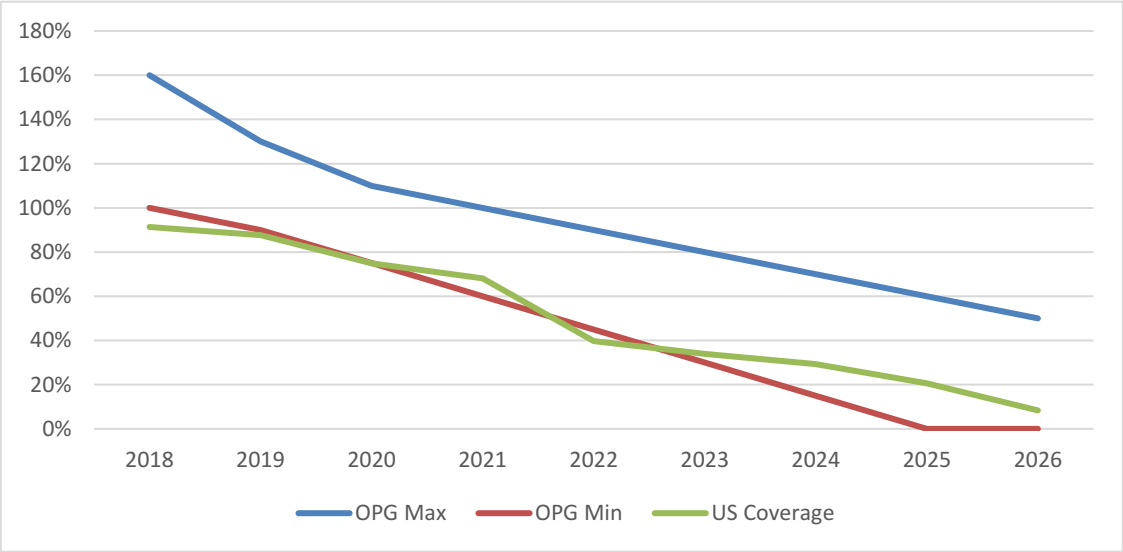


In comparing OPG's practices (i.e. physical hedging limits) to the EU practices, OPG's maximum limits closely match the EU's actual contracted purchases.

3.1.2 United States Utilities Uranium Hedging

A review of the hedging practices of United States nuclear generators as outlined in the US Department of Energy's 2017 (released May 2018) Uranium Marketing Annual Report presented the following picture:

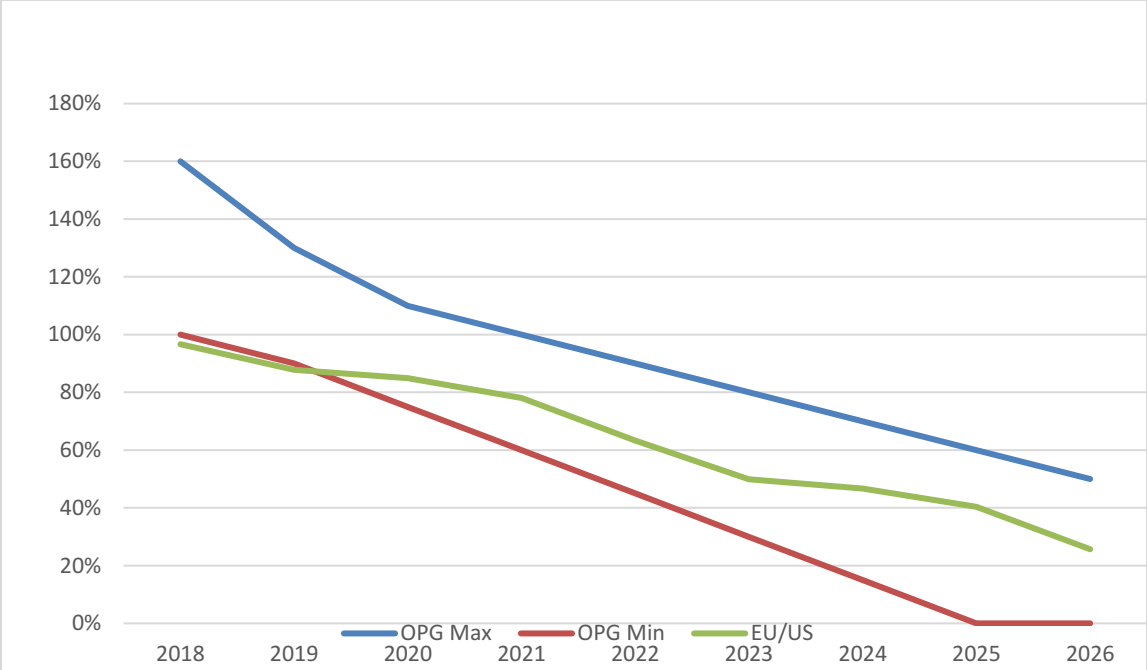
United States Uranium Coverage Rate vs. OPG Physical Coverage Limits



In comparing OPG's practices (i.e. physical hedging limits) to the U.S. practices, OPG's minimum limits closely match the US's actual contracted purchases.

Averaging the EU and U.S. contracted forward purchases and comparing them to OPG's minimum and maximum limits presents the following:

Average (EU and US) Uranium Coverage Rate vs. OPG Physical Coverage Limits



Overall, OPG's Physical Coverage Limits align well with the observed practices of the EU and US nuclear operators.

Recommendations

R1 – It is recommended that the lower (minimum) bound and upper (maximum) bound of OPG's uranium forward purchases (Physical Coverage Limits) remain as currently established.

3.2 Financial Limits

The purpose of Financial Coverage Limits is to optimize the mix between fixed price and variable price supply contracts and ultimately minimize fuel cost variability. When OPG buys under a fixed price contract, there is protection against upward movements in the market price, but a risk that the fixed price will be higher than market prices at the time of delivery. However, the opposite is true when purchasing under a market priced contract.

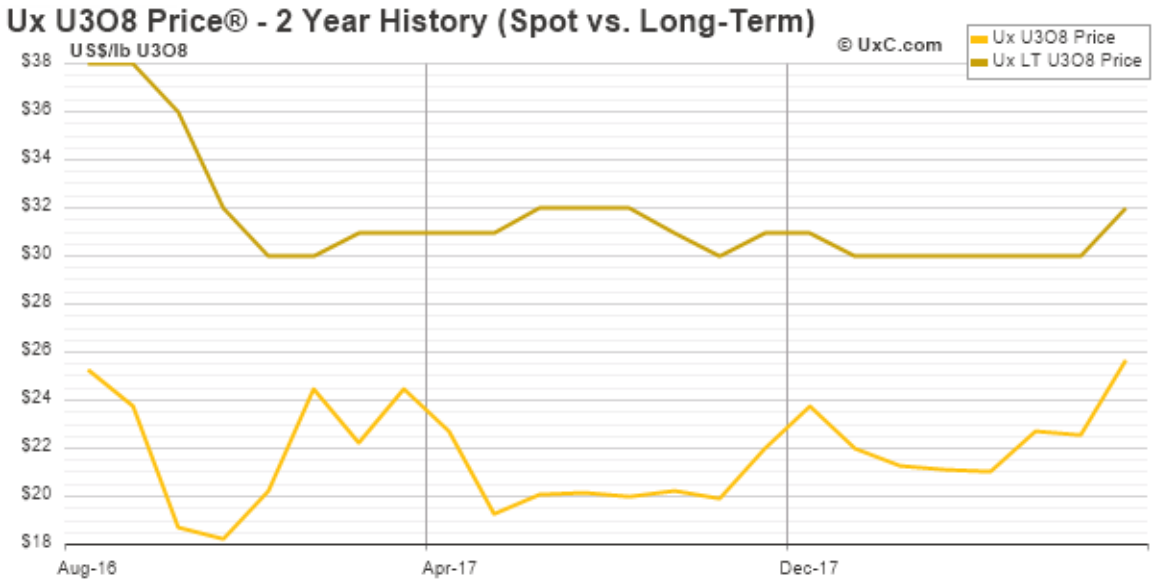
A uranium risk model (see Appendix B) was developed based on the expected uranium requirements for the next 10 years to determine the profit risk, cost risk and the hedge ratios for uranium (inventory and purchases). The inputs to this model include GDP, CPI, reactor

operation plans, forward prices curves, fuel inventory levels and contract information which are updated regularly to reflect current market and operating conditions.

In general, the decision to hedge (buy forward fixed) is based on the trade-off of cost risk versus profit risk. Cost risk exists if a company does not contract for a fixed price in the future and future prices end up being higher. Profit risk is the opposite, a company locks into a fixed future price and prices end up lower at that future date.

Details of the calculations are found in Appendix B and it is recommended that 45% of future purchases be contracted as fixed price. This is moderately higher than the 40% figure determined in 2016, and within the current limit range of 45% to 65%. The key difference in the 2018 study is an increased potential for prices to begin to trend up.

Uranium prices had weakened over the last 5 years but have shown signs of strengthening..



Data provided by UXC Consulting

Given that the model data suggests a 45% fixed hedge ratio and recent data suggests an upward movement in prices, it is recommended that the current range be maintained at 45% to 65%.

Recommendation

R2 – It is recommended that the upper (maximum) bound and lower (minimum) bound of OPG's uranium forward fixed purchases (Financial Coverage Limits) remain as currently established.

Supply and Demand Considerations

The World Nuclear Association published their report "The Nuclear Fuel Report – Global Scenarios for Demand and Supply Availability 2017-2035" in September 2017. This report outlined three potential scenarios for nuclear generating capacity, Reference, Upper and Lower. The Reference scenario (or most likely) will be used to provide an overview for the outlook for uranium demand and supply.

Supply Factors

Uranium supply comes either from mine production or secondary sources. In recent years, secondary sources have supplied approximately 20% of the yearly demand.

Primary Production

Mine production peaked at 162 million lbs. U_3O_8 in 2016, fell to approximately 154 million lbs. in 2017, and is expected to drop further to 140 million lbs. in 2018 (Uranium Participation Corporation website). The key producing countries are Kazakhstan, Canada and Australia.

Although uranium prices have been falling, mining company revenue has been supported by the higher fixed priced contracts that were signed a number of years ago. These higher priced contracts have been rolling off. For example, the average price paid by U.S. utilities in 2011 was US$55/lb, but has dropped to $40/lb. by 2017 (TradeTech). Spot prices have fallen from an average of US$52 in 2011 to $US23 in 2017. Recent long-term fixed pricing has been at the US$32/lb. level, while spot prices have risen moderately to US$27. As the realized selling price has continued to drop, the result has been production cuts and losses at many higher cost mines.

Currently, there are only a few mines under development with approximately 5 million lbs. of U_3O_8 capacity. With the slump in prices, there are no mines in the planning state (advanced feasibility studies, financing etc.) which may lead to a decrease in primary production as the existing mine reserves are depleted.

- According to Azarga Resources Ltd. Chairman, Alexander Molyneux, more than 50% of the uranium mines are unprofitable due to reduced uranium prices. Reported mining costs vary in the range of $25-$35 per pound (average unit cost of sales at Cameco Corp was $31 per pound) and if prices continue to decline, many of these mines will become unprofitable.

- As a response to persistently low uranium prices and an oversupply, several companies have suspended and shut down their uranium mines. Prominent sites include McArthur River and Key Lake (the largest uranium producing mine globally) in Canada, and Langer Heinrich in Namibia. These operation halts will remove approximately 20 million pounds of U_3O_8 per year from the market.

Secondary Sources

Over the last number of years, secondary sources of supply have provided approximately 20% of the required demand. The key secondary sources for uranium are 1) Commercial inventories held at the utilities or processing facilities, 2) Inventories held with mining companies, 3) Highly enriched uranium from military supplies, 4) Tailings from previously processed/used uranium (the largest secondary source). By 2025, secondary sources are expected to contribute under 15% of demand and by 2035, under 10%.

- According to Red Cloud Klondike Strike Inc., about 20% of the global supply comes from secondary sources which are being depleted at a rapid rate and are expected to contribute less and less over time. Secondary supplies are expected to decline by 10-15 million pounds of U_3O_8 over the coming years,

<u>Demand Factors</u>

The only significant commercial use for U_3O_8 is as a fuel for nuclear power plants for the generation of electricity.

In 2017, nuclear generating capacity was 391 GWe including the idled Japanese reactors. Generation is expected to rise moderately to 403 GWe by 2025, and further to 482 GWe by 2035. Currently, nuclear generates approximately 11% of the world's electricity, and this is expected to remain relatively stable out to 2025.

In 2017, the world uranium requirement was 65,000 tU or approximately 170 million lbs. U_3O_8 (note: 1.18 lbs of U_3O_8 = 1 lb of U). However, uranium requirements are projected to rise to approximately 75,000 tU in 2025 and 94,000 tU in 2035.

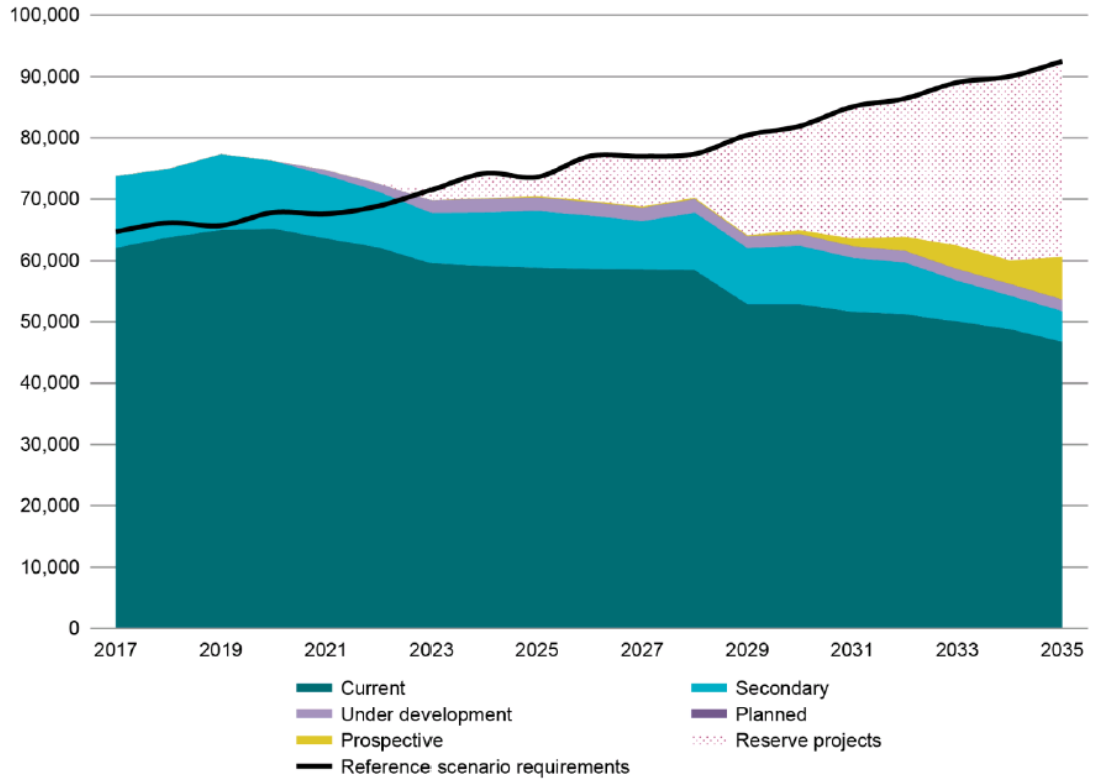
In general, electricity demand growth is limited in the developed world (North America, Europe, and Japan) where there are few new reactors under development. Existing reactors are being shutdown due either to age or the inability to compete against lower cost or subsidized technologies. On the other hand in emerging countries, such as China and India that have growing electricity needs there are a substantial number of reactors under development or planned.

- As a result of the changing electricity landscape, particularly the deregulation of power markets, there is a decrease in nuclear investment since it encourages projects with low and predictable capital intensity. Recent nuclear construction record in the Western hemisphere has not been ideal, which compounds the problem of raising nuclear finance.

- China continues to exhibit long-term growth in nuclear expansion, with 43 reactors planning to go online as of October 2018. It is projected that China's rapid expansion will result in it overtaking the U.S. as the nation with the largest atomic power capacity by 2026.

In summary, there is a divergence in the outlook for nuclear power. The developing world continues to invest heavily in the technology while the developed western countries have reduced their reliance on nuclear. However, given the minimal investment in new mine development, mining production is likely to fall. The following chart outlines the expected supply/demand outlook over the coming years. There would be an upward bias to prices under this scenario.

Figure 5.10: Reference Scenario supply, tU



4. Review of Exception Reporting

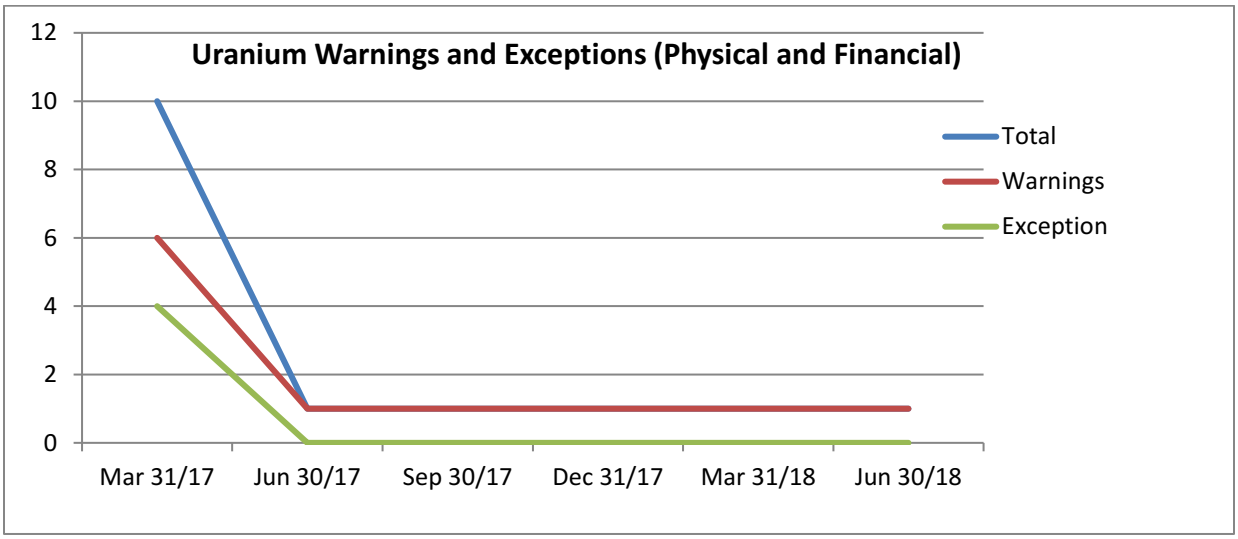
4.1 Exceptions Reported

Since the new uranium Physical and Financial Limits were implemented in Q1/17, the reported exceptions can be attributed to the change in the end of life for Pickering. The uranium procurement plan in 2015 was based on a generation outlook which reflected closure of the Pickering Generating Station in 2020. The 2016 Uranium Procurement Plan reflected extended operations at Pickering until 2024 and resulted in the need to purchase additional volume for 2020. Hence, once procurement activity increased to reflect the new plan, the reported exceptions have been addressed.

Uranium Exceptions Reported - 2017 to 2018

		Mar 31/17	Jun 30/17	Sep 30/17	Dec 31/17	Mar 31/18	Jun 30/18
Warning	Physical	4	1	1	1	0	0

	Financial	2	0	0	0	1	1
Exception	Physical	1	0	0	0	0	0
	Financial	3	0	0	0	0	0
Total		10	1	1	1	1	1
Warning		6	1	1	1	1	1
Exception		4	0	0	0	0	0



Recommendation

R3 - It is recommended that no changes be made to the existing exception reporting structure.

5. Other

Limit Review Term

The previous Uranium Market Risk Limit review was completed in the fall of 2016. In the aftermath of Fukushima incident, certain countries (e.g. Germany) have decided to phase out nuclear generation, while others (China, India) have maintained significant nuclear

development plans. Uranium spot prices have consistently declined over the last few years but have stabilized and gained short term support.

OPG has maintained a hedging program for uranium purchases that closely resembles practices in both the United States and Europe. This review has concluded that no substantive changes are required to the limits and exception reporting policies. However, given the fluid nature of the industry, OPG's Pickering's closure and the Darlington's refurbishment another review should be conducted in two years time. OPG's limits are well adapted to changing expectations given the declining limit structure (i.e. smaller percentage required to be hedged each year forward), the fact that expected production is revised yearly and the ability to hedge within a range.

Recommendation

R4 – Review the Uranium Market Risk Limits in two years time.

6. Conclusion & Recommendations

The following are recommended:

R1 -That the lower (minimum) bound and upper (maximum) bound of OPG's uranium forward purchases (Physical Coverage Limits) remain as currently established.

R2 - That the upper (maximum) bound and lower (minimum) bound of OPG's uranium forward fixed purchases (Financial Coverage Limits) remain as currently established.

R3 - No changes should be made to the existing exception reporting structure.

R4 - Review the Uranium Market Risk Limits every two years.

7. Acronyms and Defined Terms

CPI	Consumer Price Index
ERC	Executive Risk Committee
EU	European Union
FX	Foreign Exchange
GDP	Gross Domestic Product
MtM	Mark to Market
U_3O_8	Triuranium octoxide

Inventory Policy	Assessed amount of inventory required to be held in reserve (and in what state) to protect against supply disruptions.
Financial Coverage Limits	The upper and lower bounds on the portion of fixed price uranium OPG can procure on a yearly basis.
Physical Coverage Limits	The upper and lower bounds on the volume of uranium OPG can procure on a yearly basis.
Minimum Coverage Target	Lower bound on the amount of uranium OPG could procure.
Market Risk Limits	The combination of the Financial and Physical Coverage limits.
Uranium Procurement Program	The combination of activities, governance and strategy involved in procuring uranium and conversion services to meet OPG's objectives.

8. Resources

1. US Energy Information Administration, "Uranium Marketing Annual Report", May 2018, www.eia.gov
2. UxC, "Uranium Market Outlook", Q2 2018
3. EURATOM Supply Agency, "Annual Report, 2017
4. Nuclear Energy Agency, Nuclear Energy Data 2017
5. World Nuclear Association, The Nuclear Report – Global Scenarios for Demand and Supply 2017-2035
6. TradeTech, The Nuclear Review, September 2018

Appendix A - Current Risk Limits

Uranium Market Risk Overview

Uncertainty exists with respect to global uranium supply and demand, thus there is the potential for significant price volatility. Further to this, there are inherent supply risks in procuring uranium. The price and supply risk issues are outlined below along with the mitigation techniques which OPG currently employs.

Table A1 Nuclear Fuel Procurement Risks

Risk	Impact	Current Mitigation Techniques
Price	• Changes to nuclear fuel expense and cash flows as a result of fuel price changes	• Purchase within Financial Coverage Limits • Allow flexibility for spot market purchases • Price mechanism diversity
Supply	• Supplier default	• Monitor Credit Risk Limits • Diversify portfolio of suppliers
Supply	• Supply disruption or production shortage	• Purchase within Physical Coverage Limits • Maintain a strategic inventory • Diversify portfolio of suppliers

Development of Limits

Prior to 2008, OPG used a Minimum Coverage Target (MCT) (which was comparable to the current minimum Physical Coverage Limit) for the amount of uranium in inventory or under contract, which provided mitigation against supply risk. OPG had always sought to obtain diversity in price and supply source to mitigate risk, however, there was no formal price risk mitigation mechanism. The MCT did not take into account the quantity that would be sufficient versus excessive (however procurement plans have always required senior management approval). In 2009, the MCT was replaced with new Physical and Financial Coverage Ratio Limits.

Given that OPG is buying fuel for its operations (in contrast to financial markets where speculating or not transacting is an option), the fuel limits were developed to balance supply and price risk.

OPG's uranium supply portfolio consists of uranium in inventory, spot market purchases, and long term contracts with floating and fixed price mechanisms. The fixed price contracts allow OPG to lock in the delivered price of uranium in advance to hedge against future price volatility. The market exposed requirements (either un-contracted or floating price contracts) allow OPG to benefit from lower pricing when market prices decrease.

The uranium consumption forecast is based on the (board approved) Business Plan and more distant (5+) years are based on supplementary long term forecasts.

In 2008, the OPG risk governance and appetite that was in place typically restricted commodity type contracts to terms of no greater than 5 years. It was recognized that uranium procurement benefits from longer lead times, thus the timeframe used in developing the uranium limits was 10 years.

Table A2 Model Input Assumptions

<table>
<tr><th>Input Assumptions (2008)</th><th>Input Assumptions (2018)</th></tr>
<tr><td>Plant capacity taking into consideration the planned outages for the first 5 years as per Resource Outage Management System (ROMS) submission</td><td rowspan="4">Years 2018 to 2027 are based on a Nuclear Business Unit forecast.

Pickering:
• Units 1,4 shutdown at end of 2022
• Units 5 to 8 shutdown at end of 2024

Darlington Refurbishment Shutdown Schedule:
• U2 Oct 2016 – Feb 2020
• U1 Feb 2020 – Jun 2023
• U3 Jul 2021 – Sep 2024
• U4 Jan 2023 – Feb 2026</td></tr>
<tr><td>Planned outages for the years 6 to 10 equal to the average of the first 5 years</td></tr>
<tr><td>Pickering B life extension outage plan as provided by Nuclear Supply Chain</td></tr>
<tr><td>Market Risk's view on nuclear unit reliability performance (based on historical performance)</td></tr>
<tr><td>FX rate consistent with current forward curve used in all Energy Markets valuations</td><td>FX rate consistent with current forward curve used in all Energy Markets valuations</td></tr>
<tr><td>UXC price forecast (high, mid, low prices) and price weightings (2008-2020)</td><td>UXC price forecast (high, mid, low prices) and price weightings (2018-2027)</td></tr>
</table>

2018 OPG Uranium Fuel Usage based on Expected Production

Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
U3O8 (MgU)	647	568	667	547	535	602	443	392	438	446
U3O8 (klbs)	1,682	1,477	1,734	1,422	1,391	1,565	1,152	1,019	1,139	1,160

Current Market Risk Limits

The Market Risk Limits consist of i) Physical Coverage Limits, ii) Financial Coverage Limits, and iii) a Term Limit. The current coverage limits were last approved in 2016 and the term limit was approved in 2011 by the Executive Risk Committee (ERC).

i. Physical Coverage Limits

The Physical Coverage Ratio Limits were developed to ensure security of supply in future years by requiring contracts for a certain percentage of future need. The Physical Coverage ratio accounts for all sources of uranium including excess inventory, and also allows for spot purchases to hold in inventory when market conditions indicate that this is the best option (difference between Min. and Max.). The current Physical Coverage Limits are presented below:

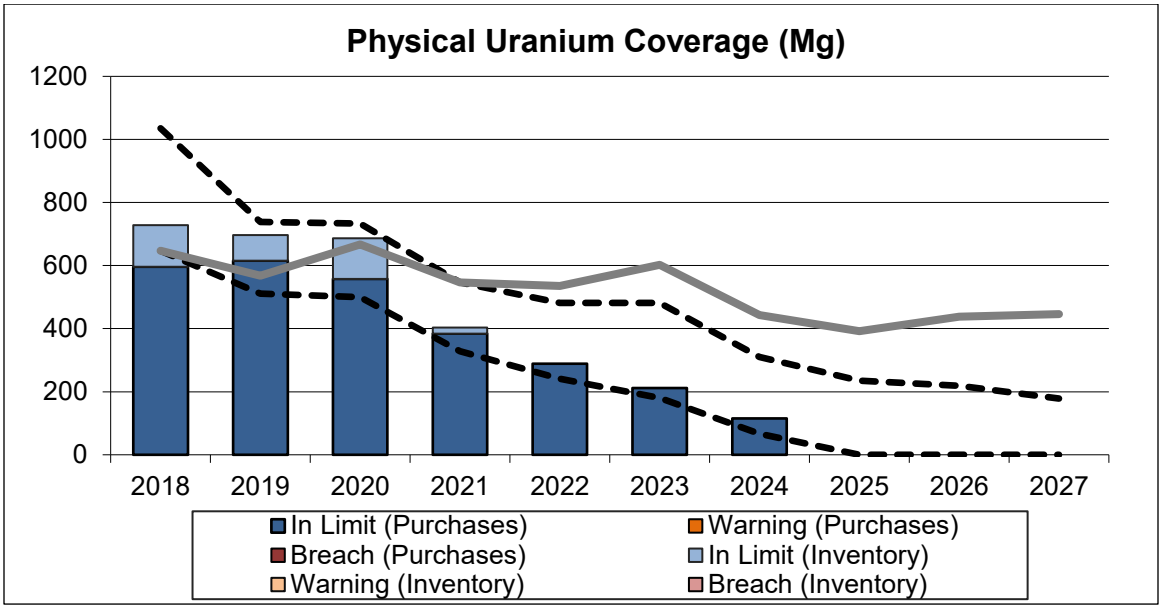
Table A3 Physical Risk Limits

	Minimum Physical Coverage Ratio Limit	Maximum Physical Coverage Ratio Limit
Current Year	100%	160%
Year +1	90%	130%
Year +2	75%	110%
Year +3	60%	100%
Year +4	45%	90%
Year +5	30%	80%
Year +6	15%	70%
Year +7	0%	60%
Year +8	0%	50%
Year +9	0%	40%

Inventories in excess of the strategic target are included in the coverage ratios. If the uranium concentrate requirement in the current year is met then the uranium inventory in excess of the strategic target is carried over to the following year to be included in the following year's coverage ratios.

Figure A1 (below) shows the current Physical Coverage (as of Q3 2018).

Figure A1 Q3 2018 OPG Physical Coverage



ii. Financial Coverage Limits

The purpose of Financial Coverage Limits is to establish a formal guideline that optimizes the mix between fixed price and variable price supply and ultimately minimize fuel cost variability. If OPG buys under a fixed price contract, it is protected against fluctuations in the market price, but is subject to the risk that the fixed price will be higher than market prices at the time of delivery. However, when purchasing under a market priced contract OPG is subject to price risk and uncertainty in cost due to changing market conditions (i.e. mining conditions, new plant construction, catastrophic events such as Fukushima, consolidation of mining companies, etc.).

Traditional price risk management alternatives are limited in the global uranium market.

- Limited liquidity in the uranium market and few financial hedging instruments available.
- Reported market price indexes, both spot and long term, are based on limited information, particularly for long term indexes.
- Although low, the risk of index manipulation exists which could impact OPG's fuel expense.
- Depending on market conditions, contract pricing methods are subject to "sellers market" challenges and pricing structures.

The current Financial Coverage limits are displayed below.

Table A4 Financial Risk Limits

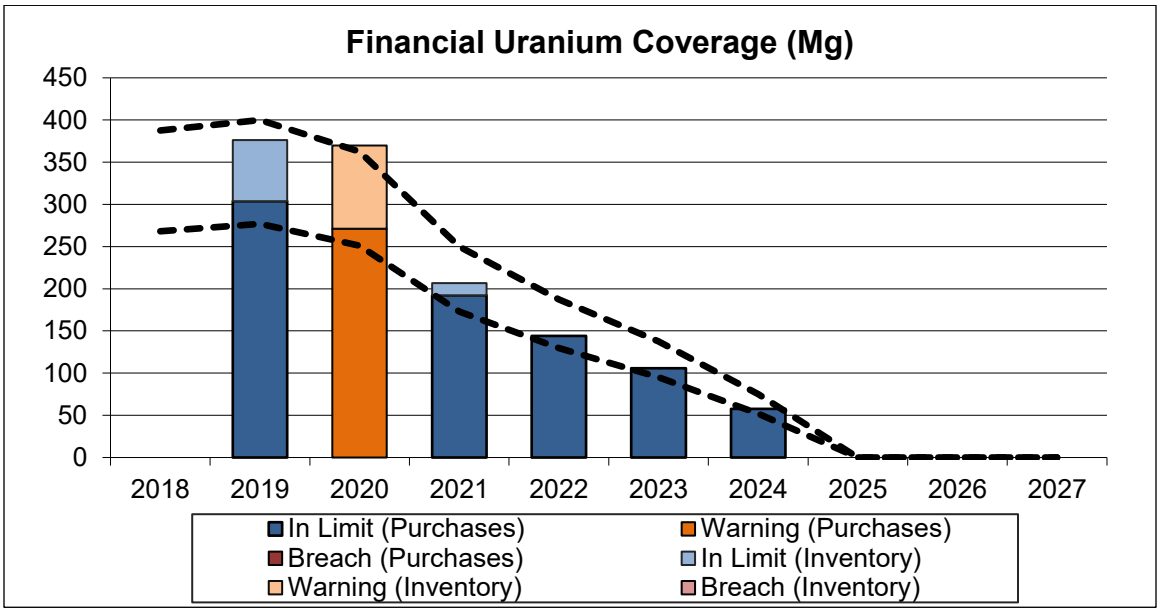
	Minimum Financial Coverage Ratio Limit	Maximum Financial Coverage Ratio Limit
Current Year*	45%	65%
Year +1	45%	65%
Year +2	45%	65%
Year +3	45%	65%
Year +4	45%	65%
Year +5	45%	65%
Year +6	45%	65%
Year +7	45%	65%
Year +8	45%	65%
Year +9	45%	65%

*Financial Coverage Limits are excluded for current year due to inventory carryovers.

Inventories of uranium in excess of the strategic targets are included in the coverage ratios and are carried over to be included in the following years' coverage ratios.

Figure A2 below shows the current Financial Coverage (as of Q3 2018).

Figure A2 Q3 2018 OPG Financial Coverage



Appendix B – Market Risk Limits Methodology

A uranium risk model was developed to calculate the expected uranium requirements for the next 10 years as well as the profit risk, cost risk and the hedge ratios for uranium (inventory and purchases) and for use in scenario analysis. The inputs to this model include GDP, CPI, reactor operation plans, forward prices curves, fuel inventory levels and contract information which are updated regularly to reflect current market and operating conditions.

Derivation:

The limits were derived in 2008 and updated in 2012, 2014, 2016 and 2018 using a mixture of efficient frontier methodology (maximizing efficiency as shown in Figure B1 Cost Risk vs. Profit Risk) and a qualitative assessment to determine if the framework could be realistically implemented given current inventory, energy forecasts, market conditions and outlook, and procurement processes.

In 2016 the optimal hedge ratio for the Financial Coverage was determined to be ~40% since this hedge ratio corresponds to the highest efficiency score.

> The Financial Coverage ratio limit decreases progressively in the future years. Why reduce the fixed price ratio for future years?
>
> - More accurate price forecasts are available for the current and short term time frame.
> - To avoid locking in larger quantities at fixed prices where there is increased uncertainty in future prices.
> - Counterparty risk increases in future years (i.e. mining disruptions in the future threatens delivery).
> - More lead time to adjust for changes in future years (i.e. future uncertainty in generation, economy, political climate, prices, and regulations).

In order to allow for flexibility, a range was created (minimum and maximum limits) vs. a single limit (i.e. 40%) to allow for spot purchases as well as to discourage procuring excess amounts of uranium at a fixed rate. The limits are represented in percentages (as opposed to lbs) to show its relationship to expected requirements. The limits provide a sufficient envelope for Nuclear Supply Chain to develop and execute a strategy which takes into account the broader market conditions.

<u>Methodology – Financial Risk Limits</u>

The determination of the Efficient Frontier consisted of evaluating the trade-off between the following parameters:

- **Cost Risk** - represents the risk to OPG that the fuel expense can increase (prices go up)
  Cost Risk = ($\mathbf{P}_{95\%}$[Cost] - **E**[Cost])

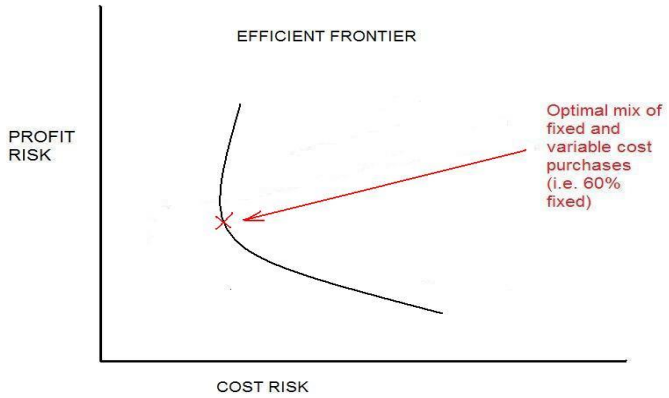
Where [Cost] is a distribution of consumption cost, $\mathbf{P}_{95\%}$ is the 95th percentile, and **E** is the expected value (mean).

- **Profit Risk** - represents opportunity cost of locking in the prices at the wrong time, which is represented by the risk that Mark to Market (MtM) will be negative (prices go down). Profit Risk = (**E** [MtM] – $\mathbf{P}_{5\%}$[MtM])

Where [MtM] is a distribution of (U3O8 Purchase Quantity * (Market Price – U308 Purchase Price)), $\mathbf{P}_{5\%}$ is the 5th percentile, and **E** is the expected value (mean).
Step One: Cost Risk and Profit Risk are calculated for each sample hedge ratio strategy from 0% to 100% (this represents the % of fixed price contracts).
Step Two: The Efficiency was calculated for each of the hedge ratio's, which provides the minimum of the two risks:

Optimal Point = Minimize $[\sqrt{(Cost\ Risk)^2 + (Profit\ Risk)^2}]$

Figure B1 Cost Risk vs. Profit Risk



- The Optimal Hedge Ratio (both risks are minimized) is shown in red

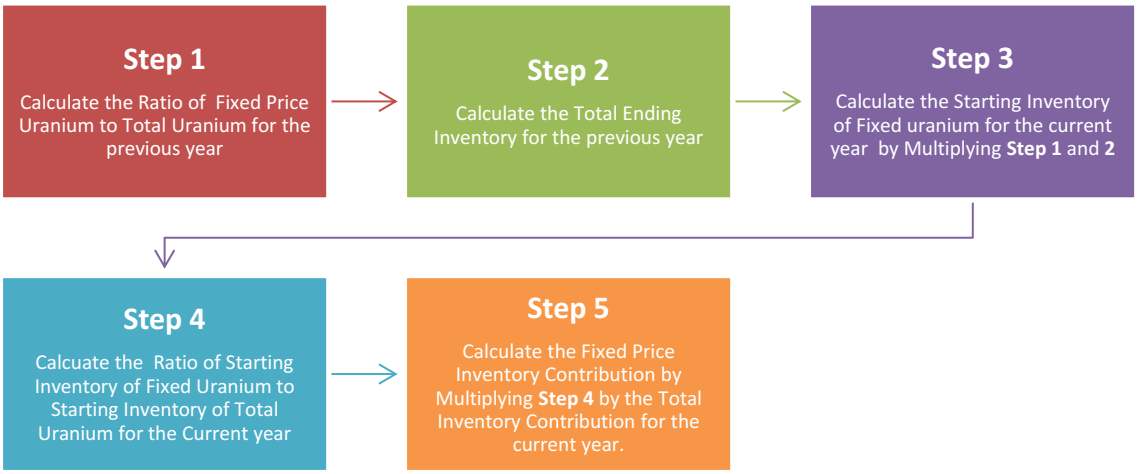
Step Three:
The Optimal Hedge Ratio was determined to be 45%. The Optimal Hedge Ratio was determined based on the efficiency ranking as well as taking into consideration the qualitative assessment.

<u>Financial Coverage Ratio Limits</u> - The Financial Coverage ratio describes the quantity of uranium under **fixed price** contracts expressed as a percentage of the overall requirement including adjustments for inventory levels.

$$\frac{Fixed\ Price\ Committed\ Deliveries + Year\ Start\ Inventory - Year\ End\ Inventory\ Target}{Consumption\ Forecast}$$

Note: Inventory in the equation above refers to the fixed price portion and is calculated as follows:

Figure B3 Fixed Inventory Contribution



COMPARISON BETWEEN 2016 and 2018 Results

The CMR tool was re-run with updated assumptions in both 2016 and 2018. Current purchases and inventory were set to zero in order to yield a fixed % which does not compensate for existing uranium purchased. The tool was run at each of the "% Fixed" of full requirements as shown in the table below. For example, this means that for all 10 years the fixed ratio was set at 25% and then the optimal point was recorded, and then re-run for 40% in all 10 years and the optimal point was recorded and so on. Results are shown in the table below.

Table B3 Calculated Efficiency Ranking 2016 vs. 2018

	2016	2018		
% Fixed	Optimal Point	Cost Risk (MCAD)	Profit Risk (MCAD)	Optimal Point
0%	168.6	133.2	0.0	133.2
25%	136.7	99.9	38.1	106.9
40%	131.0	79.9	60.9	100.5
45%	131.8	73.3	68.5	100.3
50%	133.9	66.6	76.2	101.2
55%	137.3	59.9	83.8	103.0
60%	141.9	53.3	91.4	105.8
75%	161.7	33.3	114.2	119.0
100%	208.1	0.0	152.3	152.3

The optimal point was found to be at 45% which compares with the optimal point of 40% which was determined in 2016.

Appendix C – Physical Limit Input Assumptions and Market Outlook

As the Physical Limits are intended to encourage uranium procurement which provides adequate assurance of future supply, the Physical Limits are influenced by an examination of the trends in worldwide fundamental supply and demand factors. The following table provides a summary of the selected factors, with a comparison of these factors at the time of the last report (2016) versus the factors today.

Table C1 Comparison of Market Factors

	2016	2018	Difference
Reasonably Assured Resources (million pounds U3O8)[1]	3146	3177	+31
Uranium mine production (million pounds U3O8)[2]	162	136	-26
Uranium requirements (million pounds U3O8)[2]	168	173	+5
Uranium mine production as a percent of requirements	96	78	-18
Expected uranium requirements (million pounds U3O8)[2] 2020 2025 2030 2035	 183 202 232 na	 161 170 190 202	 -22 -32 -42
Expected uranium production[2] (million pounds U3O8) 2020 2025 2030 2035	 180 163 162 na	 143 163 119 122	 -37 0 -43
References: [1]World Nuclear Association: "The Global Nuclear Fuel Market – Supply and Demand 2017 – 2035" [2]UxC Market Outlook (quarterly reports Q3/16 to Q3/18)			

Reasonably Assured Resources

Reasonably assured resources are those for which there has been sufficient direct measurement to conduct pre-feasibility studies and sometimes feasibility studies, and for which there is a high confidence in estimates of grade and quantity compatible with mining decision making standards.

Reasonably assured resources, which are expected to be economically recoverable at a cost of less than US $80 per kg, have increased by 1% percent since the last report, although there has been a reduction in lower cost resources and an increase in higher cost resources primarily due to an increase in mining costs.