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Uranium Production Cost Study

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Introduction and Overview

Introduction

Given the move toward cleaner energy, reduced carbon emissions, and more secure long-term energy sources, uranium supply is becoming more important to utilities worldwide. In the 2015 UPCS, our post-Fukushima demand forecast was more positive, as we projected it to increase by 53% through 2030. In the current forecast, base case demand is projected to only increase by 9% through 2030, which is a major reduction from two years ago. The majority of the increased demand is still expected to come from Southeast Asia – China and India in particular.

Although the end of the U.S.-Russia HEU Agreement in 2013 was certainly a positive event for producers seeking to bring online new production, the reduction in demand stemming from the Fukushima accident has essentially negated the loss of 24 million pounds U_3O_8 per year resulting from the end of the HEU deal.

Secondary supply sources also continue to be a huge factor impacting uranium prices and the viability of new and existing uranium projects. Enricher underfeeding has become a very important part of secondary supply in the post-Fukushima environment. Even though underfeeding is less profitable given the current low price of uranium, spare enrichment capacity resulting from lower than expected demand (as noted above) is being utilized by enrichers to yield uranium totaling up to 18 million pounds U_3O_8e per year. Furthermore, U.S. Government inventories and the use of MOX/Reprocessing meet a comparable amount of demand in the near term. Add to this inventory build-up from shuttered reactors in the wake of the Fukushima disaster, and secondary supplies total between 42-45 million pounds U_3O_8 per annum for the next few years.

Given the impact of secondary supplies on the ultimate need for primary production, there is enough prospective production at a full cost below $40 per pound to meet UxC's post-Fukushima base case demand through 2020. Accordingly, planned or potential projects with production costs at or above $40 per pound will be forced to delay or defer production until higher demand necessitates this higher cost production. Currently, production at a cost above $40 per pound is seen being more critical in the years from 2021 to 2025 when some existing uranium mines become depleted and demand shows greater growth.

While uranium exploration experienced a revival in the last price run-up, exploration expenditures since the Fukushima accident have fallen off as many suppliers now find it more difficult to obtain project financing in a flat market. As a result, the current menu of worldwide projects is not all that exhaustive because most of the recent exploration has been on brownfield sites that were discovered 20, 30, or even 40 years ago. Although uranium resources within the widely known IAEA "Red Book" are extensive, the vast majority of these are neither delineated nor developed. As the

nuclear industry transforms itself into a safer and more robust industry, one of the challenges will be for the supply side of the industry to expand and bring new production to a market that is still reeling from the effects of Fukushima.

This study complements UxC's *Uranium Supplier's Annual* in identifying where expanded and new uranium supply will come from among 110 worldwide projects to meet future demand through 2030. Cost curves for operational, planned, and potential projects are developed to identify those projects most likely to produce in the future, as well as present a long-run cost structure for the industry. Additionally, the study identifies key factors impacting how production costs are calculated as well as their weight in a supplier's decision of whether to advance a project to production.

Structure of Report

The *Uranium Production Cost Study* is organized as follows: **Chapter 1 – Key Factors Affecting Production Costs** reviews factors that impact productions costs, including ore grade, reserve tonnage, deposit depth, spatial density, ore thickness, deposit composition and chemical agents, various technical factors, water flows and drainage, energy costs, labor costs, transportation/hauling costs, etc. **Chapter 2 – Uranium Mining Methods** covers the three key mining methods (open pit, underground, and in-situ recovery) in uranium mining and highlights the positives and negatives of each method.

In **Chapter 3 – Uranium Mining Costs**, we discuss uranium mining costs for conventional (open pit and underground) and in-situ recovery deposits, specifically focusing on the breakdown of capital costs for each mining method. Specific variables impacting capital mining costs for each mining method are discussed in detail. **Chapter 4 – Uranium Processing and Milling Costs** identifies the capital and operating costs associated with uranium processing plants. This chapter specifically looks at the direct and indirect costs related to total milling operating expenses. **Chapter 5 – Financial & Market Considerations on Costs** discusses the time value of money and how this works in calculating the present value of a project. This chapter also discusses the difference between escalation and inflation and how each can impact the economics of a deposit. Lastly, this chapter focuses on how important market conditions are accounted for in deciding whether to make an investment and development decision.

In the following four chapters, we detail estimated production costs for prospective world uranium deposits. **Chapter 6 – World Production Costs** presents a production cost curve for all worldwide uranium projects, breaking the cost curve down by four tiers. Additionally, the production cost curve is broken down by operating, planned, and potential projects. Production cost curves for 2017, 2020, 2025, and 2030 are also presented. **Chapter 7 – World Production Cost Case vs. Demand (2016-2030)** compares UxC's URM High and Base Demand Cases to potential world production stacked by cost range for the 2016-2030 period. **Chapter 8 – Production Costs by Region** shows production costs for Africa, Australia, North America, and

the Former Soviet Union and Asia. In addition, a competitive cost comparison of 2016 production by countries/regions is presented. **Chapter 9 – Production Costs by Mine Method** illustrates potential production from all three mining methods in the 2016-2030 period, providing costs curves and production by cost for each method.

Chapter 10 – A Slow Return to Normal Queuing details how the market is slowly moving back to being production-driven, but still faces the challenge of high utility inventory levels and demand growth hindered by the slow return of Japanese reactors. Accordingly, even low-cost producers are struggling to survive until enough inventories are depleted and/or until enough higher-cost supply is eliminated while prices stay artificially low.

Chapter 11 – Financial Implications on Prices analyzes how financial implications not only affect uranium production costs directly, but also indirectly impact the sales price of uranium through variations in country exchange rates. Furthermore, inflation impacts uranium price formation, as increasing cost pressures on uranium prices then result in similar upward price pressure on the factor inputs for uranium production.

Chapter 12 – Matching Production Costs to Prices analyzes why prices are currently lower than our marginal-cost pricing picture, with a broad discussion of floor prices, term contract prices, and spot prices.

Lastly, **Chapter 13 – Issues Affecting Next Generation of Projects** identifies key issues mostly likely to affect the development of new uranium projects over the next 15-20 years.