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Uranium Production Cost Study

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Table of Contents

List of Figures

List of Tables

Introduction and Overview

Introduction

Given the global shift toward cleaner energy production, reduced carbon emissions, and more secure long-term energy sources, uranium supply is becoming more important to utilities worldwide. Moreover, higher geopolitical risk associated with some uranium-producing countries has forced many utilities to evaluate their contracting portfolios and mitigate risk exposure going forward. In the 2023 *Uranium Production Cost Study* (UPCS), our base case demand forecast shows projected growth of 35% between 2023 and 2040. Recent updates to UxC's Uranium Requirements Model (URM) have yielded increases in global uranium requirements due to higher revised transactional tail assays assumptions, while also incorporating strong "secondary demand" uranium market demand estimates given ongoing purchases by investor and hedge funds. Between 2028 and 2040, base case demand rises by 23%, which is a period wherein new primary production will be necessary.

One of the biggest influences on the uranium market over the last several years has been the availability of various secondary sources of supply. However, the COVID-19 pandemic in 2020 sparked a rapid reduction in secondary supplies as primary production dipped and utility inventory drawdown accelerated. The availability of secondary supplies was further hindered in 2021 with the start-up of the Sprott Physical Uranium Trust, which has since led to the sequestration of more than 43 million pounds U_3O_8 from the market through purchases. Additionally, Russia's military invasion of Ukraine is forcing Western utilities to shift away from Russian enrichment, resulting in higher demand for Western enrichment, and subsequently reducing the forward availability of natural uranium derived from tails re-enrichment and underfeeding from excess SWU capacity. It is estimated that total secondary supplies in all forms will account for 48 million pounds U_3O_8e in 2023, or 25% of total world supply. However, going forward, these levels are expected to decline significantly, falling to 27 million pounds U_3O_8 in 2025 and 18 million pounds U_3O_8 in 2030.

UxC projects small supply deficits in 2023 through 2027, but these deficits are projected to be filled through a combination of unutilized production capacity, the restart of mines on standby, and potential additional inventory drawdown. However, UxC foresees a dire need for new uranium projects to enter service between 2028 and 2040, which will require incentive pricing as many existing uranium mines are depleted while base case demand strengthens.

While uranium exploration experienced a revival in the early 2000s during the last price upcycle, exploration expenditures over the last nine years have dropped as producers and junior miners focused their efforts on reducing operating costs in response to persistently weak uranium prices. As a result, the current menu of worldwide uranium projects is less comprehensive given that much of the recent exploration has focused on known brownfield sites that were discovered 20, 30, or even 40 years ago.

The latest 2022 OECD Nuclear Energy Agency and IAEA "Red Book" reported that total identified resources, which consists of reasonably assured resource and inferred resources, were 7.92 million tU (~20.6 billion pounds U_3O_8) in the highest cost category of <US$260/kgU (<US$100/lb U_3O_8) as of January 1, 2021. Although uranium resources within the 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 that is an important component of the growing clean energy paradigm, one of the challenges for the supply side will be to produce uranium in a socially responsible manner that mitigates detrimental impacts to the surrounding environment.

This study complements UxC's *Uranium Supplier's Annual* in identifying the leading sources of expanded and new uranium supply from among 104 worldwide projects to meet future demand through 2040. Cost curves for operational, planned/advanced, 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 uranium industry. Additionally, the UPCS identifies key factors that impact how production costs are calculated, as well as their weight in suppliers' decisions on 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 (ISR) 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 impacts 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 discusses the importance of considering market conditions when making 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 2023, 2025, 2030, 2035, and 2040 are also presented. Additionally, production cost curves for the same periods are shown with projected rate of returns. **Chapter 7 – World Production Cost Case vs. Demand (2022-2040)** compares UxC's URM Demand Cases to potential world production stacked by cost range for the 2022-2040 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 2023 production by countries/regions is presented. **Chapter 9 – Production Costs by Mine Method** illustrates potential production from all three mining methods in the 2022-2040 period, providing costs curves and production by cost for each method.

Chapter 10 – A Return to Normal Queuing details how the market is transitioning to being production-driven following years of declining global demand, primary production cuts, and inventory utilization. More recently, the influence of secondary demand – investor/hedge funds and junior producers – has served to remove a significant amount of excess supply in the market, and is, in essence, accelerating the return to a normal queuing cycle as global demand continues to rise.

Chapter 11 – Financial Implications on Prices analyzes how financial implications can directly affect uranium production costs and indirectly impact the sales price of uranium through variations in currency exchange rates. Furthermore, inflation impacts uranium price formation, as increasing cost pressures on uranium prices similarly result in upward price pressure on the factor inputs for uranium production.

Chapter 12 – Matching Production Costs to Prices analyzes the relationship between production costs and the 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 that are likely to affect the development of new uranium projects over the next 17 years.