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## Nuclear Zirconium Alloy Market



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## Introduction & Overview

UxC, LLC (UxC) is pleased to present the ninth edition in its special report series on the *Nuclear Zirconium Alloy Market*.

Since 2008, UxC has been closely tracking the nuclear-grade zirconium alloy market and publishing updated reports given the nuclear fuel market's desire for current information and analysis on this unique marketplace.

Nuclear-grade zirconium alloys and components are employed in the fabrication of fuel assemblies used in the vast majority of commercial nuclear reactors currently operating, under construction, and planned around the world. These days, in light of increasingly improving prospects for nuclear power around the world, many aspects of the international nuclear fuel supply chain are gaining new interest.

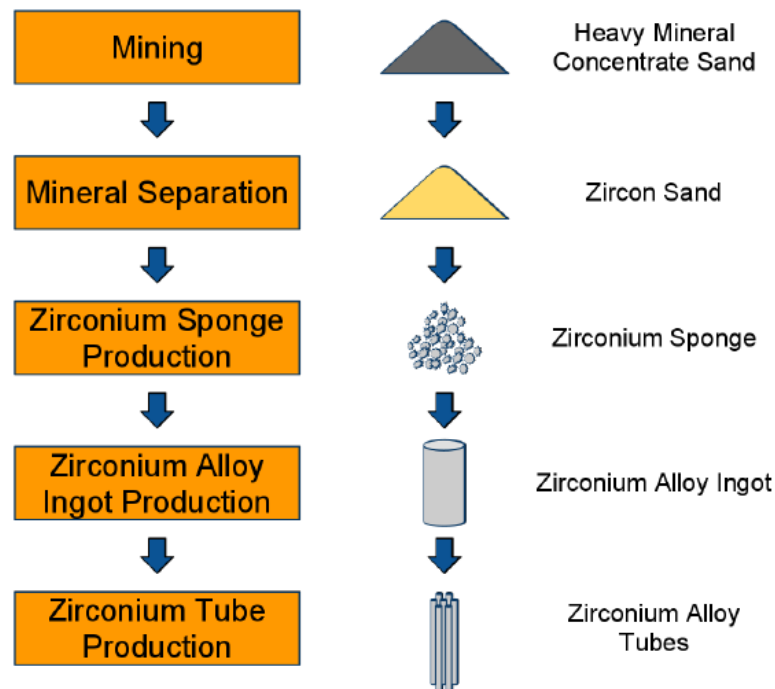
The supply of nuclear-grade zirconium alloys – from the mining of zircon mineral sand through the manufacture of cladding and other components used in finished nuclear fuel assemblies – has not escaped this scrutiny. Therefore, the primary objective of this report is to factually and analytically approach the current and expected future direction of the nuclear-grade zirconium alloy market with the aim of reaching some clear conclusions about how producers of fuel assemblies for nuclear reactors will obtain the necessary zirconium alloys for their finished products and at what cost.

This fully updated report, published in November 2023, offers UxC's most recent analyses and opinions of the various sectors that make up the nuclear-grade zirconium sponge, alloy, materials, and tubing markets. Beginning with a detailed review of the latest situation in the upstream zirconium mineral market, this report provides a thorough analysis of all steps in the nuclear-grade zirconium supply chain. Additional details are included on the interplay of the nuclear fuel fabrication and zirconium alloy supply markets, and of the fabrication process itself. The report also assesses major trends in this unique industry by analyzing the global and regional supply and demand balances for nuclear-grade zirconium sponge, alloy, and tubing as well as the supply and demand situation based on reactor fuel types. We conclude with some final observations on the global market, recent emerging market trends, as well as the status and expectations for future price developments for zirconium alloy products.

## Comprehensive Coverage of the Global Nuclear Zirconium Industry

This report encompasses every aspect of the global nuclear zirconium industry. As such, it provides a detailed analysis and the associated market implications of the numerous steps that convert zircon mineral sand to finished nuclear fuel components. Figure 1 below provides a brief introduction to the principal steps currently employed in the nuclear zirconium industry.

**Figure 1. Nuclear Zirconium Manufacturing Overview**



Source: Lundberg (Uppsala University)

## Availability of Data

Over the 15 years that UxC has been closely tracking this market, it has been evident that many of the various processors and fabricators of nuclear-grade zirconium sponge, alloys, and fuel assembly components are reluctant to publish, or even discuss, the details of their businesses. Much of their data is considered proprietary and information sharing is restricted. Over the years, however, UxC has been able to identify additional sources of information allowing us to fill in a number of blanks on specific data. However, most industry participants remain reticent to share information, and some of them have actually reduced the amount of information presented on their websites and in their public pronouncements over the years.

To supplement our own data collection process for this 2023 edition, UxC reached out to principal zirconium processors and producers to gain insights into current and future operations. Generally, the best information available from public and private sources was used to complete all supplier reviews. Where possible, we confirmed data from one source with another, independent source.

We believe that the information contained herein is accurate or, at a minimum, representative of the operations, production levels, expansion plans, etc. of the companies discussed in this report. However, the possibility still exists that there may be a few inaccuracies or that the information has changed since the data were obtained. In a couple of instances, there was no available non-proprietary data, and therefore the missing information is listed as “not available” in the affected data tables.

It should also be noted that all price and cost data is quoted in U.S. dollars (US\$) throughout this report unless otherwise indicated.

## What's New in the 2023 Report?

In this November 2023 edition of the *Nuclear Zirconium Alloy Market* report, we have continued to employ the format and content of the previous documents but have updated all the relevant information to reflect current circumstances. Other improvements to our market coverage and analysis have been made as well.

Since 2010, the markets for zircon sand and some of the downstream zirconium products have experienced significant volatility. Shortages of zircon led to explosive price increases for raw materials and created substantial uncertainty as to the future performance of these markets. This was followed in 2012 by a collapse of demand, production, and prices, thus raising questions about the future of the zircon market. Despite optimistic pronouncements by zircon producers, the market did not recover and subsequently hit a bottom in 2016. Since then, zircon producers responded by cutting back production and working off inventories, which, coupled with recent increases in demand, led to price recovery in the zircon market. Although U.S.-China trade tensions coupled with the COVID-19 pandemic had significant negative impacts on the global zircon market from 2019 through 2020, the market has been on a steady recovery path ever since with prices rising significantly as of late 2023.

Consequently, we have substantially updated our analysis of the zircon minerals market in this latest report. This includes detailed analysis of the role of China, both as the world's largest importer of zircon sand and the largest exporter of processed zirconium products, such as zirconium oxychloride, which is a major input product for nuclear zirconium sponge producers. Updates have been made on the latest status of the zircon market through late 2023 and the outlook for zircon supply and demand as well as prices for the key raw input material to the nuclear zirconium alloy market.

This report also includes detailed descriptions of the zircon mining and refining process as well as the processes employed for the manufacture of nuclear-grade zirconium sponge and downstream zirconium alloy products.

While the nuclear zirconium industry did not escape various negative impacts over the decade after the 2011 Fukushima accident in Japan, a renewed growth trend has emerged for nuclear power in the past 1-2 years with rapidly improving prospects in light of the global energy transition. However, there are significant variations in terms of future growth projections depending on the region and/or country. Thus, all

analyses in this report have taken account of the implications of recent nuclear power market developments and how they continue to influence the current status and future prospects of the nuclear zirconium industry.

Over the past decade, the prospects for future growth of nuclear power around the world have gone through major fluctuations, and therefore the demand for nuclear fuel assemblies and the zirconium alloy components have also experienced significant shifts. New for this 2023 edition, UxC has updated demand projections first time through 2040 for zirconium sponge, alloys, and tubing to consider all the latest major developments affecting nuclear fuel demand over the past few years.

Our updated demand projections incorporate UxC's detailed calculations of the zirconium weight and tube content in all the major nuclear fuel assemblies in the world, including improved estimates of the quantities of material used in various assembly designs. Moreover, the forecasts make use of UxC's recently refined *UxC Requirements Model* (URM) to forecast global reactor fuel loading requirements and the resulting demand for zirconium alloy materials and products. The URM projects demand on a reactor-by-reactor basis taking account of each plant's refueling schedule (and/or construction schedule for new plants), the specific fuel assembly design used in that plant, the size of the reload batch (or initial core), and the zirconium alloy content of the individual fuel assemblies.

The core of this report again contains detailed profiles and analysis of every company active in the global nuclear-grade zirconium supply chain, including producers of nuclear zirconium sponge, alloys, and tubing. These updated profiles cover current capacities, future production plans, and any other important issues affecting each supplier's current status and future outlook.

This new 2023 edition also presents separately updated supply and demand forecasts for nuclear-grade zirconium sponge, alloys, and tubing out to 2040 to provide readers clear insights into the future direction of each market sector.

Various factors affecting both the supply and demand for nuclear zirconium products as well as global trade for these products are also analyzed in this latest edition. This includes discussion of government policies, technological developments, as well as the impact of tangential markets on the nuclear zirconium sector.

Finally, we have also noted that many of the subscribers to the previous editions of this report represented organizations that did not participate directly in the nuclear fuel fabrication market. Thus, for those not familiar with the specifics of the fabrication industry, we have again included brief profiles of the main nuclear fuel fabricators, a review of the global market outlook for nuclear fuel fabrication, as well as a discussion of the design of BWR and PWR fuel assemblies, the zirconium alloy components of which they are constructed, and the fuel fabrication process itself.

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## Structure of the Report

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This report contains separate chapters for various aspects of the nuclear-grade zirconium alloy market, supply and demand, and other related areas. In addition to this **Introduction & Overview**, the report includes the following chapters:

**Chapter 1 – General Zirconium Overview & Zircon Market Review** provides a broad exploration of the zirconium mineral occurrence, resource base, and industrial applications, including the role of zirconium alloy production in the nuclear fuel industry. This chapter describes the mining and refining of zircon sand, and most importantly, it addresses the current and projected supply, demand, and price of zircon in the global marketplace with emphasis on China’s critical role. This helps to put the specific nuclear-grade zirconium alloy market analysis in perspective, as there are numerous applications for the zirconium mineral beyond nuclear reactor fuel.

**Chapter 2 – Manufacturing Processes for Nuclear Fuel Components** covers the processing steps from zircon sand through zirconium sponge and alloy production to the manufacture of nuclear fuel components, i.e., the overall “nuclear zirconium cycle” for production of the materials and components used in nuclear fuel assemblies.

**Chapter 3 – Nuclear Zirconium Alloy Materials & Product Suppliers** presents a profile of each of the companies involved in nuclear-grade zirconium alloy materials and product supply. This includes all the companies in the world involved in nuclear-grade zirconium sponge and alloy production and processing through manufacture of sheet, plate, bar stock, and tube-reduced extrusions (TREX), as well as tubing and other component manufacture.

**Chapter 4 – Nuclear Fuel Fabricators & Zirconium Components Supply** provides a brief overview of the global nuclear fuel fabrication industry and indicates the source of each fabricator’s fuel assembly tubing and other components. This chapter also includes a discussion of the individual components that make up fuel assemblies and describes the fuel fabrication process.

**Chapter 5 – Nuclear Zirconium Supply & Demand Analysis** offers UxC’s most recent analysis of the global supply and demand balance for nuclear fuel-related zirconium sponge and alloy products as well as zirconium tubing. In addition, this chapter includes an analysis of zirconium supply and demand by region as well as by reactor type. All forecasts in this chapter now extend out to 2040.

**Chapter 6 – Overall Conclusions & Market Analysis** summarizes our findings on the nuclear-grade zirconium market and offers some final thoughts on the current situation and forecast of future trends. Included in this chapter is also a review of new and emerging trends that could impact the nuclear zirconium market over the longer term. This chapter also provides UxC’s estimates of the current nuclear-grade zirconium alloy prices and expectations for future price developments.

Finally, the **Appendices** include the data and assumptions used in the analyses discussed in the body of the report as well as several additional reference materials.