



UCX

Special Report

November | 2023

A PUBLICATION OF **UC**

UXC.COM

Nuclear Zirconium Alloy Market



1501 MACY DRIVE
ROSWELL, GA 30076
PH +1 770 642-7745

– NOTICE –

UxC, LLC (“UxC”) shall have title to, ownership of, and all proprietary rights in this Report. Under United States federal copyright law (17 USC 101 et seq.) it is illegal to reproduce this Report by any means without written permission from UxC.

The information contained in this Report is obtained from sources that UxC believes to be reliable. UxC makes no warranty or representation, express or implied, with respect to the accuracy, completeness or usefulness of the information contained in this Report and UxC, to the maximum extent permitted by law, assumes no liability for the use or effects of any of the information or data contained in this Report.

It is UxC’s strict policy not to endorse, promote, or recommend any particular securities, currencies, or other financial products or instruments. Nothing contained in this Report is intended to constitute investment, legal, tax, accounting or other professional advice and the reader should not rely on the information provided in this Report for making financial decisions.

The Ux U₃O₈ Price[®] and other Ux Price indicators are developed by UxC and are proprietary and exclusive intellectual property of UxC. These price indicators are provided to UxC’s customers through the Ux Weekly[®] publication and are made available on UxC’s public website solely at UxC’s discretion. They may not be reproduced or otherwise used without UxC’s express permission.

UxC[®], Ux Weekly[®], Ux U₃O₈ Price[®], UxC BAP[®], U-PRICE[®], and SWU-PRICE[®] are trademarks of UxC, LLC.

Table of Contents

Introduction & Overview	7
Comprehensive Coverage of the Global Nuclear Zirconium Industry	8
Availability of Data	8
What's New in the 2023 Report?	9
Structure of the Report	11
1 – General Zirconium Overview & Zircon Market Review	12
Occurrence	12
• Primary Producing Countries	13
• Hafnium Occurrence	14
General Uses	15
• Zirconium Metal	18
Nuclear Applications	18
• New Nuclear Zirconium Alloys Under Development	20
Zircon Resources and Production	23
• Reserves and Resources	23
• Zircon Mining	23
• Zircon Production	26
Individual Company Production	29
Zircon Consumption and Prices	32
• Overview	32
• Consumption of Zircon	33
Influence of Tile Manufacturing Techniques	35
• Market Dynamics	36
• Zircon Prices	38
Zirconium Oxychloride Market	39
The Influence of China	40
Conclusions	41
2 – Manufacturing Processes for Nuclear Fuel Components	42
Production of Zirconium Sponge	42
• The Importance of Hafnium Separation	43
• Zircon Sand Processing	44
• Hafnium Removal	44
• Final Sponge Production	44
Manufacture of Zirconium Alloy Ingots	46
Manufacture of Zirconium Alloy Plate, Sheet, Bar Stock, and Tube-Reduced Extrusions (TRES)	47
Production of Nuclear Fuel Tubing	49
3 – Nuclear Zirconium Alloy Materials & Product Suppliers	52
Zirconium Sponge Producers	53
• China	54
State Nuclear Baoti Zirconium Industry Company, Ltd. (SNZ)	54
China Nuclear Jinghuan Zirconium Industry Co. Ltd. (CNNC Jinghuan)	55
Guangdong Orient Zirconic Industry Science & Technology Company Ltd. (Orient Zirconic)	56
• France	57
Framatome Zirconium Division	57
• India	58
Nuclear Fuel Complex (NFC)	58
• Russia	60
Chepetsy Mechanical Plant (CMP)	60
• United States	64
ATI Specialty Alloys and Components (ATI-SAC)	64
Western Zirconium (WZ)	65
Zirconium Alloy Plate, Sheet, Bar Stock, and TRES Producers	66
• Argentina	67
Fabricación de Aleaciones Especiales, SA (FAE)	67
• China	68
State Nuclear Baoti Zirconium Industry Company, Ltd. (SNZ)	68

Other Chinese Facilities	68
• France	69
Framatome Zirconium Division.....	69
• India	71
Nuclear Fuel Complex (NFC).....	71
• Russia	72
Chepetsky Mechanical Plant (CMP).....	72
• Sweden	73
Alleima AB	73
• United States.....	73
ATI Specialty Alloys and Components (ATI-SAC).....	73
Western Zirconium (WZ).....	74
Zirconium Alloy Traders and Scrap Recyclers	74
Nuclear Fuel Tubing Manufacturers	75
• Argentina.....	76
Fabricación de Aleaciones Especiales, SA (FAE).....	76
• Canada.....	76
BWXT Nuclear Energy Canada (BWXT Canada)	76
Cameco Fuel Manufacturing, Inc. (CFMI)	77
• China.....	77
State Nuclear Baoti Zirconium Industry Company, Ltd. (SNZ)	77
CNNC Framatome Shanghai Tubing Co. (CAST).....	78
• France	79
Framatome Zirconium Division.....	79
• India	80
Nuclear Fuel Complex (NFC).....	80
• Iran.....	80
Zirconium Production Plant (ZPP).....	80
• Japan	81
Mitsubishi Nuclear Fuel Company (MNF)	81
• Russia	82
Chepetsky Mechanical Plant (CMP).....	82
• South Korea	82
KEPCO Nuclear Fuel (KNF).....	82
• Sweden	84
Alleima AB	84
• United Kingdom.....	85
Fine Tubes, Ltd.	85
• United States.....	85
Global Nuclear Fuel-Americas (GNF)	85
Alleima AB	86
Superior Tube Company	86
Veridiam.....	86
Westinghouse Specialty Metals Plant (SMP)	87
Discontinued Suppliers.....	88
• SSPE “Zirconium” (Discontinued)	88
• Duisburg Special Tubes GmbH (Germany)	89
• Zirco Products (Japan).....	89
Possible Future Supply Developments	90
4 – Nuclear Fuel Fabricators & Zirconium Components Supply	92
Fabrication Market Overview.....	92
Key Players	93
• Framatome.....	93
• Global Nuclear Fuel	93
• Westinghouse Electric Company	93
• TVEL Fuel Company.....	94
• KEPCO Nuclear Fuel	94
• National and Regional Fuel Suppliers.....	95
• Non-LWR Fuel Fabricators	95
Fabrication Supply & Demand.....	96
• Non-LWR Fuel Supply and Demand.....	99

Fabrication Market Dynamics.....	100
Zirconium Alloy Components and the Fuel Fabrication Process	101
• Fuel Cladding.....	102
• End Plugs or Caps.....	102
• Fuel Rods.....	102
• Spacer Grids.....	103
• BWR Water Rods/Channels	103
• BWR Fuel Channels	103
• PWR Guide Tubes/Thimbles and Instrument Tubes	104
• End Fittings.....	104
• Construction of the Assembly	104
Zirconium Tubing & BWR Channel Supply to Fabricators	106
• Argentina.....	106
• Brazil.....	106
• Canada	106
• China.....	106
• France.....	106
• Germany	106
• India	107
• Japan	107
• Kazakhstan	107
• South Korea	107
• Romania.....	107
• Russia	108
• Spain.....	108
• Sweden.....	108
• United Kingdom	108
• United States	108
5 – Nuclear Zirconium Supply & Demand Analysis	109
UxC Nuclear Zirconium Demand Modeling.....	109
• Unaccounted for Zirconium Demand	110
UxC Nuclear Zirconium Supply Forecasting	111
Global Supply and Demand for Nuclear-Grade Zirconium Sponge	112
• Zirconium Sponge Demand Forecasts	112
• Zirconium Sponge Supply Forecast.....	113
Global Supply and Demand for Nuclear-Grade Zirconium Alloys	115
• Zirconium Alloy Demand Forecasts.....	115
• Zirconium Alloy Supply Forecast	116
Global Supply and Demand for Zirconium Tubing	117
• Zirconium Tubing Demand Forecasts.....	117
• Zirconium Tubing Supply Forecast	118
Regional Demand and Supply Considerations	120
• Regional Demand Distributions	121
Zirconium Alloy.....	121
Zirconium Tubing.....	122
• Analysis of Regional Supply	123
Zirconium Alloy	123
Zirconium Tubing.....	124
Reactor Type Demand and Supply Considerations	125
• Reactor Type Demand Distributions	125
Zirconium Alloy	125
Zirconium Tubing.....	126
• Analysis of Reactor Type Zirconium Supply and Demand.....	127
6 – Overall Conclusions & Market Analysis	128
Influence of Zircon and ZOC Prices.....	128
Nuclear Zirconium Alloy Market in the Energy Transition	130
Emerging Market Issues	132
• Government Policies and Trade Actions.....	132

- Impact of Advanced Fuels and Claddings..... 133
- The Growing Hafnium Market 135
- Nuclear Zirconium Alloy Market Trends and Outlook..... 136
- Nuclear-Grade Zirconium Prices 137
- Appendix A: Zirconium Weight Calculations for Fuel Assemblies _____ 139**
- Appendix B: UxC Nuclear Power Forecasts _____ 140**
 - UxC Base Case Reactor Forecast 140
 - Alternative UxC Reactor Forecast Cases..... 142
- Appendix C: UxC Nuclear Power Regions _____ 143**
- Appendix D: Statistics on Reactor Technologies and Vendors _____ 144**
- Appendix E: Websites of Nuclear Zirconium Companies _____ 146**
 - Zirconium Sponge Companies 146
 - Zirconium Alloy Companies..... 146
 - Zirconium Tubing Companies 147
- Glossary _____ 148**

List of Figures

Figure 1. Nuclear Zirconium Manufacturing Overview	8
Figure 2. Zircon Sand	13
Figure 3. Microphotograph of Zircon Sand	13
Figure 4. Countries with Major Zirconium Resources	14
Figure 5. Applications for Zirconium Materials	15
Figure 6. Manufacture of Zirconium Products	16
Figure 7. Historical Demand for Zircon by End Use (1970-2010)	17
Figure 8. Zircon Utilization in 2020	17
Figure 9. Zircon Mining Process	24
Figure 10. Zircon Mining Pond	24
Figure 11. Zircon Mining Dredging Operations	25
Figure 12. World Zirconium Reserves Distribution, 2022	27
Figure 13. World Zirconium Mine Production Distribution, 2022	28
Figure 14. Zirconium Mineral Concentrates Production, 2000-2022	28
Figure 15. Zirconium Mineral Concentrates Production by Supplier in 2022	29
Figure 16. Global Zircon Consumption, Actual and Forecast, Circa 2012	33
Figure 17. Global Zircon Consumption, 2010-2016	34
Figure 18. Zircon Supply vs. Demand Forecast, 1990-2020, Circa 2010	36
Figure 19. Zircon Supply vs. Demand, 2013-2023	37
Figure 20. COVID-19 Impacts on Zircon Supply & Demand	37
Figure 21. Zircon Price Trends, 2011-2022	39
Figure 22. Typical Zirconium Sponge Production Process	42
Figure 23. Examples of Nuclear-Grade Zirconium Sponge	45
Figure 24. Nuclear Zirconium Alloy Manufacturing Process	46
Figure 25. Nuclear Zirconium Alloy Ingot Production	47
Figure 26. Typical Zirconium Alloy Sheet	47
Figure 27. Typical PWR Fuel Assembly Spacer Grid	48
Figure 28. Typical Zirconium Alloy Bar Stock	48
Figure 29. Typical Zirconium Tube-Reduced Extrusions (TRES)	49
Figure 30. Pilgering Process	50
Figure 31. Schematic of the Pilgering Process	50
Figure 32. Zirconium Alloy Nuclear Fuel Cladding	51
Figure 33. Typical BWR (left) and PWR (right) Fuel Assemblies	51
Figure 34. Nuclear Zirconium Sponge Producer Capacity Shares	53
Figure 35. First Nuclear-Grade Zirconium Sponge Produced at SNZ's Nantong Plant	54
Figure 36. CNNC Jinhuan Nuclear Zirconium Sponge Readied for Export to Russia	56
Figure 37. Framatome's Zirconium Division	57
Figure 38. ATI-SAC Production Facility in Oregon, USA	64
Figure 39. Nuclear Zirconium Alloy Producer Capacity Shares	67
Figure 40. Zirconium Alloy Fabrication at India's NFC	71
Figure 41. Nuclear Zirconium Alloy Tubing Manufacturer Capacity Shares	76
Figure 42. Worker Inspecting Zirconium Tubes at CAST Plant	78
Figure 43. Nuclear Tubing Fabrication Process at KNF	83
Figure 44. Worldwide LWR Fabrication Supply and Demand, 2008-2040	97
Figure 45. Typical BWR Fuel Assemblies	101
Figure 46. Typical PWR Fuel Assembly	102
Figure 47. Typical Fuel Rod	103
Figure 48. Typical PWR (left) and BWR (right) Skeletons/Cages	105
Figure 49. UxC Projection of Global Zirconium Sponge Demand, 2008-2040	112

Figure 50. Nuclear Zirconium Sponge Supply vs. Demand, 2008-2040	114
Figure 51. UxC Projection of Global Zirconium Alloy Demand, 2008-2040	115
Figure 52. UxC Global Zirconium Alloy Supply vs. Demand, 2008-2040.....	116
Figure 53. UxC Projection of Global Zirconium Tubing Demand, 2008-2040.....	117
Figure 54. UxC Global Zirconium Tubing Supply vs. Demand, 2008-2040	118
Figure 55. Regional Distribution of Zirconium Alloy Demand, 2008-2040	121
Figure 56. Regional Distribution of Zirconium Tubing Demand, 2008-2040	122
Figure 57. Regional Distribution of Zirconium Alloy Supply	123
Figure 58. Regional Distribution of Zirconium Tubing Supply	124
Figure 59. Reactor Type Distribution of Zirconium Alloy Demand, 2008-2040.....	125
Figure 60. Reactor Type Distribution of Zirconium Tubing Demand, 2008-2040.....	126
Figure B-1. UxC Nuclear Generating Capacity Forecast, 2008-2040	140
Figure B-2. UxC Base, High, and Low Case Nuclear Capacity Forecasts, 2008-2040	142
Figure C-1. Map of NPO Countries by Region	143
Figure D-1. Percentages of Different Operating Reactor Types	144
Figure D-2. Percentages of New Reactor Types, 2023-2030	145
Figure D-3. Percentages of New Reactor Vendors, 2023-2030.....	145

List of Tables

Table 1. Chemical Composition of Principal Zr Alloys (%)	19
Table 2. TVEL's Zirconium Alloys.....	21
Table 3. Chemical Composition of HANA™ Alloys	22
Table 4. World Zirconium Mine Production and Reserves	27
Table 5. New Zircon Mining Projects.....	31
Table 6. World Nuclear Zirconium Sponge Producers	53
Table 7. World Zirconium Alloy, Plate, Sheet, Bar Stock & TREX Producers	66
Table 8. World Nuclear Zirconium Alloy Tubing Manufacturers	75
Table 9. Worldwide LWR Fuel Fabrication Capacity in 2023.....	96
Table 10. UxC Projection of Global Zirconium Sponge Demand, 2022-2040.....	112
Table 11. UxC Projection of Global Zirconium Alloy Demand, 2022-2040	115
Table 12. UxC Projection of Global Zirconium Tubing Demand, 2022-2040	117
Table 13. Regional Distribution of Zirconium Alloy Demand, 2022-2040	121
Table 14. Regional Distribution of Zirconium Tubing Demand, 2022-2040	122
Table A-1. Zirconium Alloy Weight and Tubing Calculations for Fuel Assembly Designs	139
Table B-1. Reactor Units & Nuclear Capacities Anticipated by Country by 2040	141
Table B-2. UxC Base, High, and Low Case Nuclear Reactor and Capacity Forecasts, 2022-2040.....	142
Table C-1. List of NPO Countries by Region.....	143
Table D-1. Operating Reactor Types in November 2023	144
Table D-2. New Reactor Types, 2023-2030.....	144
Table D-3. New Reactor Vendors, 2023-2030	145
Table F-1. Glossary of Terms.....	148

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.

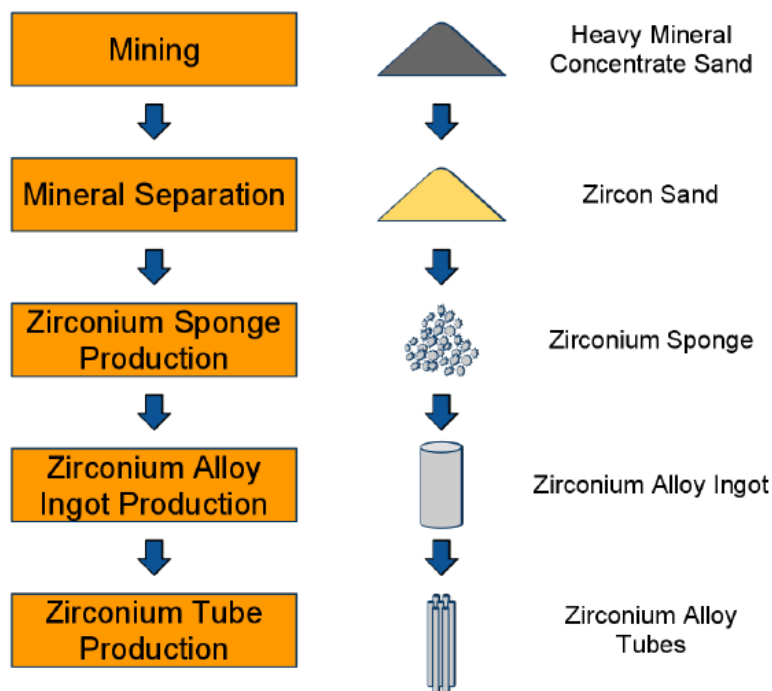
The supply of nuclear-grade zirconium alloys – from the mining of zircon mineral sand through the manufacture of cladding and other components used in finished nuclear fuel assemblies – has not escaped this scrutiny. Therefore, the primary objective of this report is to factually and analytically approach 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.

Structure of the Report

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.