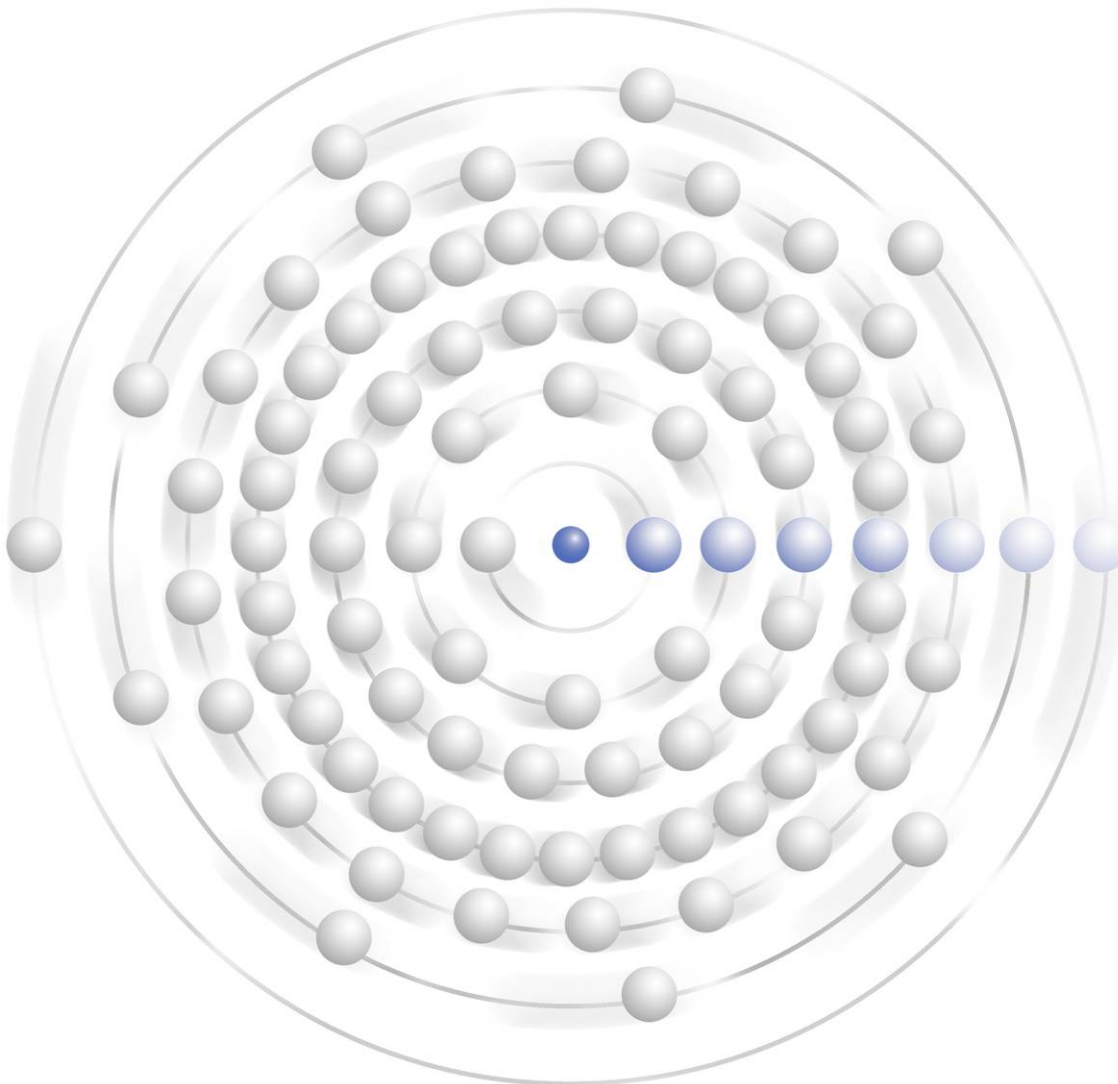




# Nuclear Zirconium Alloy Market



**– NOTICE –**

The Ux Consulting Company, 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.

# Table of Contents

<b>1 – Introduction &amp; Overview</b>	<b>5</b>
Availability of Data.....	5
Structure of the Report.....	6
<b>2 – General Zirconium Overview</b>	<b>8</b>
Occurrence.....	8
General Uses.....	9
• Zirconium Metals.....	10
Nuclear Applications.....	11
Zircon Resources and Production.....	12
Zircon Consumption and Prices.....	16
• Consumption of Zircon.....	16
• Market Dynamics.....	17
• Zircon Prices.....	18
• Other Zirconium Pricing Data.....	19
• Looking Forward.....	20
<b>3 – Manufacturing Processes for Nuclear Fuel Cladding</b>	<b>21</b>
Production of Zirconium Sponge.....	21
• Zircon Sand Processing and Hafnium Removal.....	21
• Final Sponge Production.....	22
Manufacture of Zirconium Alloy Ingots.....	23
Manufacture of Zirconium Alloy Plate, Sheet, Bar Stock, and Tube-Reduced Extrusions (TRES).....	23
Production of Nuclear Fuel Tubing.....	26
<b>4 – Nuclear Zirconium Alloy Materials &amp; Product Suppliers</b>	<b>28</b>
Zirconium Sponge Producers.....	29
• China.....	30
State Nuclear Baoti Zirconium Industry Company, Ltd. (SNZ).....	30
Chaoyang Baisheng Zirconium Company (CBZC).....	30
Other Chinese Facilities.....	30
• France.....	31
Compagnie Européenne du Zirconium Cezus, S. A. (CEZUS).....	31
• India.....	32
Nuclear Fuel Complex (NFC).....	32
• Russia.....	33
Chepetsky Mechanical Plant (CMP).....	33
• Ukraine.....	33
Zirconium.....	33
• United States.....	34
ATI Wah Chang.....	34
Western Zirconium (WZ).....	35
Producers of Zirconium Alloy Plate, Sheet, Bar Stock, and TRES.....	35
• Argentina.....	37
Fabricación de Aleaciones Especiales, SA (FAE).....	37
• Canada.....	37
Cameco Fuel Manufacturing, Inc. (CFMI).....	37
• China.....	37
State Nuclear Baoti Zirconium Industry Company, Ltd. (SNZ).....	37
Other Chinese Facilities.....	38
• France.....	38
Compagnie Européenne du Zirconium Cezus, S.A. (CEZUS).....	38
• India.....	39
Nuclear Fuel Complex (NFC).....	39
• Korea.....	39
POSCO.....	39
• Russia.....	40

Chepetsky Mechanical Plant (CMP).....	40
• United States .....	40
ATI Wah Chang.....	40
Western Zirconium (WZ).....	41
Zirconium Alloy Scrap Recycle.....	41
Manufacturers of Nuclear Fuel Tubing.....	41
• Argentina.....	43
Fabricación de Aleaciones Especiales, SA (FAE).....	43
• Canada .....	43
General Electric Hitachi Nuclear Energy Canada (GEH Canada).....	43
Cameco Fuel Manufacturing, Inc. (CFMI).....	43
• China.....	43
State Nuclear Baoti Zirconium Industry Company, Ltd. (SNZ).....	43
Other Chinese Facilities .....	43
• France.....	44
Compagnie Européenne du Zirconium Cezus, S.A. (CEZUS).....	44
• Germany .....	44
Compagnie Européenne du Zirconium Cezus, S.A. (CEZUS).....	44
• India .....	44
Nuclear Fuel Complex (NFC).....	44
• Japan .....	45
Mitsubishi Materials Corporation (MMC).....	45
Zirco Products.....	45
• Korea.....	46
Korea Nuclear Fuel Company (KNFC).....	46
• Russia .....	46
Chepetsky Mechanical Plant (CMP).....	46
• Sweden .....	46
Sandvik Materials Technology (SMT) .....	46
• United Kingdom .....	47
Fine Tubes, Ltd. ....	47
New Metals and Chemicals, Ltd. (NewMet) .....	47
• United States .....	47
Global Nuclear Fuel-Americas (GNF) .....	47
Sandvik Special Metals Corporation (SSM) .....	48
Veridiam.....	48
Westinghouse Specialty Metals Plant (SMP).....	48
Possible Future Developments .....	49
<b>5 – Nuclear Fuel Fabricators &amp; Zircaloy Tubing Supply .....</b>	<b>50</b>
Fabrication Market Overview.....	50
Key Players .....	51
• AREVA.....	51
• Global Nuclear Fuel .....	51
• Westinghouse Electric Company .....	52
• National and Regional Fuel Suppliers.....	52
Supply & Demand .....	53
Market Dynamics.....	56
Zircaloy Tubing & BWR Channel Supply to Fabricators.....	57
• Argentina.....	57
• Belgium .....	57
• Brazil .....	57
• Canada .....	57
• China.....	57
• France.....	58
• Germany .....	58
• India .....	58
• Japan .....	58
• Korea.....	58
• Romania.....	59

• Russia .....	59
• Spain .....	59
• Sweden .....	59
• United States .....	59
<b>6 – Nuclear Zirconium Supply &amp; Demand Analysis</b> .....	<b>60</b>
UxC Nuclear Zirconium Demand Modeling .....	60
• Unaccounted for Zirconium Demand .....	61
Supply and Demand for Nuclear-Grade Zirconium Alloy .....	62
• Comparison with Global Alloy Supply .....	63
Supply and Demand for Zirconium Alloy Tubing .....	64
• Comparison with Global Tubing Supply .....	65
Regional Supply and Demand Balances .....	66
• Regional Demand Distributions .....	66
Zirconium Alloy .....	66
Zircaloy Tubing .....	67
• Analysis of Regional Supply and Demand Balances .....	68
Selected Country Supply and Demand Balances .....	70
• United States .....	70
• Russia .....	72
• China .....	73
• India .....	75
Reactor Type Supply and Demand Balances .....	77
• Reactor Type Demand Distributions .....	77
Zirconium Alloy .....	77
Zircaloy Tubing .....	78
• Analysis of Reactor Type Supply and Demand Balances .....	78
<b>7 – Overall Conclusions &amp; Market Analysis</b> .....	<b>79</b>
Nuclear-Grade Zirconium Prices .....	80
<b>Appendix A: Zirconium Weight Calculations for Fuel Assemblies</b> .....	<b>81</b>
<b>Appendix B: UxC Nuclear Power Forecasts</b> .....	<b>82</b>
UxC Base Case Reactor Forecast .....	82
Alternative UxC Reactor Forecast Cases .....	85
<b>Appendix C: UxC Nuclear Power Regions</b> .....	<b>86</b>
<b>Appendix D: Statistics on Reactor Technologies and Vendors</b> .....	<b>87</b>

## List of Figures

Figure 1. Zircon Sand .....	8
Figure 2. Countries with Major Zirconium Resources .....	9
Figure 3. Zirconium End Uses by Sector, 2008 & 2012 .....	10
Figure 4. World Zirconium Reserve Base Distribution, 2009 .....	14
Figure 5. World Zirconium Mine Production Distribution, 2009 .....	15
Figure 6. Zr Mineral Concentrates Production, 2000-2009 .....	15
Figure 7. Regional Zircon Consumption Trends (1990-2015) .....	16
Figure 8. Zircon End-Use Consumption Trends (1990-2015) .....	17
Figure 9. Zr Mineral Concentrates Prices, 2005-2011 .....	19
Figure 10. Typical Zirconium Sponge .....	22
Figure 11. Typical Zirconium Alloy Sheet .....	24
Figure 12. Typical BWR Fuel Assembly Spacer Grid .....	24
Figure 13. Typical Zirconium Alloy Bar Stock .....	25
Figure 14. Typical Zirconium Tube-Reduced Extrusions (TRES) .....	25

Figure 15. Pilgering Process .....	26
Figure 16. Schematic of the Pilgering Process .....	27
Figure 17. Zirconium Alloy Nuclear Fuel Cladding .....	27
Figure 18. Nuclear Zirconium Sponge Producer Capacity Shares .....	29
Figure 19. Nuclear Zirconium Alloy Producer Capacity Shares .....	36
Figure 20. Nuclear Zirconium Alloy Tubing Manufacturer Capacity Shares .....	42
Figure 21. UxC LWR Fuel Fabrication Supply & Demand Forecast, 2008-2030 .....	54
Figure 22. UxC Estimates for Global Zirconium Alloy Demand, 2008-2030 .....	62
Figure 23. UxC Estimates for Global Zircaloy Tubing Demand, 2008-2030 .....	64
Figure 24. Regional Distribution of Zirconium Alloy Demand, 2008-2030 .....	67
Figure 25. Regional Distribution of Zircaloy Tubing Demand, 2008-2030 .....	68
Figure 26. Regional Distribution of Zirconium Alloy Supply .....	69
Figure 27. Regional Distribution of Zircaloy Tubing Supply .....	69
Figure 28. U.S. Zirconium Alloy Demand, 2008-2030 .....	71
Figure 29. U.S. Zircaloy Tubing Demand, 2008-2030 .....	71
Figure 30. Russia Zirconium Alloy Demand, 2008-2030 .....	72
Figure 31. Russia Zircaloy Tubing Demand, 2008-2030 .....	73
Figure 32. China Zirconium Alloy Demand, 2008-2030 .....	74
Figure 33. China Zircaloy Tubing Demand, 2008-2030 .....	74
Figure 34. India Zirconium Alloy Demand, 2008-2030 .....	75
Figure 35. India Zircaloy Tubing Demand, 2008-2030 .....	76
Figure 36. Reactor Type Distribution of Zirconium Alloy Demand, 2008-2030 .....	77
Figure 37. Reactor Type Distribution of Zircaloy Tubing Demand, 2008-2030 .....	78
Figure B-1. UxC Nuclear Generating Capacity Forecast, 2008-2030 .....	82
Figure B-2. UxC Base, High, and Low Case Nuclear Capacity Forecasts, 2008-2030 .....	85
Figure C-1. Map of NPO Countries by Region .....	86
Figure D-1. Percentages of Different Operating Reactor Types .....	87
Figure D-2. Percentages of New Reactor Types, 2009-2020 .....	88
Figure D-3. Percentages of New Reactor Vendors, 2009-2020 .....	88

## List of Tables

Table 1. Chemical Composition of Principal Zr Alloys (%) .....	12
Table 2. World Zirconium Mine Production, Reserves, and Reserve Base .....	14
Table 3. Leading Zircon Producers .....	16
Table 4. World Nuclear Zirconium Sponge Producers .....	29
Table 5. Chinese Zirconium Processing Industry .....	31
Table 6. World Zirconium Alloy Plate, Sheet, Bar Stock & TREX Producers .....	36
Table 7. World Nuclear Zirconium Alloy Tubing Manufacturers .....	42
Table 8. Current Worldwide LWR Fabrication Capacity .....	53
Table 9. UxC Estimates for Global Zirconium Alloy Demand, 2008-2020 .....	62
Table 10. UxC Estimates for Global Zircaloy Tubing Demand, 2008-2020 .....	64
Table 11. Regional Distribution of Zirconium Alloy Demand, 2008-2020 .....	67
Table 12. Regional Distribution of Zircaloy Tubing Demand, 2008-2020 .....	68
Table A-1. Zirconium Alloy Weight and Tubing Calculations for Fuel Assembly Designs .....	81
Table B-1. Reactor Units & Nuclear Capacities Anticipated by Country by 2030 .....	83
Table B-2. UxC Base, High, and Low Case Nuclear Reactor and Capacity Forecasts, 2008-2020 .....	85
Table D-1. Operating Reactor Types .....	87
Table D-2. New Reactor Types, 2009-2020 .....	87
Table D-3. New Reactor Vendors, 2009-2020 .....	88

## 1 – Introduction & Overview

In November 2008, The Ux Consulting Company (UxC), a leading nuclear fuel market consultancy, published a Special Report on the Nuclear Zirconium Alloy Market. That report was intended to be a one-of-a-kind snapshot of the contemporary zirconium alloy industry.

However, the highly favorable response to that original report convinced us that there was a need and desire for an update and expansion of that effort. That has been accomplished and our latest findings and conclusions are presented herein.

Nuclear-grade zirconium alloys and components are employed in the fabrication of fuel assemblies used in the vast majority of nuclear reactor designs currently operating, under construction, and planned around the world. As the nuclear renaissance takes hold to varying degrees in countries all over the globe, many questions about the international nuclear fuel supply chain have arisen. The supply of nuclear-grade zirconium alloys – from the mining of zircon mineral sand through the manufacture of cladding and components used in finished 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 to help arrive at some clear conclusions about how producers of fuel assemblies for nuclear reactors will obtain the necessary zirconium alloys for their finished products.

This updated report 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. Additional details are included on the interplay of the nuclear fuel fabrication and the zirconium alloy supply markets. We then identify major trends in this unique industry by analyzing the global, regional, and selected country supply and demand balances for nuclear-grade zirconium alloy and tubing. We conclude with some final observations on the global market as well as expectations for future price developments for the related zirconium alloys and tubing.

### Availability of Data

---

During the preparation of the original report, it became clear that, in general, the various processors and fabricators of nuclear-grade zirconium sponge, alloys, and fuel assembly components were reluctant to publish or even discuss the details of their businesses. Much of their information is considered proprietary and thus restricted from inclusion in reports such as this. Consequently, in the prior report, there were some gaps in the data.

It has been suggested that one reason for this reticence is the concern among zirconium alloy producers and processors that with the expected increase in demand resulting from the nuclear renaissance, new competitors might decide to enter the nuclear-grade zirconium business.

Nonetheless, in the period since the original report was published, we have been able to develop additional sources and to fill in a number of the blanks. Thus, we believe that this report provides a significantly more comprehensive and more accurate picture of the industry than the earlier document.

To supplement the data collection process, we provided each of the principal processors and producers with a draft of the portion of the report that described their operations. If corrections were received, the appropriate changes were made in the text. If our data were confirmed, or if no response was forthcoming, the original language, based on the best information available from public and private sources, was used. Where possible, we confirmed data from one source with a second, independent source.

We believe that this information is accurate or at least representative of the operations, production levels, etc. of the companies discussed in the succeeding chapters of the report. However, the possibility still exists that there may be some errors or that the information has changed since the data were obtained. In a few cases, there were no available non-proprietary data, and, therefore, the missing information is listed as “not available” in the affected data tables.

Another significant improvement on the previous report is the demand analysis and forecasts for zirconium alloy and tubing. This new report incorporates detailed UxC calculations of the zirconium weight and tube content in all the major nuclear fuel assemblies in the world. Moreover, the forecasts presented in the report make use of UxC’s recently developed UxC Requirements Model (URM) to forecast global reactor fuel loading requirements and consequent 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 fuel assemblies. This has resulted in a far more accurate presentation than that used previously.

## Structure of the Report

---

This report includes separate chapters for various aspects of the nuclear-grade zirconium alloy market, supply and demand, and other related areas. Following this **Chapter 1 – Introduction & Overview**, the report includes:

**Chapter 2 – General Zirconium Overview** provides a broad summary of the zirconium mineral occurrence, resource base, and industrial applications, including the role of zirconium alloy production for the nuclear fuel industry. This discussion helps to put the specific nuclear-grade zirconium alloy market analysis in better perspective, as there are numerous applications for the zirconium mineral beyond nuclear reactor fuel. Additional discussion is provided on the broader global market for zircon and how this impacts the specific nuclear-grade zirconium alloy market.



**Chapter 3 – Manufacturing Processes for Nuclear Fuel Cladding** discusses the manufacturing processes and the overall “zirconium cycle” for production of the materials and components used in nuclear fuel assemblies.

**Chapter 4 – Nuclear Zirconium Alloy Materials & Product Suppliers** offers 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 zirconium sponge and alloy production and processing through manufacture of sheet, plate, bar stock, and tube-reduced extrusions (TRES), as well as tubing and other component manufacture.

**Chapter 5 – Nuclear Fuel Fabricators & Zircaloy Tubing Supply** provides a brief overview of the global nuclear fuel fabrication business and indicates the source of each fabricator’s fuel assembly tubing and other components.

**Chapter 6 – Nuclear Zirconium Supply & Demand Analysis** offers UxC’s analysis of the global supply and demand balance for nuclear fuel-related zirconium alloy products. In addition, this chapter includes regional breakdowns as well as supply and demand discussions for some of the key countries in the nuclear zirconium market. Finally, zirconium demand based on the different reactor types is also analyzed.

**Chapter 7 – Overall Conclusions & Market Analysis** completes our nuclear-grade zirconium market analysis with some final thoughts on the current situation and forecast of future trends, as well as current nuclear-grade zirconium alloy prices and expectations for future price developments.

A number of additional relevant items are included in the attached **Appendices**.