



Global Nuclear Fuel Inventories



– 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
Purpose of Report	7
What's New in the 2022 Edition?	8
Structure of Report	8
1 – Inventories in Context	10
Fundamentals of Inventories	10
• The Nuclear Fuel Cycle	10
• Forms of Inventories	12
• Inventory Holders	13
Utility Inventories	14
• Types of Inventories	14
Pipeline	14
Strategic	14
Other	14
• Brief History of Regional Utility Inventories	15
United States	15
Europe	16
Japan	17
China, Russia, South Korea, and India	17
Supplier Inventories	18
Government Inventories	20
• United States	20
• Russia	20
Inventories and the Market	21
Other Inventory Developments	25
• Financial Inventories	25
• Nuclear Fuel Banks	26
Inventories Created by Excess Enrichment Capacities	27
2 – Assessing Current Inventories: Utilities	28
United States	28
• Current Inventory Levels	28
Analysis of Recent EIA Data	30
• Individual Utility Data	30
• Inventory Changes Since 2020 Report	32
• Location of Inventories	32
• Forward Coverage	32
• Impact of Reactor Shutdowns	33
• Future Outlook	33
European Union	35
• Current Inventory Levels	35
• Individual EU Country and Utility Profiles	36
France – EDF	37
Sweden – Vattenfall & Uniper	37
Spain – ENUSA (Endesa, Iberdrola, & Naturgy)	37
Belgium – Synatom (Electrabel)	38
Finland – TVO & Fortum	38
Germany – RWE, Preussen Elektra, & EnBW	38
Netherlands – EPZ	39
Czech Republic – CEZ	39
Slovakia – Slovenské Elektrárne	39
Romania – SNN	39
Hungary – MVM Paks	39
Bulgaria – Kozloduy	40
• Inventory Changes Since 2020 Report	40
• Location of Inventories	40
• Forward Coverage	40
• Impact of Reactor Shutdowns	41

• Future Outlook	42
Japan.....	43
• Current Inventory Levels	43
• Inventory Changes Since 2020 Report	45
• Location of Inventories	46
• Forward Coverage	46
Impact of Future Fuel Deliveries	50
• Future Outlook	50
Future of Japan's Closed Nuclear Fuel Cycle	53
China.....	54
• Current Inventory Levels	54
Inventory Forms	56
Total Inventory Quantities	57
• Inventory Changes Since 2020 Report	57
• Location of Inventories	58
• Forward Coverage	58
• Future Outlook	59
Future Uranium Imports	61
Future of Inventories	63
Other Utilities.....	64
• United Kingdom – EDF Energy	64
• South Korea – Korea Hydro and Nuclear Power (KHNP)	65
• Russia – Rosenergoatom.....	65
• Canada – Bruce Power, OPG, and NB Power.....	66
• Ukraine – Energoatom	66
• India – Nuclear Power Corporation of India Ltd. (NPCIL)	67
• Others	68
Taiwan – Taipower.....	68
Switzerland – Axpo & KKG	69
Mexico – CFE.....	69
Brazil – Eletronuclear & INB.....	69
Argentina – NA-SA & Dioxitek.....	69
South Africa – Eskom.....	70
UAE – ENEC.....	70
Pakistan – PAEC.....	71
Iran – Bushehr NPP	71
Belarus – Belenergo.....	71
Armenia – Metzamor NPP	71
• Inventory Changes Since 2020 Report	72
• Summary.....	73
3 – Assessing Current Inventories: Suppliers & Intermediaries	74
Suppliers	74
• U.S. Supplier Data	74
• Orano	76
• Cameco.....	76
• Urenco.....	77
• Russian Suppliers: ARMZ, Uranium One, TENEX, and TVEL	78
ARMZ.....	78
Uranium One.....	78
TENEX	78
TVEL.....	79
• Kazatomprom.....	80
• Navoi Mining and Metallurgical Combine.....	81
• Fabricators – Framatome, Westinghouse, GNF, KEPCO, etc.	81
• Other Suppliers	82
Junior Miner Purchases of Spot Uranium.....	83
Traders and Financials.....	84
• Brokers.....	84
• Traders.....	84
• Banks	85

• Hedge Funds	86
• Publicly Traded Uranium Funds.....	87
Sprott Physical Uranium Trust (SPUT)	87
Yellow Cake plc (YCA)	88
Uranium Royalty Corporation (URC)	88
ANU Energy Ltd.....	89
Summary of Investment Fund Holdings.....	89
Summary.....	90
• Inventory Changes Since 2020 Report	90
• Future Outlook	90
4 – Assessing Current Inventories: Governments & Others	91
United States Government.....	91
• Highly Enriched Uranium	93
HEU Downblending Offering for Tritium (DBOT)	93
• U.S. and Russian-Origin Natural UF ₆	94
• Off-Spec UF ₆ and Non-UF ₆	95
• Depleted Uranium as UF ₆	96
Depleted Uranium – 2012 Program	97
Depleted Uranium – Global Laser Enrichment (GLE).....	97
• Other U.S. Inventory Categories.....	98
Plutonium	98
MOX Backup Inventory Program	99
• Uranium Reserve & Other Inventory Building Initiatives	99
Uranium Reserve.....	100
LEU Production Initiative	100
HALEU Production Initiative	101
• Disposition of Excess U.S. Government Inventories	102
UxC Forecasts for U.S. Government Inventory Disposition	103
• Summary.....	103
Russian Government	105
• Reprocessed Uranium	105
• Slightly Irradiated Uranium.....	106
• Highly Enriched Uranium	107
HEU Feed Monitored Inventory	108
• Plutonium	108
• Depleted Uranium	110
• Summary.....	111
Multilateral Security of Supply Mechanisms: Fuel Banks.....	113
• Russia’s Fuel Bank	113
• American Assured Fuel Supply.....	114
Potential Expansion of AAFS.....	114
• IAEA Fuel Bank.....	115
• Summary.....	115
Other Inventories.....	116
• Excess Military and Civilian Separated Plutonium.....	116
• Reprocessed Uranium	118
France	118
Japan.....	119
UK	119
Others.....	120
• Iran.....	120
5 – Market Analysis and Global Forecasts	122
Total Global Inventories	122
• Changes in Totals Since 2020 Report	123
Factors Contributing to Current Inventory Conditions	125
• Legacy of a Thwarted Nuclear Renaissance	125
• Shifting Market Mentality.....	125
• Reduction Cutbacks Leading to Inventory Work-Off.....	126
• Excess Inventories Shifting Hands	126
Pipeline vs. Strategic vs. Excess Inventories	127

- Utilities..... 127
 - Regional Utility Analysis..... 128
- Suppliers 128
- Traders and Financials..... 129
- Governments..... 129
- Summary..... 129
- Inventory Mobility 130
 - Forms of Inventories 130
 - Locations of Inventories 131
 - Holders of Inventories 132
 - Other Considerations 132
 - Mobility of Japanese Inventories..... 132
- Market Shocks Affecting Inventories since 2020..... 134
 - Potential for Additional Inventory Buying 134
 - Potential for Additional Inventory Disposition..... 134
- Security of Supply vs. Costs..... 135
- National Security Policies Influencing Inventory Levels 136
- Uranium Inventory Forecasts and Market Analysis..... 137
 - Inventory Growth vs. Disposition 137
 - Inventory Growth..... 137
 - Inventory Disposition..... 137
 - UxC Forecasts 138
 - Base Case 138
 - Utility Forecast..... 138
 - Global Forecast..... 139
 - High Case 141
 - Low Case 142
 - Market Analysis..... 143
 - China’s Outsized Global Role 144
- Conversion Inventory Forecasts and Market Analysis 145
 - UxC Forecasts 145
 - Base Case 145
 - High and Low Cases 146
 - Market Analysis..... 147
- Enrichment Inventory Forecasts and Market Analysis 148
 - Inventory Forecasts..... 148
 - Base Case 148
 - High and Low Cases 149
 - Market Analysis..... 150
- Government Inventory Disposition Forecast 151
 - U.S. Government Dispositions 151
 - Russian Government Dispositions 152
 - Uranium Disposition Forecasts 153
 - Base Case 153
 - High and Low Cases 153
 - Conversion Market Impacts 154
 - Enrichment Disposition Forecasts..... 155
 - Market Analysis..... 156
- A Future of Persistent High Inventories?..... 157
- Long-Term Market Outlook 159
- 6 – Summary and Conclusions 160**

List of Figures

Figure 1. The LWR Nuclear Fuel Cycle.....	10
Figure 2. U.S. Inventory Holdings, 1983-2021	15
Figure 3. EU Utility Inventory Holdings, 2005-2021	16
Figure 4. U.S. Supplier/Broker/Trader Inventory Holdings, 1987-2021.....	19
Figure 5. World Uranium Production, Requirements, and Prices, 1948-2022	21
Figure 6. Ux U ₃ O ₈ Spot Price, 2000-2022	23
Figure 7. Spot Purchases of Uranium, 1990-2022	23
Figure 8. Historical Buildup and Drawdown of Uranium Inventories, 1948-2020.....	24
Figure 9. SWU vs. Uranium Feed Requirements at Various Tails Assays	27
Figure 10. U.S. Utility Inventories by Form, 1983-2021	29
Figure 11. EU Utility Inventories, 2005-2021	35
Figure 12. Japanese Utility Nuclear Fuel Holdings, 2010-2022	45
Figure 13. UxC Forecast Scenarios for Japanese Reactor Restarts, 2015-2030.....	48
Figure 14. China Uranium Supply/Demand Balance, 2000-2021	55
Figure 15. China Nuclear Fuel Imports by Form, 2000-2021	56
Figure 16. China Uranium Imports by Country of Origin, 2001-2021	61
Figure 17. U.S. Supplier Inventories, 1987-2021	74
Figure 18. U.S. Supplier vs. Broker/Trader Inventories, 2004-2021	75
Figure 19. Composition of TENEX's Inventory Holdings, 2020 vs. 2019	79
Figure 20. SPUT Cumulative Uranium Holdings, July 2021-August 2022	87
Figure 21. Breakdown of DOE's Depleted UF ₆ Inventory.....	96
Figure 22. Slightly Irradiated Uranium (SIU) and Depleted SIU as Byproduct of Pu Production	106
Figure 23. Global Plutonium Inventories as of 2020	117
Figure 24. Global Civilian Plutonium Inventory Changes, 1945-2020.....	117
Figure 25. UxC Base Case Forecast for Global Uranium Inventories, 2008-2040	140
Figure 26. UxC High Case Forecast for Global Uranium Inventories, 2008-2040	141
Figure 27. UxC Low Case Forecast for Global Uranium Inventories, 2008-2040	142
Figure 28. UxC Base Case Utility Inventory Forecast without China, 2008-2035.....	144
Figure 29. UxC Base Case Forecast for Global Conversion Inventories, 2008-2040.....	146
Figure 30. UxC Base Case Forecast for Global Enrichment Inventories, 2008-2040.....	149
Figure 31. UxC Base Case Forecast for Government Inventories in U ₃ O _{8e} , 2008-2040.....	153
Figure 32. UxC Forecast Cases for Government Inventories in U ₃ O _{8e} , 2008-2040	154
Figure 33. UxC Base Case Forecast for Government Inventories in SWU, 2008-2040	155
Figure 34. UxC Estimates for Global Commercial Inventories, 2000-2021.....	157
Figure 35. UxC Estimates of Commercial Inventories by Holder, 2000-2021	158

List of Tables

Table 1. Examples of Past Nuclear Supply Chain Production Events	18
Table 2. U.S. Utility Inventories in 2021	29
Table 3. Recent Changes in U.S. Utility Inventories, 2018-2021	30
Table 4. U.S. Utility Nuclear Fuel Holdings Financial Values, 2012-2021	31
Table 5. U.S. Utility Forward Coverage Levels, 2010-2021	32
Table 6. EU Utility Inventories in 2021	36
Table 7. EDF Nuclear Fuel Inventory Financial Values, 2012-2021	37
Table 8. Vattenfall Nuclear Fuel Inventory Financial Values, 2012-2021	37
Table 9. TVO & Fortum Nuclear Fuel Inventory Financial Values, 2012-2021	38
Table 10. EU Utility Forward Coverage Levels, 2010-2021	40
Table 11. EU Reactor Closures, 2011-2021	41
Table 12. Anticipated EU Reactor Closures by 2030	41
Table 13. Japanese Utility Inventory Estimates as of Mid-2022	44
Table 14. Japanese Utility Inventories in 2022	45
Table 15. UxC Base Case Forecast for Japanese Reactors Operating by Utility, 2022-2037	47
Table 16. UxC Base Case Uranium Requirements Forecast for Japanese Utilities, 2022-2037	48
Table 17. Japanese Utility Inventories vs. Requirements, 2022-2037	49
Table 18. Chinese Uranium Inventory Growth, 2006-2021	55
Table 19. Chinese Utility Inventories in 2021	57
Table 20. UxC Forecast Scenarios for China, 2022-2040	60
Table 21. Total China Uranium Imports by Country, 2001-2021	61
Table 22. EDF Energy Nuclear Fuel Inventory Financial Values, 2012-2021	64
Table 23. Nuclear Fuel Inventory Estimates for Other Country Utilities as of 2022	73
Table 24. Cameco Inventory Holdings, 2016-2022	76
Table 25. TVEL Inventory Holdings	80
Table 26. Investment Fund Holdings in 2022	89
Table 27. Supplier & Investor Inventories in 2022	90
Table 28. Total Volumes of U.S. Government Inventories in 2022	92
Table 29. UxC Base Case Forecast for U.S. Government Inventory Disposition, 2022-2040	103
Table 30. Total Volumes of Russian Government Inventories in 2022	112
Table 31. Multilateral Security of Supply Mechanisms (Fuel Banks) in 2022	115
Table 32. Civilian Plutonium Inventories	116
Table 33. Total Global Nuclear Fuel Inventories as of 2022	122
Table 34. Volumetric Changes to Total Global Nuclear Fuel Inventories since 2020 Report	124
Table 35. Percentage Changes to Total Global Nuclear Fuel Inventories since 2020 Report	124
Table 36. Estimate for Global Desired Utility Inventories	127
Table 37. Estimate for Regional Desired Utility Inventories	128
Table 38. UxC Base Case Forecast for Global Utility Inventories, 2018-2035	139
Table 39. UxC Base Case Forecast for Global Uranium Inventories, 2018-2035	140
Table 40. UxC High Case Forecast for Global Uranium Inventories, 2018-2035	141
Table 41. UxC Low Case Forecast for Global Uranium Inventories, 2018-2035	142
Table 42. UxC Base Case Forecast for Global Conversion Inventories, 2018-2035	146
Table 43. UxC Base Case Forecast for Global SWU Inventories, 2018-2035	149
Table 44. UxC Base Case Forecast for Government Inventories in U ₃ O _{8e} , 2018-2035	153
Table 45. UxC Forecast Cases for Government Inventories in U ₃ O _{8e} , 2018-2035	154
Table 46. UxC Base Case Forecast for Government Inventories in SWU, 2018-2035	155

Introduction & Overview

UxC, LLC (UxC) is pleased to present our fourth edition of this special report on the topic of *Global Nuclear Fuel Inventories* (GNFI). The inaugural edition of this report, published in December 2015, represented a first-of-a-kind effort by UxC to assemble and categorize all the available information related to nuclear fuel inventories around the world and provide insights and analysis on this important topic. Since that first edition, UxC has continued to closely track the global market situation and specific issues related to inventories, and this latest 2022 edition further expands the work in the previous reports by providing updated data on global nuclear fuel inventories along with enhanced analysis of the latest trends related to these inventories.

There is perhaps no bigger issue to emerge in the nuclear fuel markets over the last decade than the growing influence of inventories, especially following the drop in global demand after the March 2011 Fukushima accident. This updated 2022 report presents UxC's detailed research and analysis on the topic of inventories to expand market understanding of this important issue and to provide expert forecasts regarding the future role that inventories will play in all the nuclear fuel market sectors.

Purpose of Report

There are many key questions surrounding the current state and future outlook nuclear fuel inventories. This report's primary objective is to provide comprehensive analyses and forecasts and respond to these and related questions. Some of the most critical questions that this report attempts to answer include the following:

- What are the total current inventory levels in each key region/country?
- Who holds these inventories and in what form?
- Where could we see future increases or reductions in inventories?
- How do current inventory levels compare to previous estimates?
- How much of these inventories is pipeline versus strategic?
- How much of these inventories can be considered “excess” or “unobligated?”
- What is the mobility of excess inventories and what factors affect how unwanted holdings may be sold or disposed of?
- What is the likely future course of disposition for government-held inventories?
- What is the potential future impact of these inventories on each of the three nuclear fuel component markets (uranium, conversion, and enrichment)?
- What critical market conditions will influence the state of inventories over the long-term?

What's New in the 2022 Edition?

With this fourth edition of the GNFI report, we have made several important enhancements and added new items to address the current market conditions, including:

- Updated data and analysis of all utility, supplier, trader/financial, and government inventory levels.
- Provided new insights into the level of utility forward coverage rates and how these may evolve in the coming years.
- Included detailed reviews of nuclear fuel inventory-related financial data of individual utilities from the past ten years.
- Updated individual profiles of EU nuclear power countries given unique differences among each in terms of inventory policies and utility approaches.
- Revised forecasts for future inventory buying and disposition and how these look for each of the uranium, conversion, and enrichment sectors.
- Added new insights into how financial-led buying of uranium by investment funds and junior miners has impacted the inventory situation.
- Updated our analysis of U.S. and Russian government stockpiles and their likely future usage.
- Updated a section on international fuel banks to highlight the unique role that these sequestered pockets of material play in the global nuclear industry.
- Increased analysis of the market impacts of inventories and key considerations for all market players for all three fuel cycle component sectors.
- Added new analysis on the role of inventories in the face of supply risks, including recent supply shocks and rising market uncertainties due to the COVID-19 pandemic and Russia's invasion of Ukraine.

Structure of Report

In addition to this **Introduction & Overview**, the report includes the following four chapters:

Chapter 1 – Inventories in Context introduces the key factors that frame the topic of nuclear fuel inventories, including historical perspectives and important market considerations. The chapter also briefly covers the main types of inventories and their holders as well as some of the primary reasons for the current excess inventory supply situation.

The next three chapters include the bulk of the research information compiled for this report. Detailed examinations of each of the inventory holding groups are presented,

including current inventory levels, forward coverage, and future needs for inventories, as well as potential future disposition trends. These chapters proceed as follows:

Chapter 2 – Assessing Current Inventories: Utilities, which includes detailed inventory discussions of nuclear power plant operators in all major countries and regions around the world.

Chapter 3 – Assessing Current Inventories: Suppliers & Intermediaries, which focuses on inventories held by major nuclear fuel suppliers and other market participants, such as from the trading and financial communities.

Chapter 4 – Assessing Current Inventories: Governments & Others, which analyzes the state of U.S. and Russian government inventories, along with international fuel banks and other unique holdings, such as civilian plutonium stockpiles.

Chapter 5 – Market Analysis and Global Forecasts presents UxC’s market impact analysis and forecasts for future inventory growth and disposition and how these will affect the three nuclear fuel commodity markets – uranium, conversion, and enrichment. The chapter includes a detailed summary of the current estimates for the world’s nuclear fuel inventories along with a comparison with our previous estimates presented in 2020 to provide a view of how global inventories have shifted over the past two years. Multiple scenarios for future inventory growth/disposition are also examined along with relevant market implications. Additional detailed analyses of factors influencing the current and future trends in inventories as well as the overall market impacts of inventories are also provided. These include analyses on the level of current “excess” inventories and their mobility as well as potential implications on inventory holdings of the COVID-19 supply shocks in 2020, the surge in financial-led uranium buying in 2021, and Russia’s invasion of Ukraine in 2022. New to this report is a historical analysis of uranium inventories over the past two decades since 2000 and what recent elevated inventory levels could mean for the long-term outlook of the market.

Chapter 6 – Summary and Conclusions summarizes the key points of this report and offers some final thoughts on the nature of inventories and how they fit into the broader nuclear fuel markets.