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Perth, Australia

24th Annual Conference Proceedings

Uranium-REE Conference

Including

Developments in IX Forum

Organised in cooperation with

IAEA
International Atomic Energy Agency

15th Annual Uranium Event

7th Annual Rare Earth Elements Event

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PROCEEDINGS OF
ALTA 2019 URANIUM-REE SESSIONS

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Developments in IX Forum

23 May 2019

Perth, Australia

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Uranium-REE Opening Address

WHAT WILL FUTURE URANIUM MINING PROJECTS LOOK LIKE?

By

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International Atomic Energy Agency, Austria

Presented by

Dr Brett Moldovan
Team Leader, Uranium Resources and Production
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ABSTRACT

Insights into the uranium mining projects of the future can be gained by a careful statistical analysis of past and present deposits, as well as examination of recent trends for uranium resource evaluation and primary uranium production.

The UDEPO database is an International Atomic Energy Agency collation of historic uranium deposits. It contains geoscientific information on over 3,000 deposits, spanning 15 deposit types and 50 subtypes including maximum known resource size from public sources. Statistical data indicate that historic resources have been dominated by sandstone-hosted uranium deposits in terms of the actual numbers of deposits. In contrast, the highest-grade uranium deposits are dominated by unconformity-related deposits, particularly the unconformity-contact subtype.

Total identified uranium resources are dominated by very low grade unconventional deposits such as phosphates, black shales, and importantly, polymetallic iron oxide breccia complexes such as the Olympic Dam Cu-Au-Ag-U deposit. The latter rely on polymetallic production and in a future where comprehensive extraction driven by sustainability and environmental concerns, these could become more important.

According to the joint OECD-NEA/IAEA Uranium Resources, Production and Demand (Red Book) 2018 publication, sandstone hosted uranium comprises the highest proportion of low cost resources. This share is reflected in nearly 50% of recent world uranium production being related to In Situ Recovery (ISR) of these low cost, low-grade resources. Production of high grade, but higher cost resources is dominated by unconformity-related deposits. Finally, production of very low grade, high cost resources are dominated by Olympic Dam.

Historical statistical deposit-type data and recent production data outlined above leads to the conclusion that the most financially attractive type of uranium deposit for future exploration expenditure will be higher grade sandstone hosted deposits. Structural geology, mineralogy, geochemistry and uranium grades will determine the type of mining and processing application for these deposits. In keeping with recent history, it is expected that the ISR will continue to play a major role in the development of uranium deposits of the future.

Development of high-grade unconformity-related deposits will also continue to focus on innovation and reducing production costs. Development of these deposit types are focusing on investigating new mining and processing options in order to reduce overall life cycle costs. One recent example of innovation through the application of low cost mining methods with high grade deposits is the recent announcement to investigate in-situ recovery well field testing at the Phoenix deposit; an unconformity based uranium hosted deposit.

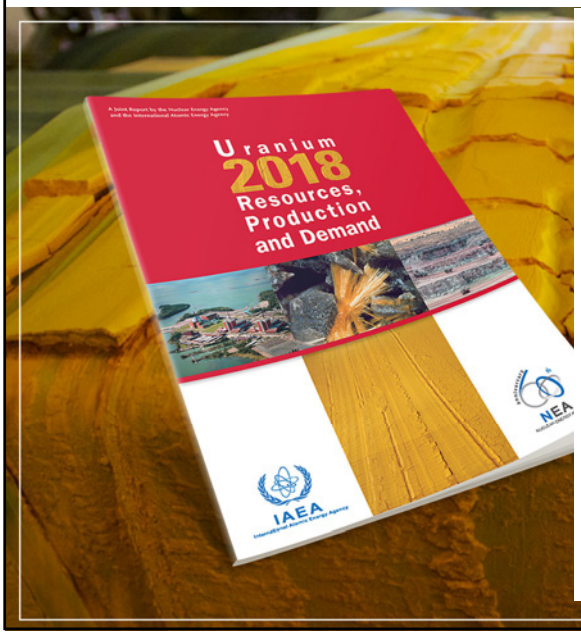
This presentation will present on the results of the UDEPO and OECD-NEA/IAEA Uranium Resources, Production and Demand publications and provide considerations for future uranium mines based on geology, mineralogy (geochemistry) and hydrometallurgical processing.

Keywords: Uranium Resources, Uranium Production, Uranium Deposits, Uranium Mining, In Situ Recovery, ISR

Overview

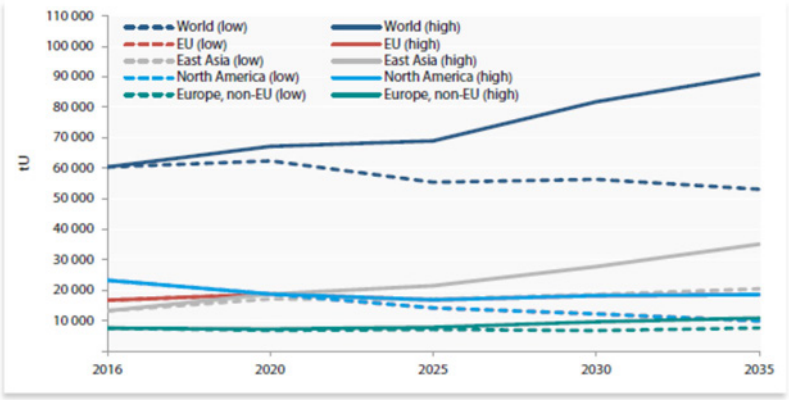
- Global uranium demand forecast
- Global uranium supply forecast
- Overview of global Reasonably Assured Resources
- Geological summary of the above noted resources
- Grade – tonnage, structural geology and mineralogy/geochemistry
- Mining and processing considerations – technical and economic

IAEA/NEA Red Book Publication (2018)

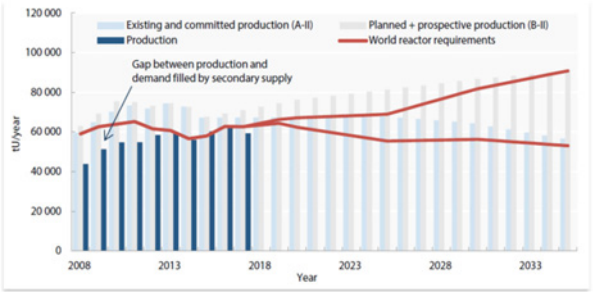


- Published since 1965.
- A joint report by the NEA-OECD and the IAEA since 1969.
- Widely recognized in the international nuclear community as a primary reference document on world uranium supply.
- Available as a PDF free of charge: https://www.oecd-nea.org/ndd/pubs/2018/7413-uranium-2018.pdf
- Sources: governmental reports (via questionnaire), Secretariat reports and estimates.
- WNA's Nuclear Fuel report is published in alternate years.
- Next edition of the Red Book (2020) is in progress.

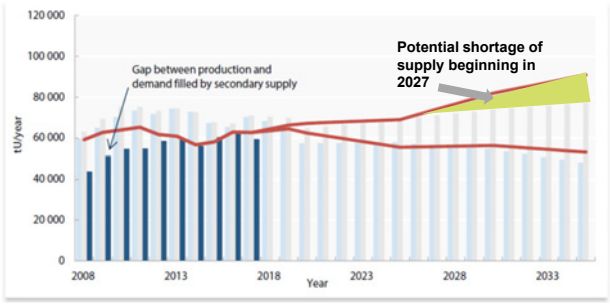
Uranium Demand Forecast (Red Book 2018)



Uranium Production Capability vs Demand (Red Book 2018)

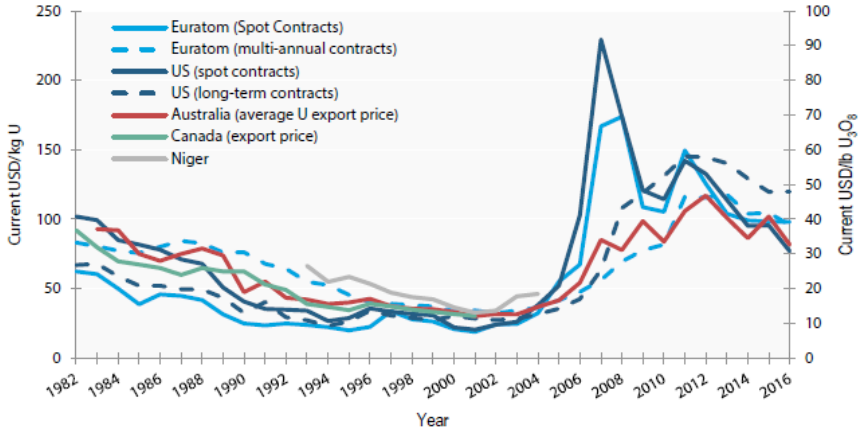


100% of forecasted nameplate production capacity achieved



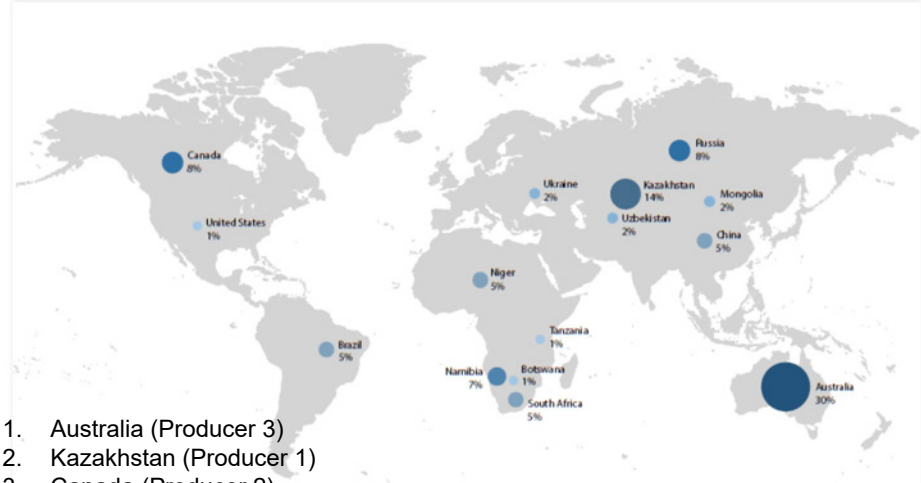
85% of forecasted nameplate production capacity achieved

Uranium Prices for Short and Long-Term Purchases and Exports (Red Book 2018)



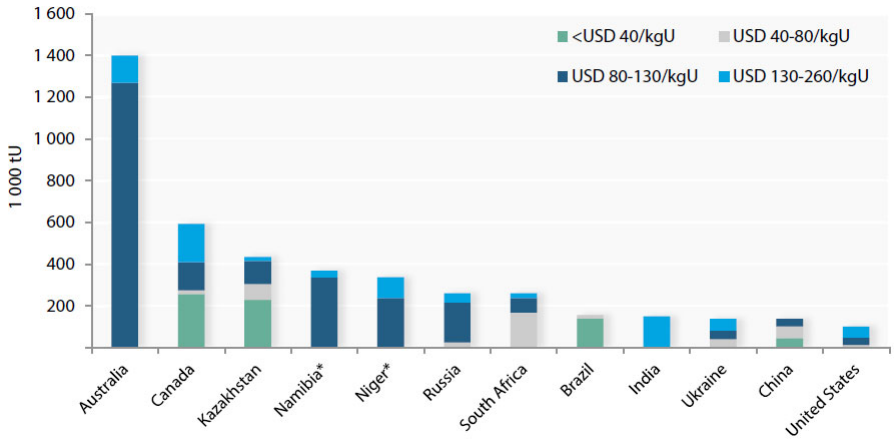
Source: Australia, Canada, Euratom (ESA), Niger and US EIA

Global Distribution of Identified Uranium Resources (Red Book 2018)



1. Australia (Producer 3)
2. Kazakhstan (Producer 1)
3. Canada (Producer 2)
4. Russian Federation (Producer 6)

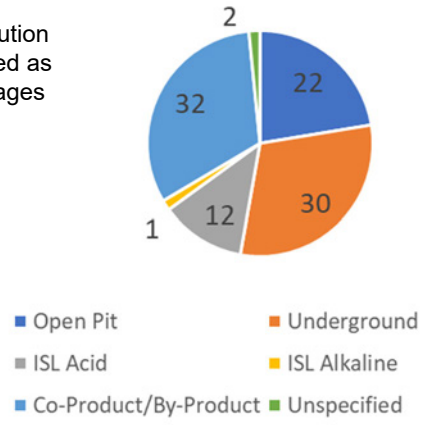
World Distribution of Uranium Resources (Red Book 2018)



Reasonably Assured Resources

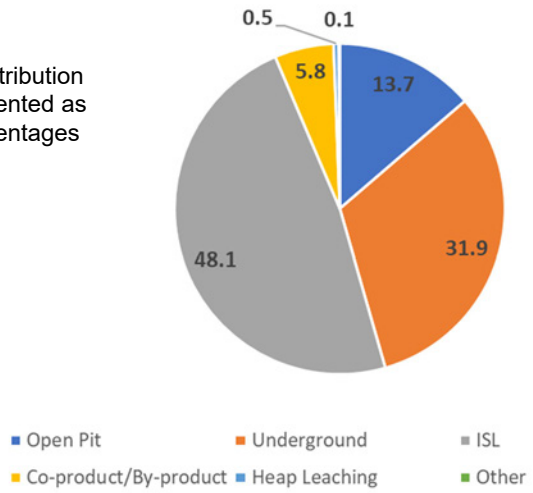
Anticipated Production Method Based on Global Uranium Resources (Red Book 2018)

* Distribution presented as percentages



Distribution of Current World Uranium Production by Production Method (Red Book 2018)

* Distribution presented as percentages



Conventional and Unconventional Resources (Red Book 2018)

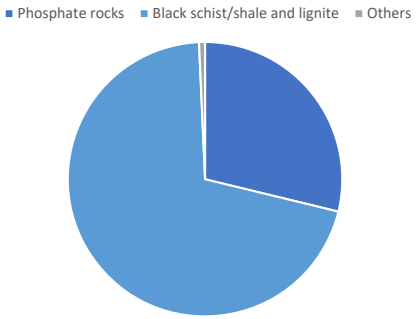
Conventional Resources
Established history of production where uranium is a primary product, co-product or an important by-product (e.g. mining of Cu and Au).

Unconventional Resources
Defined as very low grade resources or those from which uranium is only recoverable as a minor by-product.

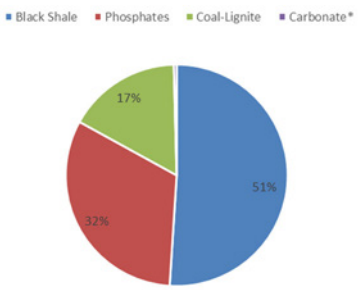
Examples include:
- Phosphates
- Black shales
- Coal
- Heavy mineral sands

Photo courtesy Rio Tinto

Unconventional Resources



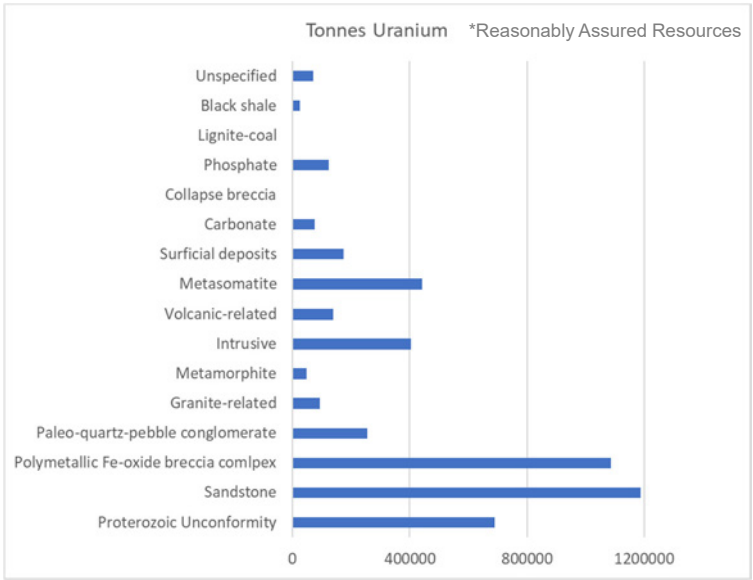
28.5 million tonnes U
(Red Book 2018)

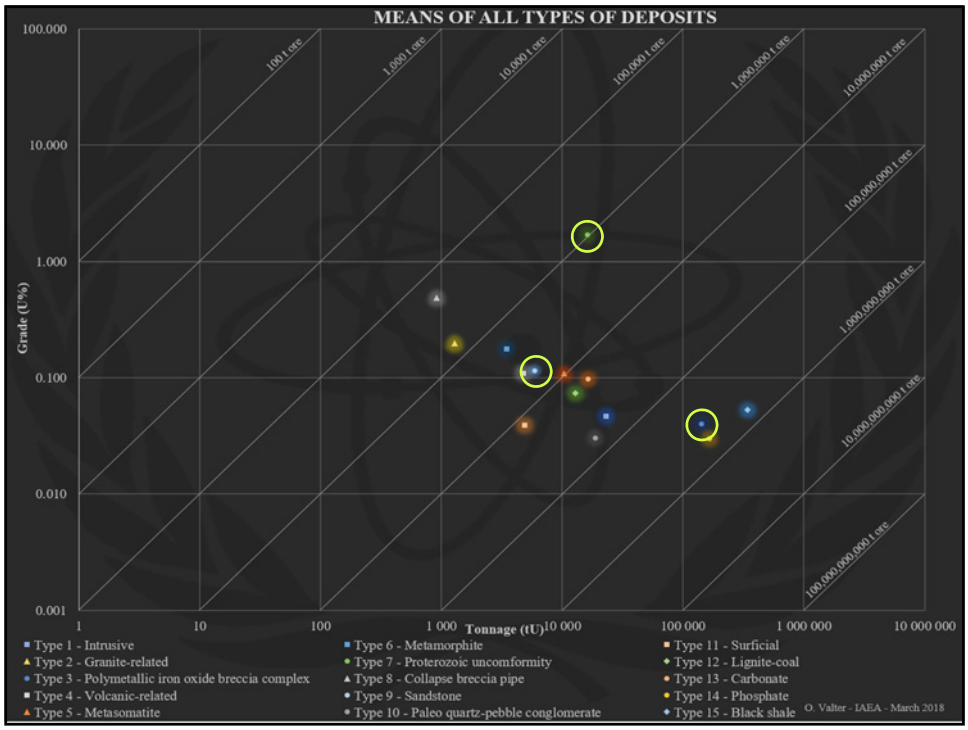


44.7 million tonnes U
(UDEPO 2018)

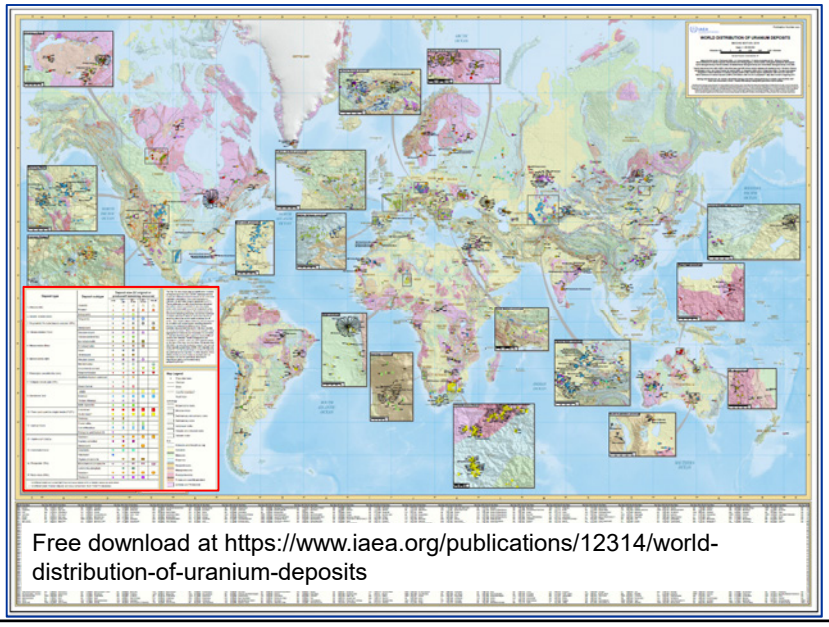
Market conditions and technological development will be the main factors that determine the contribution of unconventional U resources to world production totals in the future.

Global Resources by Deposit Type (Red Book 2018)



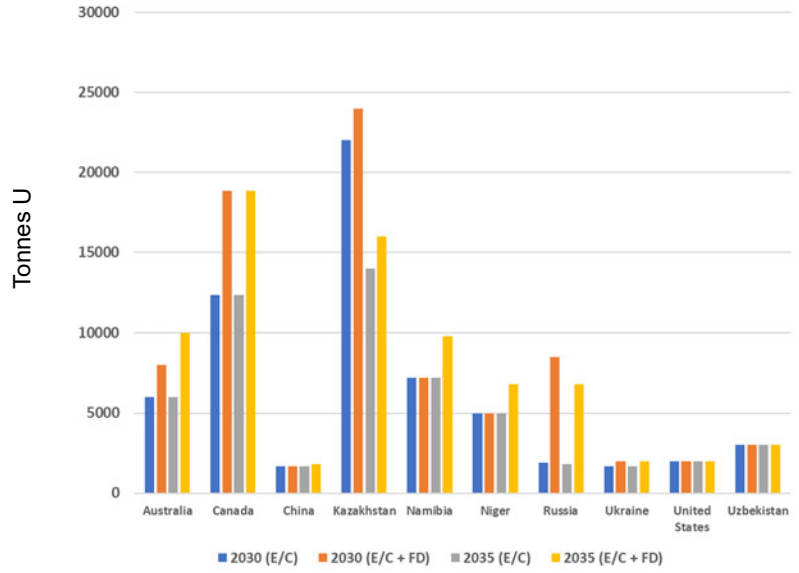


World Distribution of Uranium Deposits – interactive PDF map



Free download at https://www.iaea.org/publications/12314/world-distribution-of-uranium-deposits

World Uranium Production Capability to 2035 (Red Book 2018)



Key Considerations for Uranium Mines of the Future

- Geology, mineralogy and geochemistry will guide mine design and process flowsheet
- Lower grade uranium deposits will dominate global resources
- Red Book (2018) concludes that processing costs for about 60% of conventional uranium resources will be greater than USD 130/kg (USD 59/lb)
- Water is an important commodity in several arid uranium hosted countries – water management strategy is essential
- Long lead times for uranium mine development may result in a shortage of supply in the near term

Future Mining and Processing Considerations Based on Geology and Mineralogy

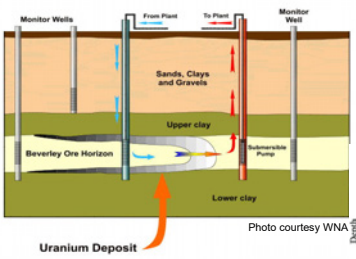


Photo courtesy WNA

Photo courtesy James St John, Colorado

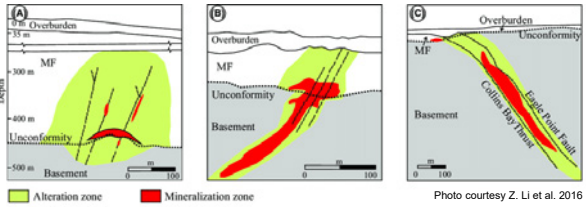


Photo courtesy Z. Li et al. 2016

- For commercial uranium producers the future will be dominated by In Situ Recovery
- The main uranium hosted deposits in the future are sandstone and unconformity-type deposits

Innovation Opportunities in the Uranium Industry

- Reduced mining costs
  - Application of ISL in unconformity type deposits
    - Similar structural geology and geometry to sandstone deposits
    - Freeze wall technology well developed
    - Higher temperature of formation – potentially different extraction chemistry
  - Stope (block) leaching
- Pre-concentration of mined ores
  - Physical
  - Chemical
- Advances in heap leaching technology for low grade ores
- Innovation in full life cycle issues, such as mine closure

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  - Stope (block) leaching
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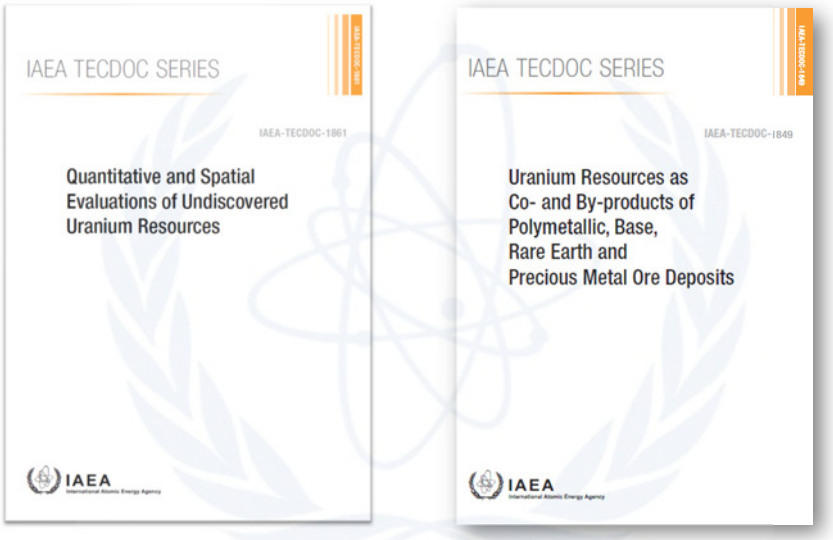
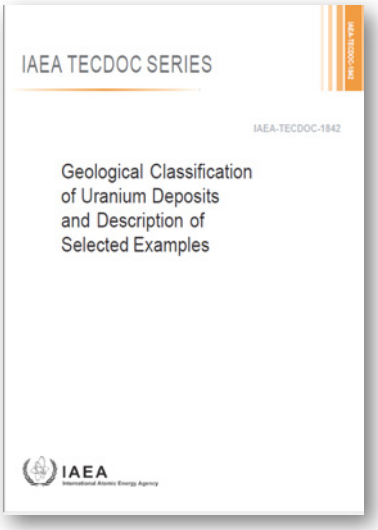
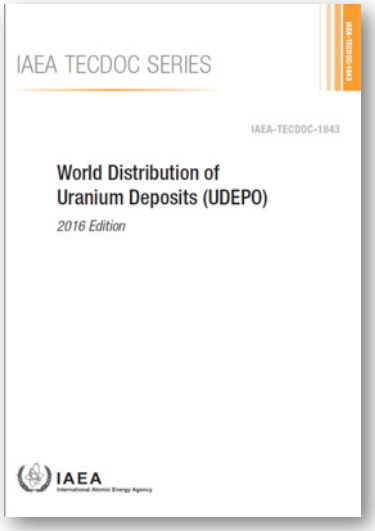
  - Chemical
- Advances in heap leaching technology for low grade ores
- Innovation in full life cycle issues, such as mine closure
- Unconventional resources: resolving potential security of supply issue
  - Advances in chemical separation of U from phosphate ore
  - Advances in recovery of U, Th and REEs from monazite and xenotime

Recent IAEA Publications Relevant to the Uranium Mines of the Future



Recent IAEA Publications Relevant to the Uranium Mines of the Future (cont'd)





Summary

- Global U demand is expected to continue to increase in the next several decades
- Sufficient resources identified, but pounds in the ground ≠ pounds in the can
- Innovation is required to make low grade deposits economical
- Security of supply is a key strategic consideration – may drive innovation for recovery of U from unconventional resources
- Advances in recognising waste issues early in life cycle

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