



The Front End of the Nuclear Fuel Cycle

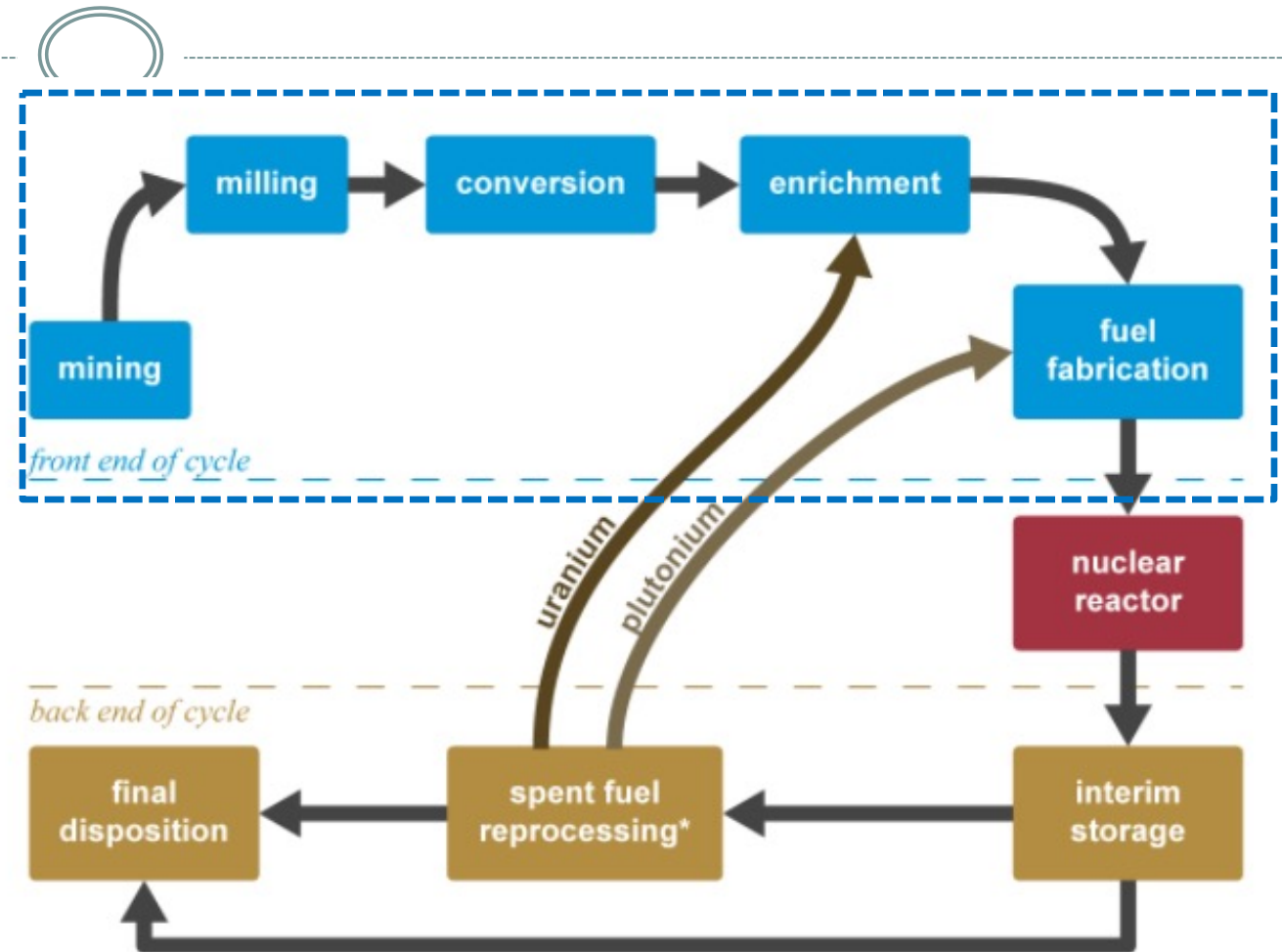
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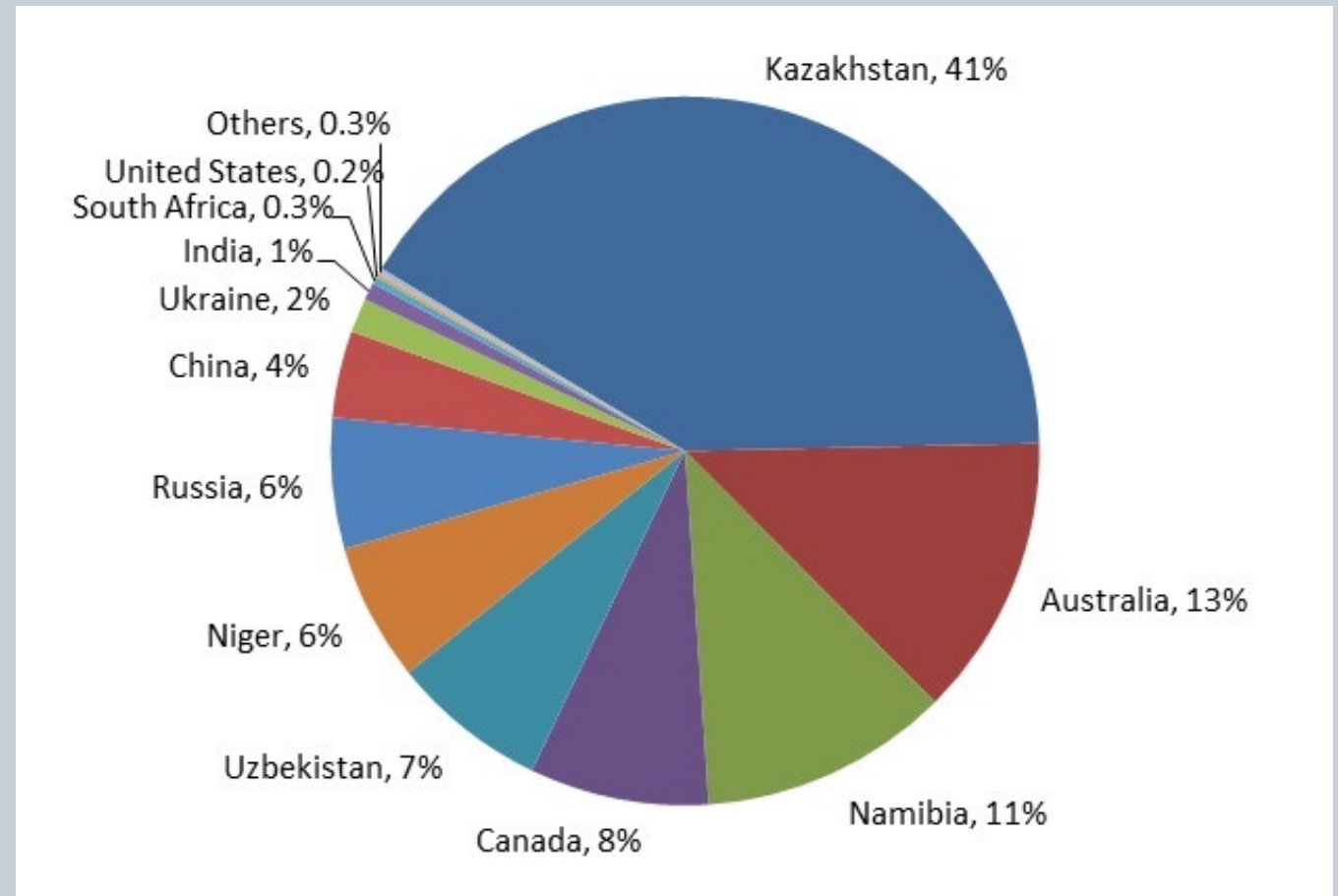
The Nuclear Fuel Cycle

- The current front-end of the nuclear fuel cycle for LWRs includes:
 - Uranium mining/milling or in-situ recovery/processing (U_3O_8)
 - Conversion of natural U_3O_8 to uranium hexafluoride (UF_6)
 - Enrichment of ^{235}U to low-enriched uranium (LEU)
 - Fuel fabrication



Uranium Supply

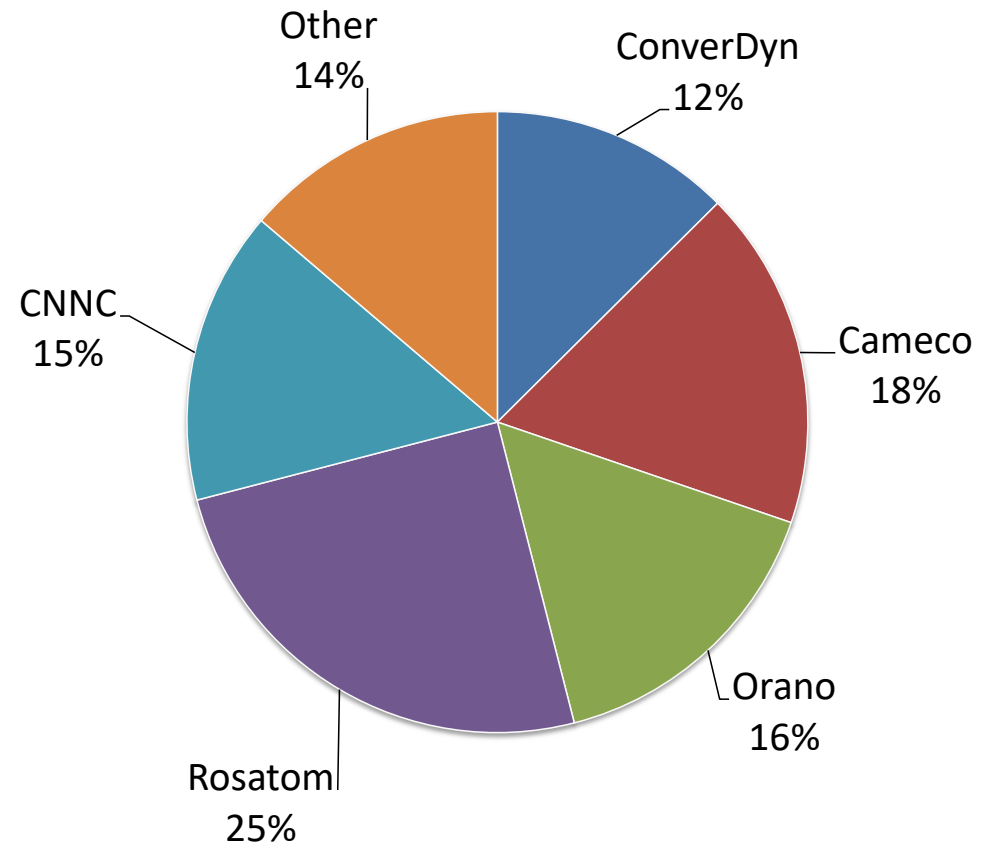
- World requirements for natural uranium are ~ 143 million pound U_3O_8 .
- Uranium production in 2020 was ~123 million pound U_3O_8 .
- The supply gap is covered by secondary supply (inventory, re-enrichment of DU tails, enrichment underfeeding, Pu and U recycle).
- Uranium production methods
 - Underground or open pit mining
 - In-situ recovery
 - Byproduct recovery



2020 Uranium Production Centers

Conversion of U₃O₈ to UF₆

- There are 5 organizations that convert U₃O₈ to UF₆:
 - ❑ ConverDyn/Honeywell, USA
 - ❑ Cameco, Canada
 - ❑ Orano, France
 - ❑ Rosatom, Russia
 - ❑ CNNC, China
- Honeywell's Metropolis Works plant in the US has been closed since late 2017 due to market conditions – it is in the process of restarting.
- Orano's Philippe Coste facility began operation in 2018 and will reach full capacity in 2023.
- CNNC capacity continues to grow to meet internal needs for Chinese reactors.



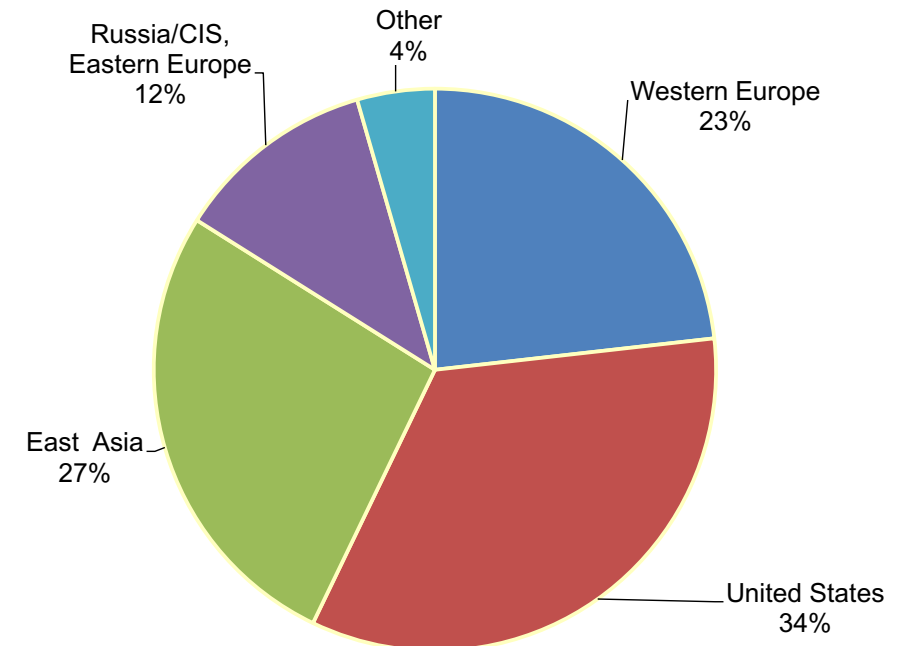
Uranium Enrichment

- All primary uranium enrichment facilities utilize gas centrifuge enrichment technology.
- Primary enrichment facilities for commercial nuclear fuel are operated by 4 entities:
 - ❑ URENCO (USA, UK, Germany, Netherlands)
 - ❑ ORANO (France)
 - ❑ Rosatom (Russia)
 - ❑ CNNC (China)
- There are several small facilities:
 - ❑ Centrus (US) is developing a demonstration a facility to produce HALEU under contract to US DOE
 - ❑ Japan, Argentina, Brazil, India, Iran and Pakistan.
- URENCO plans to to produce HALEU (LEU+) up to 10 w/o ^{235}U in US and UK, assays up to 19.5 w/o ^{235}U are also planned.
- Orano plans to produce HALEU (LEU+ in near term).
- Rosatom can currently supply HALEU.



Fuel Fabrication

- LWR fuel fabrication facilities in the U.S., Europe, Japan and Russia continue to be underutilized at <50% capacity.
- New areas for growth include:
 - Accident tolerant fuel (ATF)
 - SMR and advanced reactor designers for fuel fabrication.
- Assemblies with ATF lead test rods have been installed in plants in the U.S., Europe and Russia.
- Lead test assemblies for burnups above currently approved levels are planned in the U.S.
- Fabricators are moving forward with high-assay LEU fuel for existing LWRs – with first reloads expected in the mid-2020s.
- Limited fabrication capability exists for MOX fuel, PHWRs (CANDU), GCRs, HTRs, LMRs, RBMKs, TRISO fuel (lab scale/pilot scale)



World LWR Fuel Fabrication Market Share



Thank you!

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