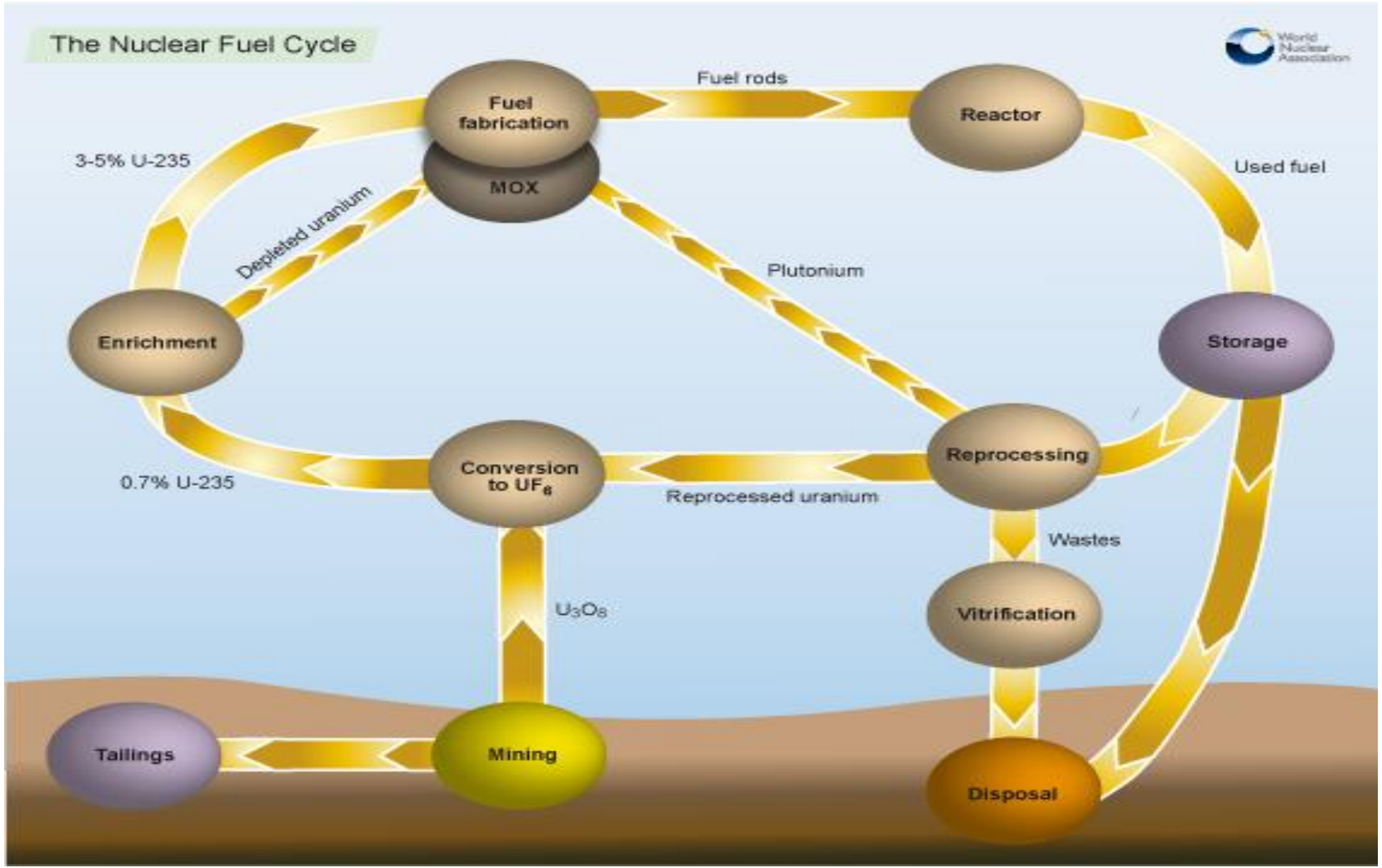
ANA 2024 Conference 11 Oct 2024
Nuclear Fuel Cycle – Replacing Russian Supplies



NFC Drivers for supply

1. Replacing Russian supplies
2. Reactor shutdowns delayed, reactor restarts
3. Reactor life extensions
4. New build
5. Japan restarting 7 more reactors + life extensions
6. US Inflation Reduction Act encourages new NFC facilities
7. Brookfield (51%) and Cameco (49%) now own Westinghouse – more NFC opportunities for Cameco
8. IAEA projects 950 GW of global nuclear capacity by 2050 (high case estimate), current 395 GW

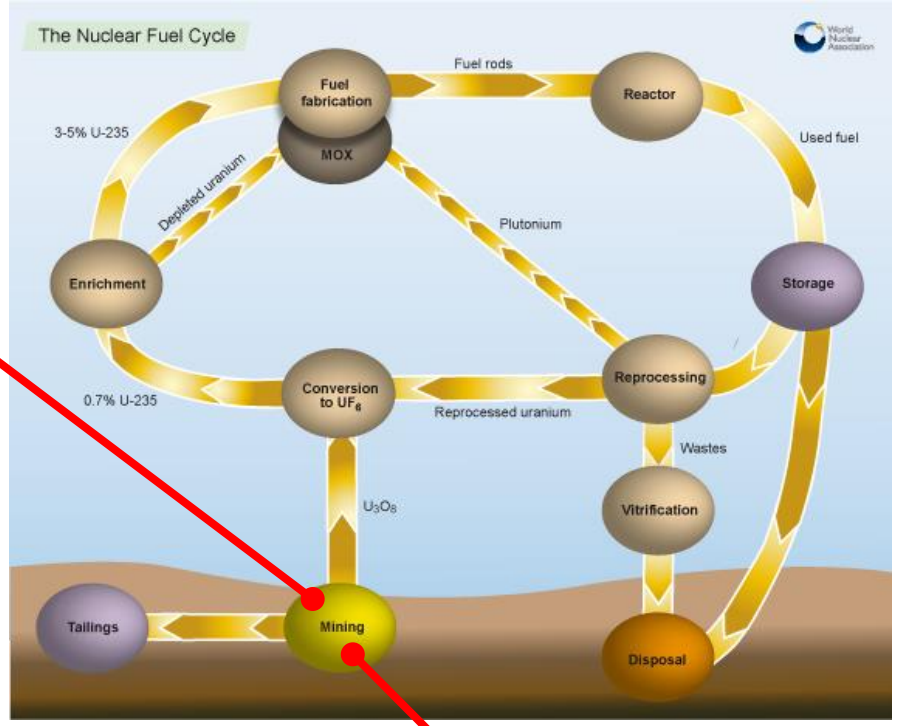
Russia and Nuclear Fuel Supplies

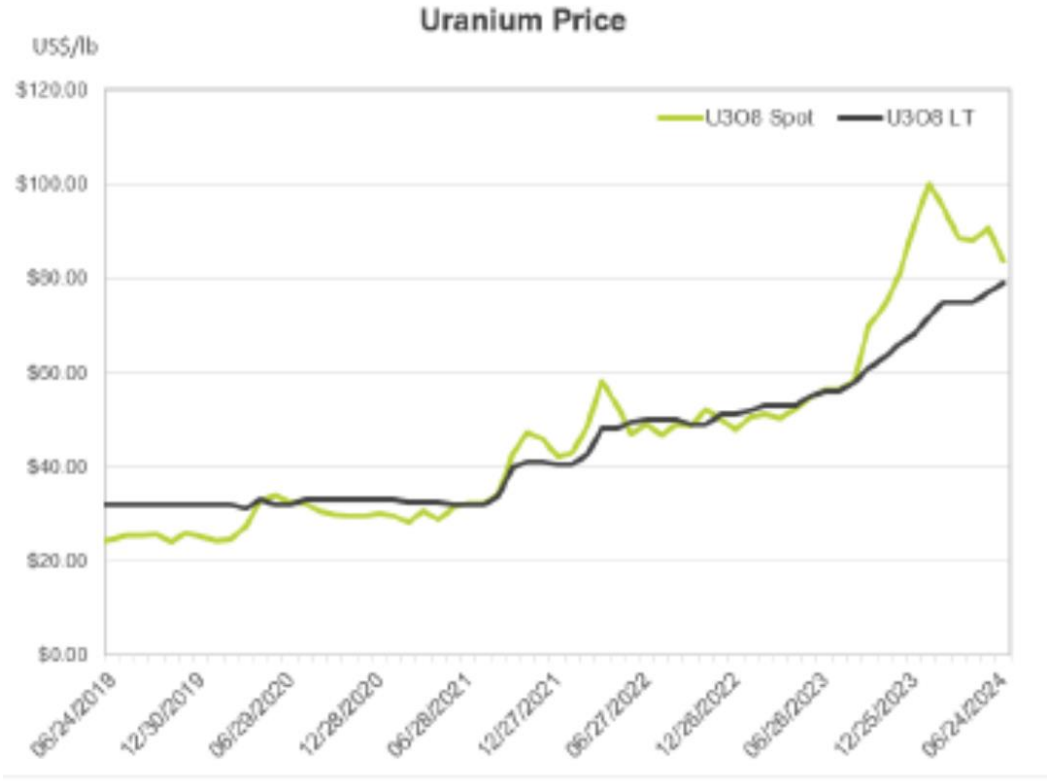
	Russian Supply Global	Russia Supply to EU	Russia Supply to USA
Uranium U_3O_8	14%	20%	14%
Conversion	27%	24%	18%
Enrichment (SWU)	45%	31%	20%

Sources: WNA and UxC 2022
Euratom Supply Agency Annual Report 2021
EIA 2021 Uranium Marketing Annual Report

Uranium milling

- Extracts uranium from ore by leaching, precipitation, drying
- Transport as uranium oxide concentrate (UOC) in drums.





Source: The Ux Consulting Company, LLC, http://uxc.com

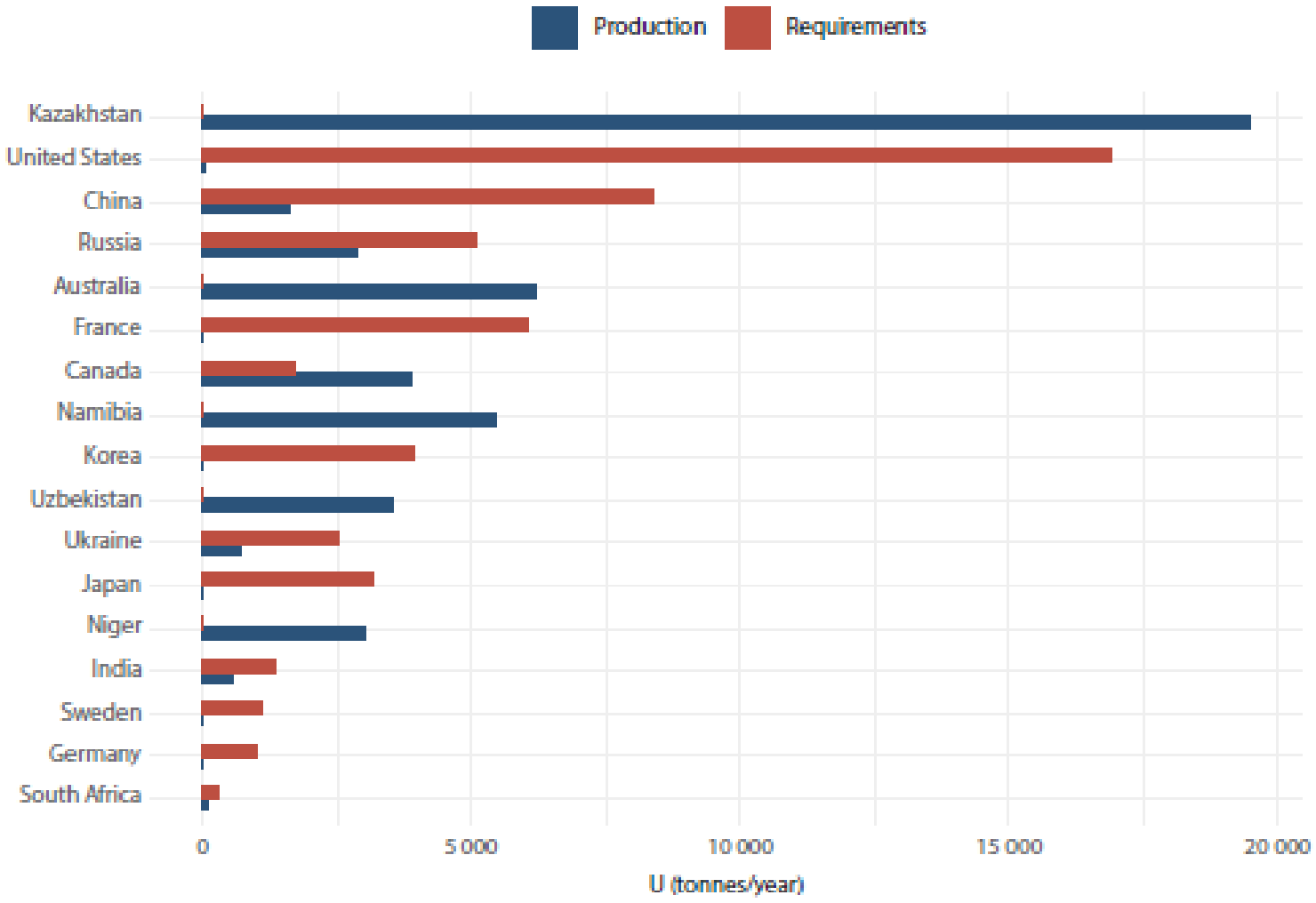
Mining

- Uranium relatively abundant
- Open pit/underground 29%
- Byproduct – 5%
- In situ leach (ISL) – 66%

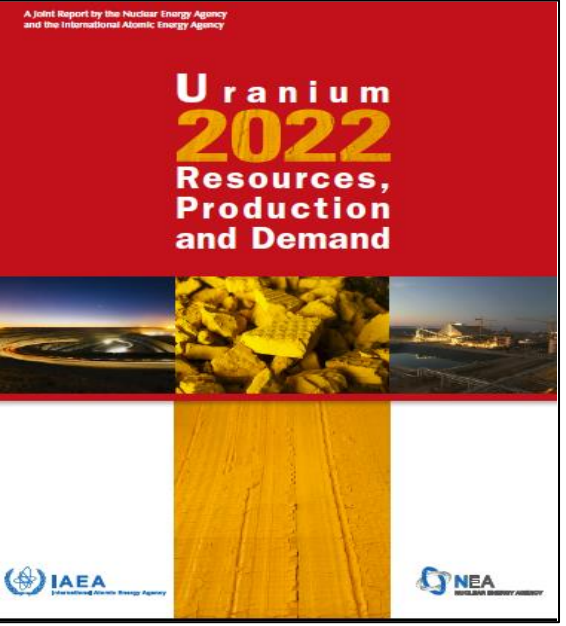
Figure 2.4. **Uranium production and reactor-related requirements for major producing and consuming countries**

(data as of 1 January 2021)

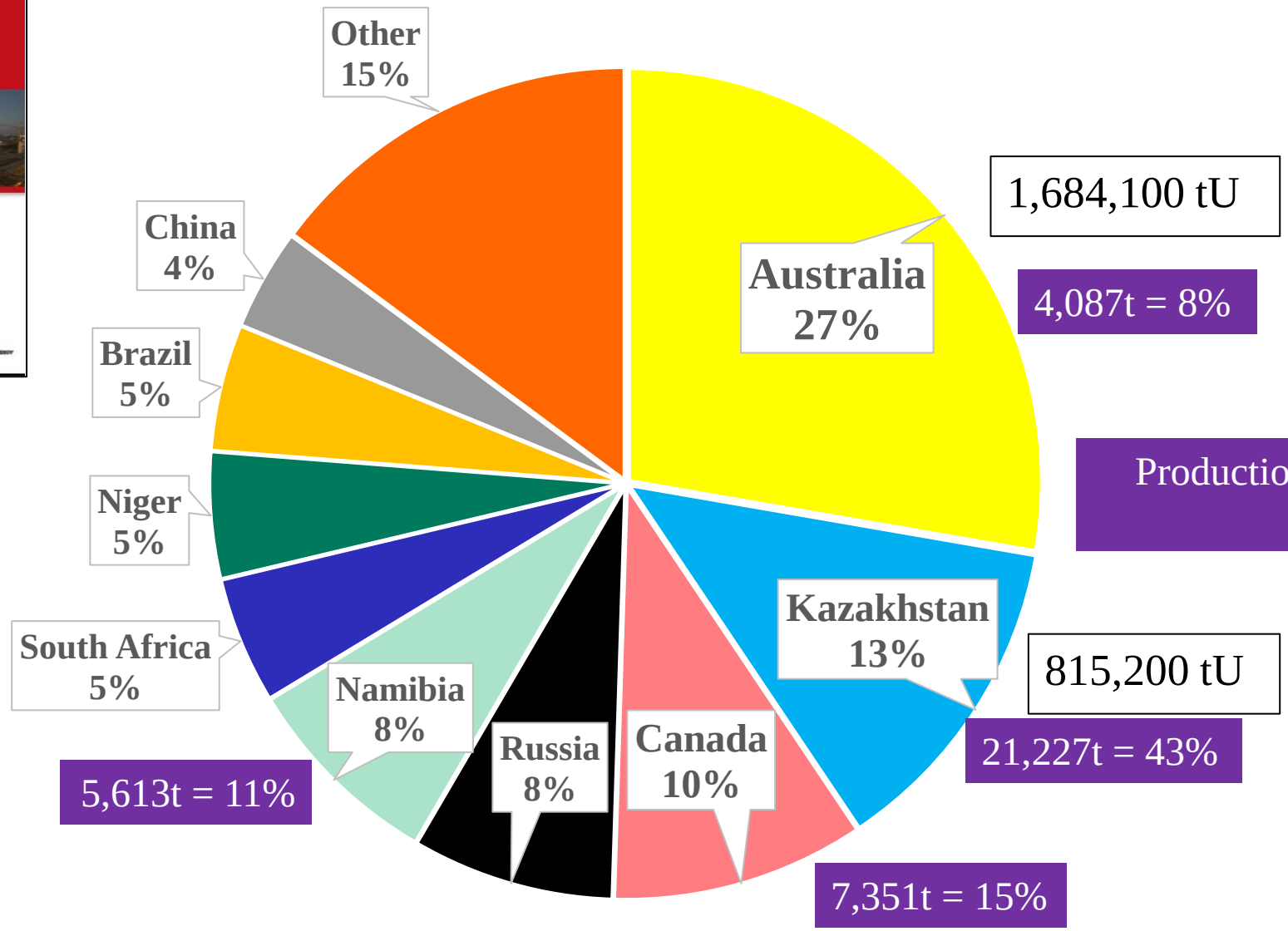
Source: 2022 Red Book



67,517 t Uranium required in 2024, 49,355 t mined in 2022



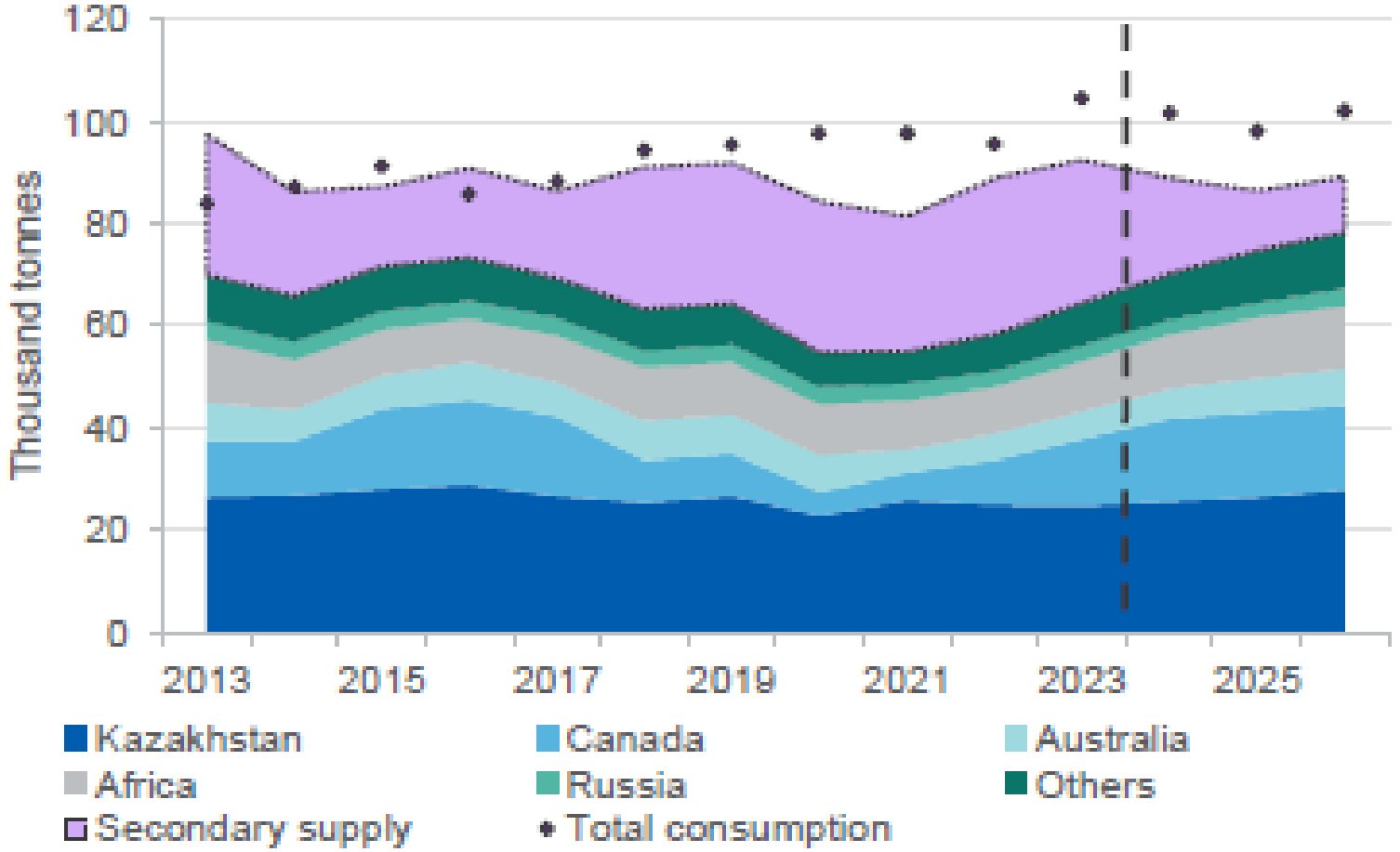
Identified Recoverable Resources < 130 USD/kgU



2022 Red Book Table 1.2a Global total 6,078,500 tU

DISR Resources and Energy Quarterly Sept 2024

Figure 8.3: World uranium production (U3O8)

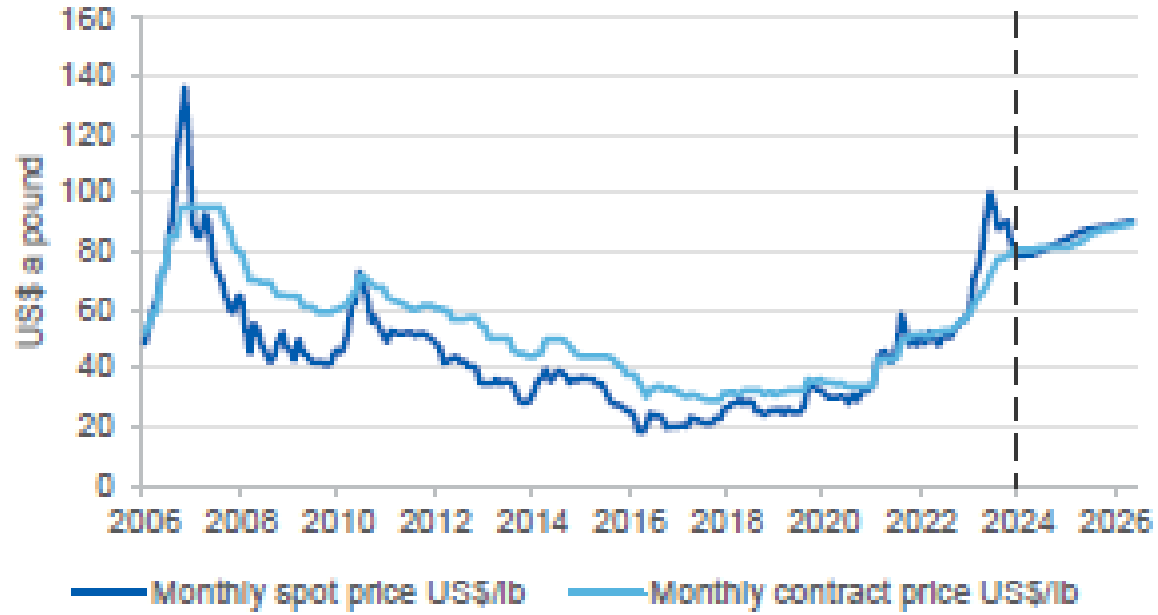


Source: International Energy Agency (2024); World Nuclear Association (2024); Ux Consulting (2023)

https://www.industry.gov.au/sites/default/files/2024-09/resource_and_energy_quarterly_september_2024.pdf

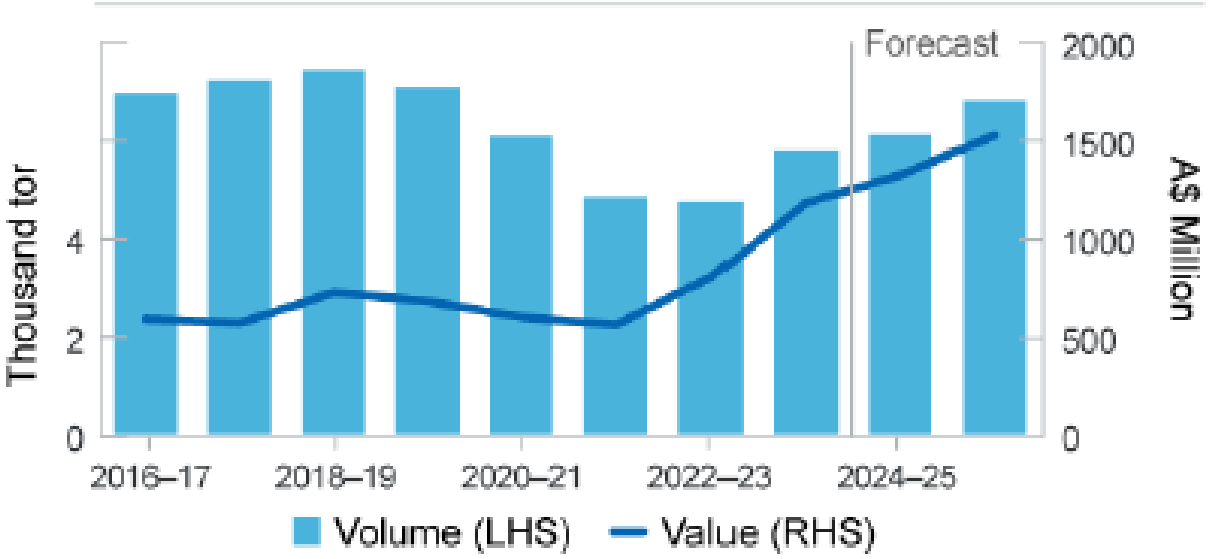
DISR Resources and Energy Quarterly Sept 2024

Figure 8.3: Uranium price outlook



Source: Cameco Corporation (2024) Uranium Spot Price; Ux Consulting (2024) Uranium Market Outlook

Australia's Uranium Exports



https://www.industry.gov.au/sites/default/files/2024-09/resource_and_energy_quarterly_september_2024.pdf

Honeymoon ISL

Boss set for first drum of uranium after commissioning the Ion Exchange circuit

IX columns working precisely to plan, marking completion of the final technical milestone in the Honeymoon re-start strategy

Boss Energy (ASX: BOE) is pleased to announce that it has successfully passed the final technical milestone in its Honeymoon re-start strategy, paving the way for the first drum of uranium to be filled in the next two weeks.

3 April 2024

Image : Boss Energy

57,364lb U_3O_8 produced by 30 June 2024 with one IX column.

First drum exported 4 July 2024

With two more IX columns, forecast 850,000 lb U_3O_8 by end of June 2025.

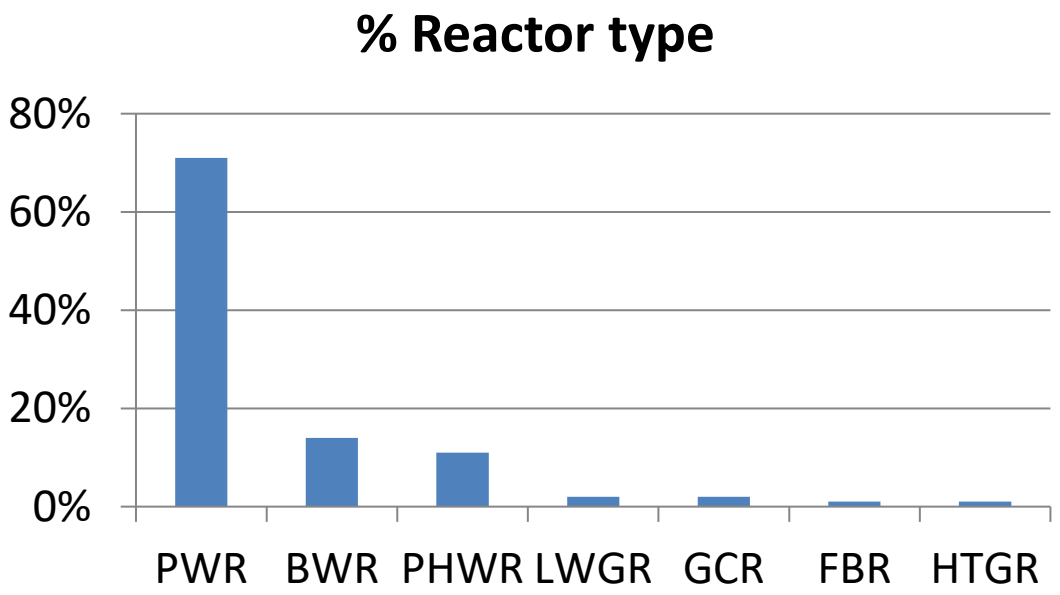
Total production in FY26 expected to meet feasibility study forecast 1.63 Mlb/year.

With addition of columns 4,5 & 6, further increase to nameplate 2.45 Mlb/year by year 3 (1,111t U_3O_8 /year).

Image 1: Wellfield electrical, instrumentation, and piping materials has been installed

October 2024 World Power Reactors

Source: WNA Reactor database



Reactors under Construction

PWR	59
BWR	2
PHWR	2
FBR	4
Total	**67**

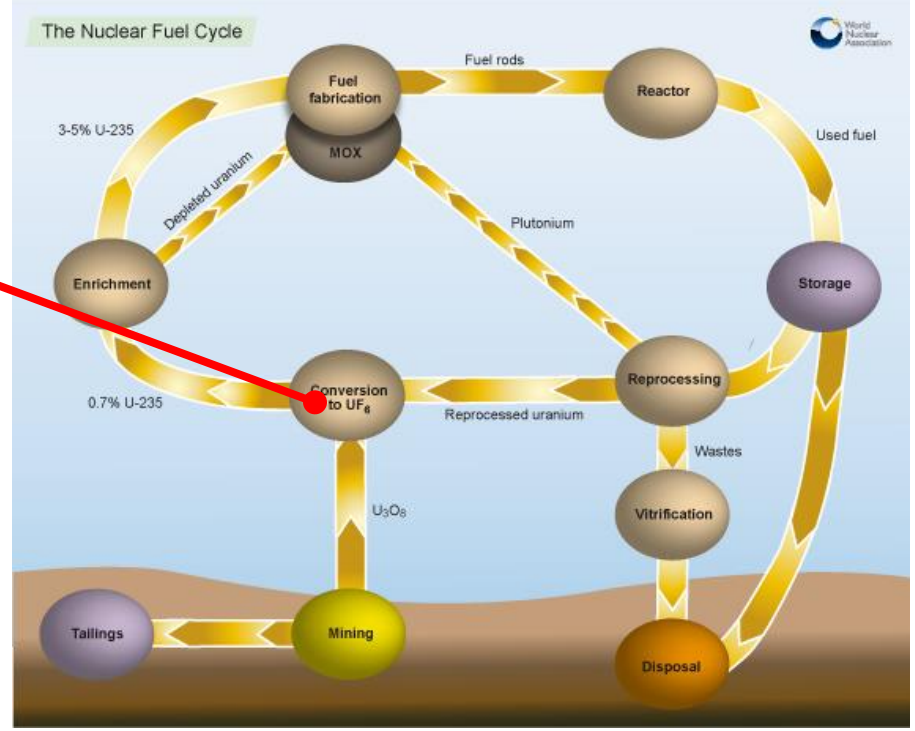
PWR	Pressurised Water Reactor	310
BWR	Boiling Water Reactor	60
PHWR	Pressurised Heavy Water Reactor	48
LWGR	Light Water Graphite Reactor	10
GCR	Gas Cooled Reactor	8
FBR	Fast Breeder Reactor	2
HTGR	High Temperature gas Reactor	1
	Total Number of operating reactors	**439**

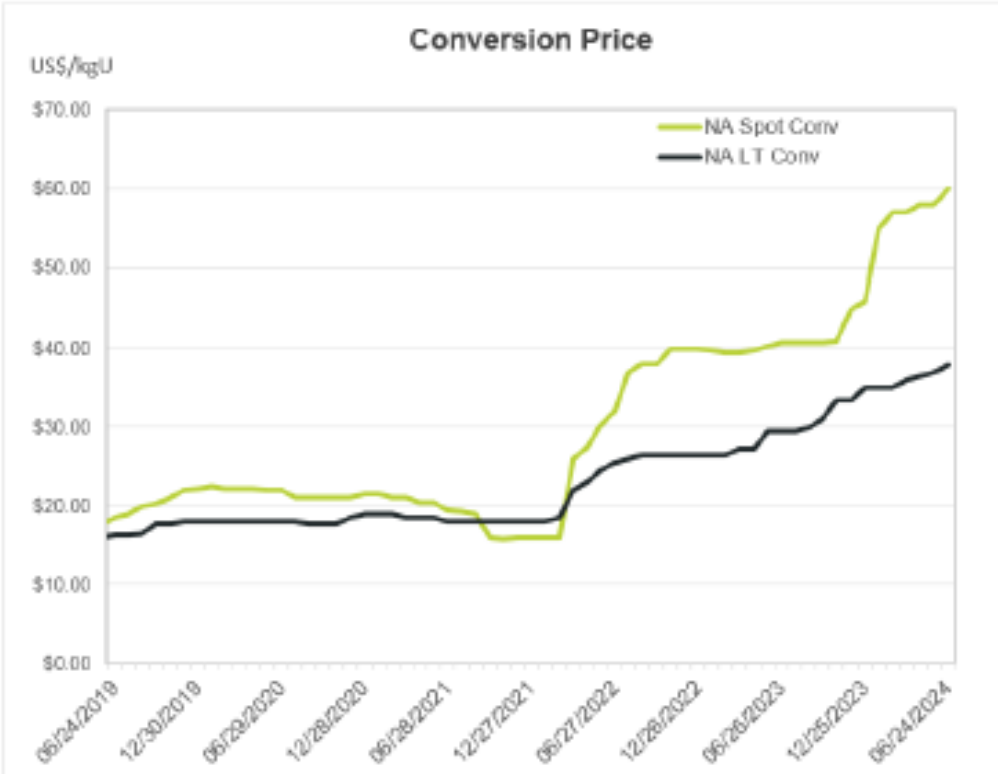
Requires enriched uranium

Uses natural uranium

Conversion to UF_6

- Uranium in gaseous form for isotope separation
- Chemical process – UO_2 - UF_4 – UF_6

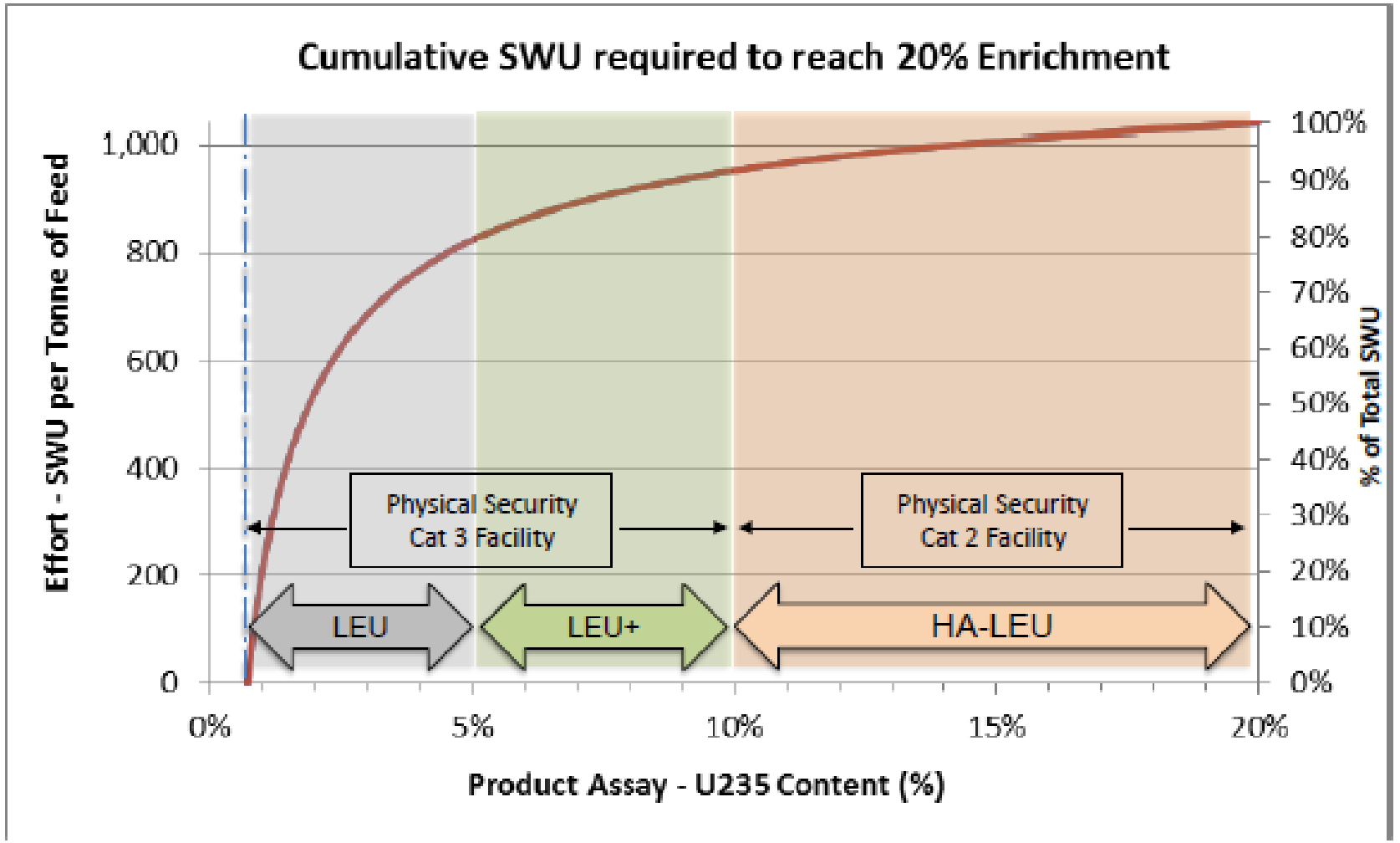




Source: The Ux Consulting Company, LLC, http://uxc.com

Country, Location	Company	Nameplate capacity tU as UF_6
Canada, Port Hope	Cameco	12,500
USA, Metropolis	Converdyn	(7,000/15,000)
France, Malvesi and Tricastin	Orano (Areva)	15,000
Russia, Seversk	JSC	12,500
China, Lanzhou Hengyang	CNNC	15,000
Brazil,	IPEN	100
	World Total	55,100 tU

URENCO : LEU, LEU+, HALEU



U235 Enrichment Levels

Feed 0.711% Natural Uranium

LEU <5% Civil Nuclear Reactors

LEU+ 5% - 10% Extended Fuel Cycles & ATFs

HA-LEU 10% - 20% Test, Research and Gen IV Reactors

US DOE estimates 40 tonnes of HALEU required by 2030

Urenco to construct a dedicated HALEU facility at Eunice, New Mexico plant

DOE Centrus contract to produce HALEU – first delivery Oct 2023, 900kg per year

HALEU – Other Sources

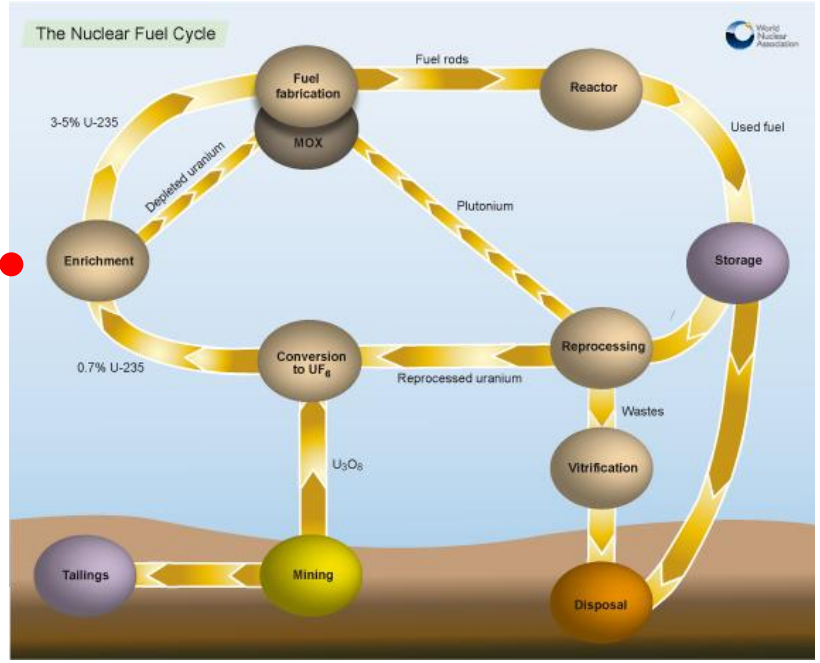
- August 2023 - US NNSA awarded BWXT $116.5m contract to produce 2 metric tonnes of 19.75% HALEU feedstock for advanced reactors over the next five years by processing thousands of kilograms of NNSA scrap material containing enriched uranium from Y-12 National Security Complex.

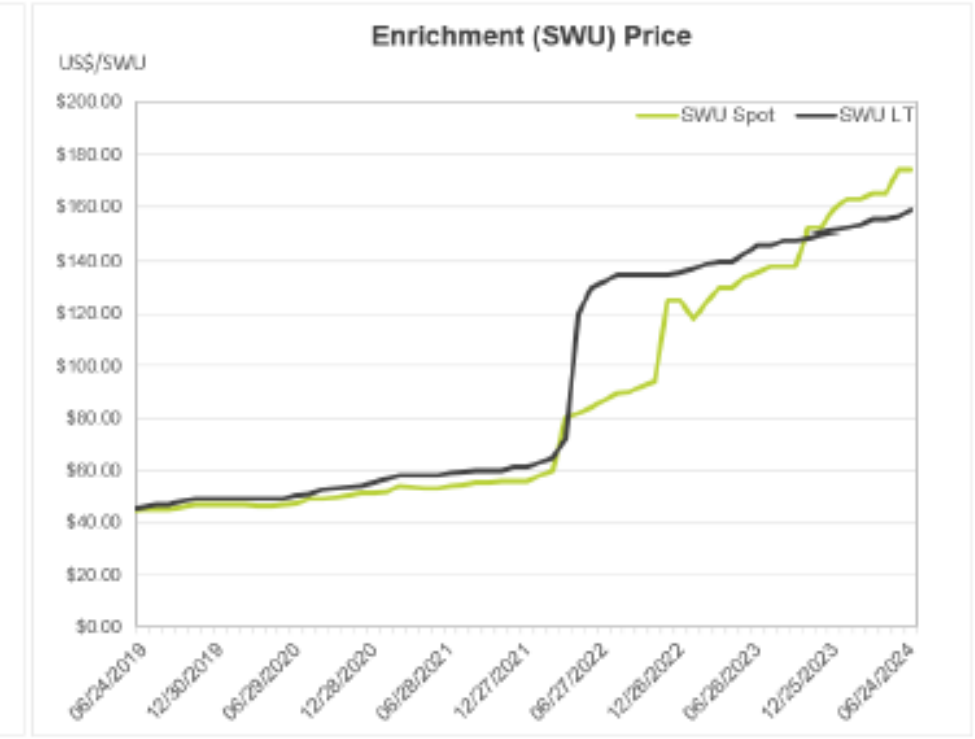
- Recover 10 metric tonnes of HALEU from EBR-II sodium cooled fast reactor fuel by December 2028 using pyroprocessing. To date, 5 metric tonnes recovered.

- Preparations have begun at the H Canyon chemical separations facility at the Savannah River Site to recycle used high-enriched uranium and downblend it to provide HALEU.
  Downblending is expected to begin in 2025.

Enrichment

- Gaseous diffusion (last shutdown 2013)
- Centrifuge
- Laser – close to commercial
- Downblended HEU





Source: The Ux Consulting Company, LLC, http://uxc.com

Country Location	Company	Capacity million SWU/yr
UK, Germany, Netherlands, USA	URENCO	18.5
France, Tricastin	AREVA George Besse II	7.5
Russia	Tenex	28.2
China	CNNC	>7
Japan, Rokkasho	JNFL	0.75
	World total	**~60 m SWU/yr**

Silex Global Laser Enrichment Projects

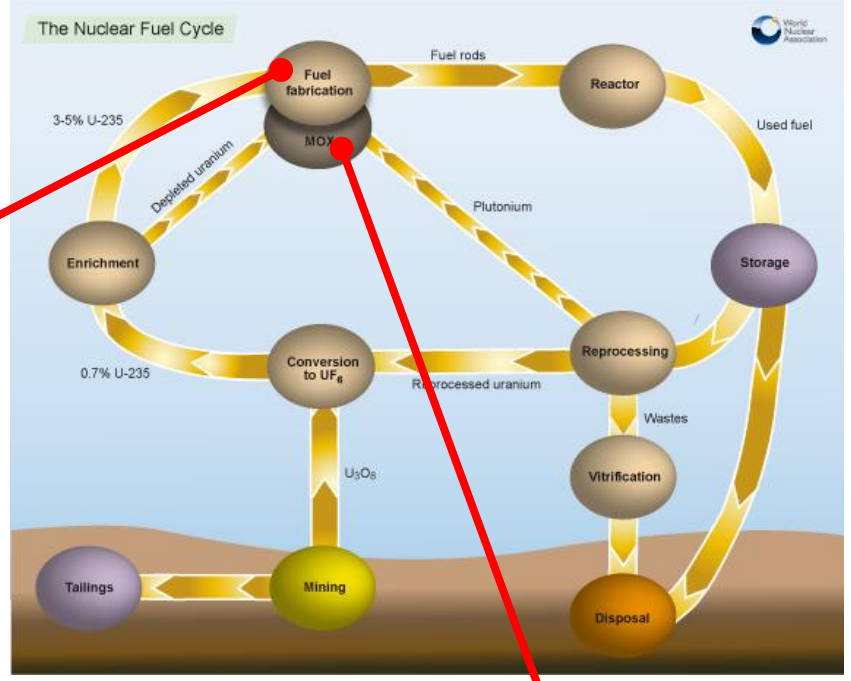
1. Natural grade uranium (Unat): via enrichment of Department of Energy (DOE) owned inventories of depleted UF6 tails at the proposed Paducah Laser Enrichment Facility (PLEF) to produce uranium (in the form of converted UF6) at natural U235 assay of ~0.7% (5 million lb/year for 30 years)

2. Low enriched uranium (LEU): for use as fuel in today's conventional large-scale nuclear power reactors – which require fuel with U235 assays of between 4% and 5%, and potentially LEU+, a new grade of fuel with U235 assays between 5% and 10% being considered by several utilities for use in current nuclear reactors to improve economic performance (2 million SWU/year)

3. High assay LEU (HALEU): a customised fuel for next generation advanced SMRs currently under development – many of which require fuel with U235 assays between 10% and 20%. (100 tonnes/year)

Fuel fabrication

- Ceramic uranium oxide (UO_2) pellets in fuel rods
- Fuel rods arranged as fuel assemblies
- Accident Tolerant Fuel (ATF)



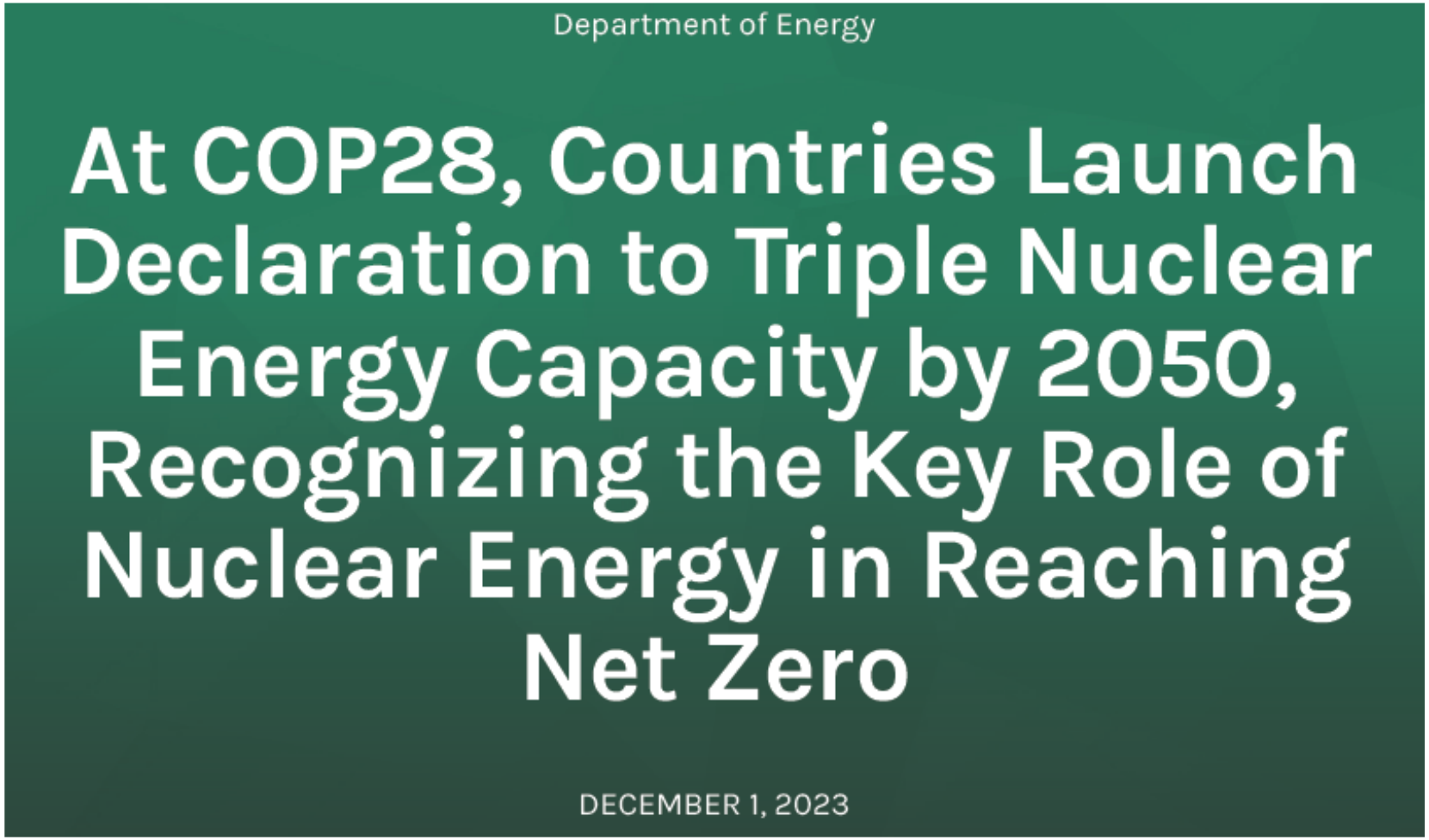
Fuel Manufacturers

Westinghouse (USA, Sweden, UK)	3,614 t HM/year
Framatome (USA, France, Germany, Belgium)	3,250 t HM/year
GNF (USA, Japan)	1,750 t HM/year
TVEL Russia	2,760 t HM/Year
CNNC China	1,400 t HM/Year
KNFC South Korea	700 t HM/year

MOX

- Mixed oxide fuel
- Plutonium + uranium

Orano Melox France	195 t HM/year
Mining and Chemical Combine, Russia	60 t HM/year



Sept 2024
Climate Week, New York City
14 major global banks and financial institutions express support to Triple Nuclear Energy

20 countries from four continents signed the declaration: USA, Bulgaria, Canada, Czech Republic, Finland, France, Ghana, Hungary, Japan, Republic of Korea, Moldova, Mongolia, Morocco, Netherlands , Poland, Romania, Slovakia, Slovenia, Sweden, Ukraine, UAE, UK.
"Recognising that nuclear energy is already the second-largest source of clean dispatchable baseload power"
"Recognising that analyses from the OECD NEA and WNA show that global installed nuclear energy must triple by 2050 in order to reach global net-zero emissions by the same year"
"Recognising the need for high-level political engagement to spur further action on nuclear power"
https://www.energy.gov/articles/cop28-countries-launch-declaration-triple-nuclear-energy-capacity-2050-recognizing-key

US Uranium and Enrichment Initiatives

- US currently imports ~95% of uranium requirements and 70% of enriched uranium requirements
- 2022 Inflation Reduction Act $700 million for HALEU
- April 2024 - US Senate passed the *Prohibiting Russian Imports Act*, effective 90 days after Presidential signature on 13 May 2024 (11 August 2024)
- Nuclear Fuel Security Act $2.7 billion
- 27 June 2024 - US DOE released the LEU Enrichment Acquisition Request for Proposals (RFP) to establish a robust supply chain for low enriched uranium (LEU)

Sapporo 5

- US, Canada, France, Japan and UK
- Created 17 April 2023 following Russia's invasion of Ukraine and increasing impacts of climate change
- Sapporo 5 members make up half the world's uranium conversion and enrichment capacity
- S5 announced plans on margins of COP28 to mobilise $4.2 billion in government-led investments to secure resilient global nuclear supply chain that is free from Russian influence

- https://www.energy.gov/articles/statement-civil-nuclear-fuel-cooperation-between-united-states-canada-france-japan-and

Summary

- No countries self sufficient
- Uranium mining opportunities for Australia
- ISL dominant mining technology
- Conversion/enrichment/fuel fabrication dominated by a few large players
- Opportunities for Silex
- Major moves by western countries to replace Russian supplies