

Uranium Exploration, Resources, And Production: A Global Overview

Belgian Nuclear Society
Evening Lecture Seminar
18:30 May 23, 2024
Fondation Universitaire
11, Rue d'Egmont
Brussels, Belgium

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Division of Nuclear Fuel Cycle and Waste Technology
Nuclear Fuel Cycle and Materials Section
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Talking Points...



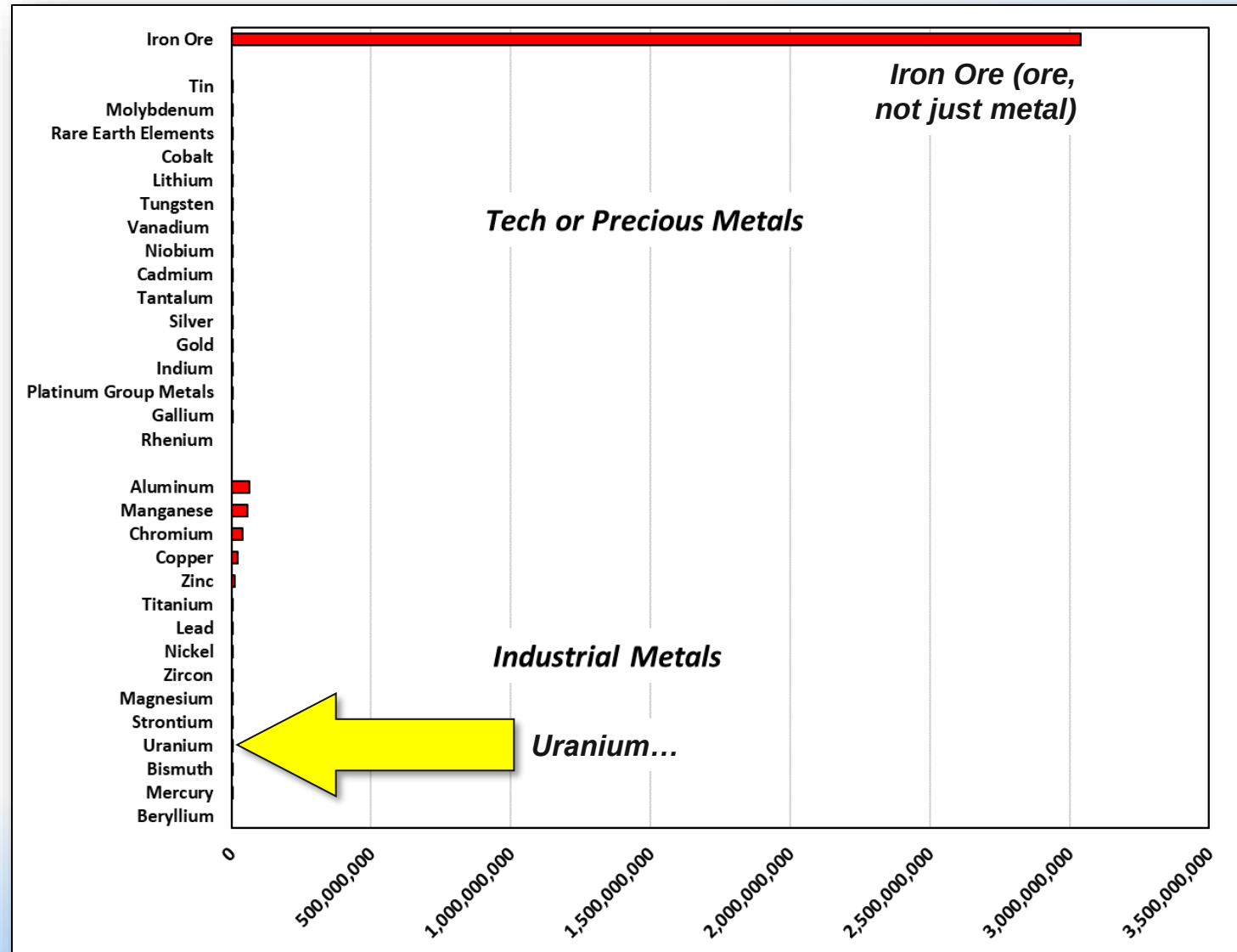
Drum of Yellow
Cake, UEC
Hobson
Processing
Plant, Texas



- Uranium... some context
- Recent interest, headlines, and some statistics
- Joint OECD-NEA/IAEA Uranium Group and the Red Book
- Uranium resource nomenclature and classifications
- Uranium supply and demand relationships
- Take-aways

Uranium: Some Context... Uranium Mined in 2019

How Does Uranium Compare? Relative Size of the Industry



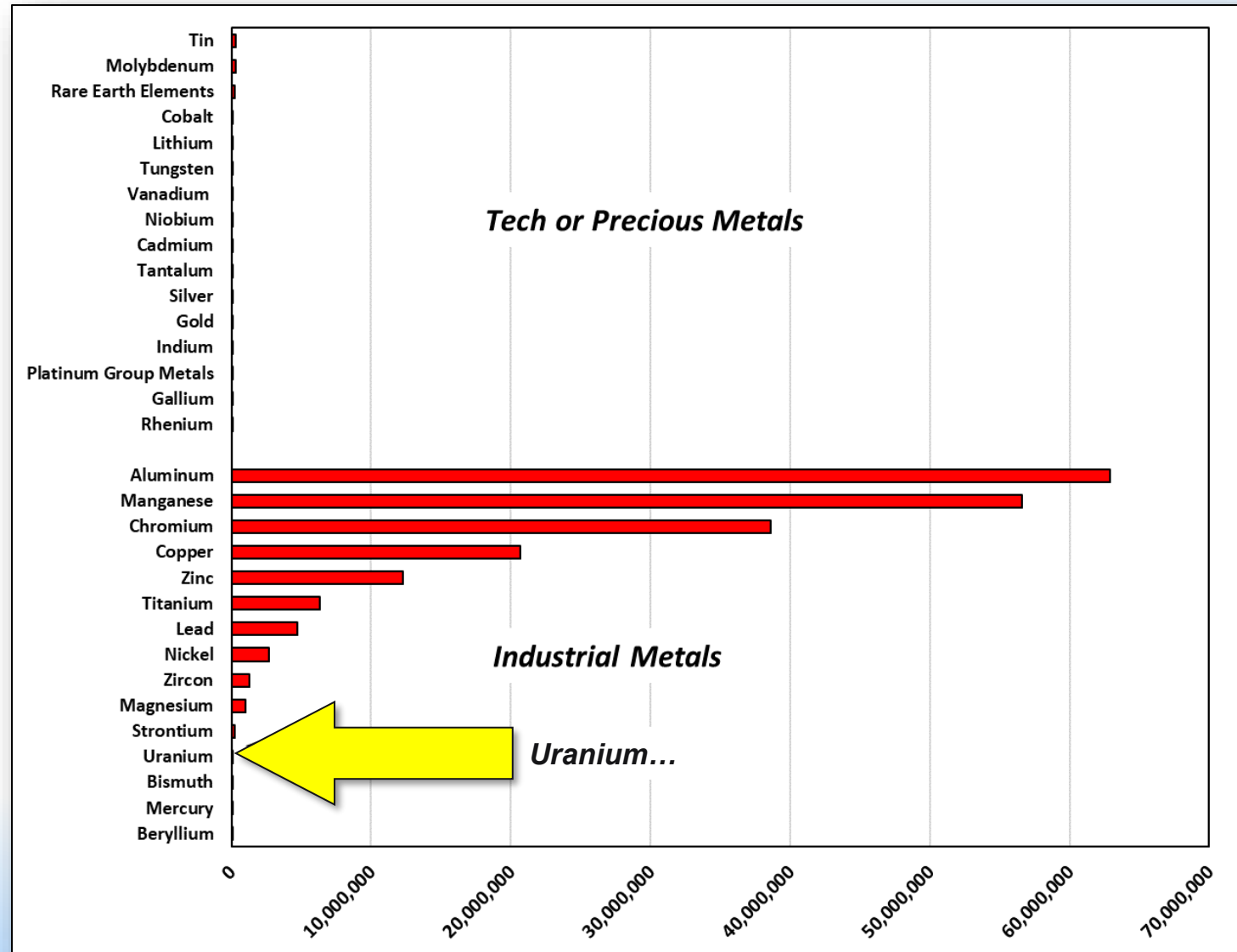
Sources: British Geological Survey (2019),
USGS Mineral Commodity Summaries (2021)

Uranium: Some Context... Uranium Mined in 2019

How Does Uranium Compare? Relative Size of the Industry



*Remove the
iron ore...*



Sources: British Geological Survey (2019),
USGS Mineral Commodity Summaries (2021)

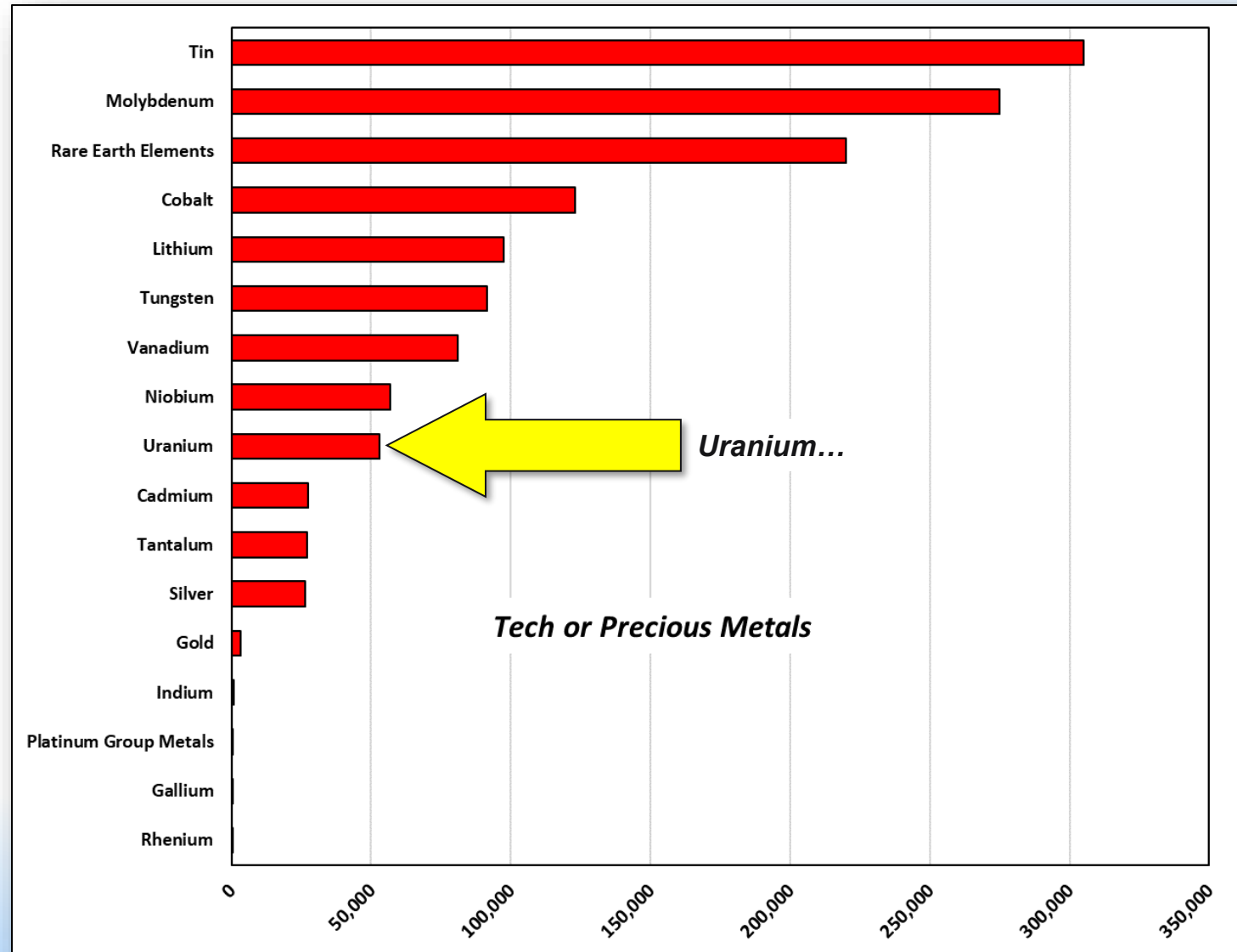
Uranium: Some Context... Uranium Mined in 2019

How Does Uranium Compare? Relative Size of the Industry



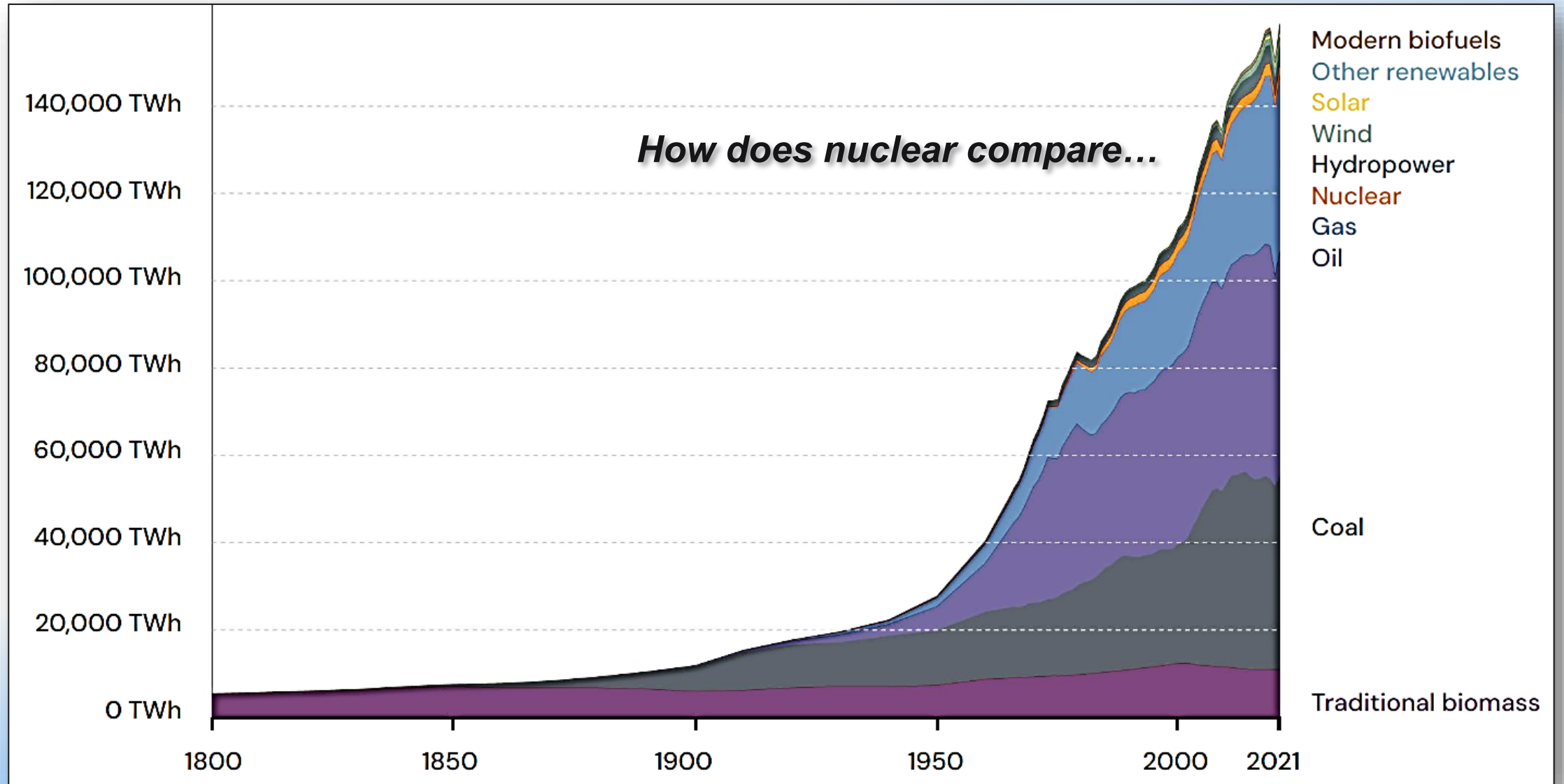
IAEA

Remove the industrial metals, except for uranium...



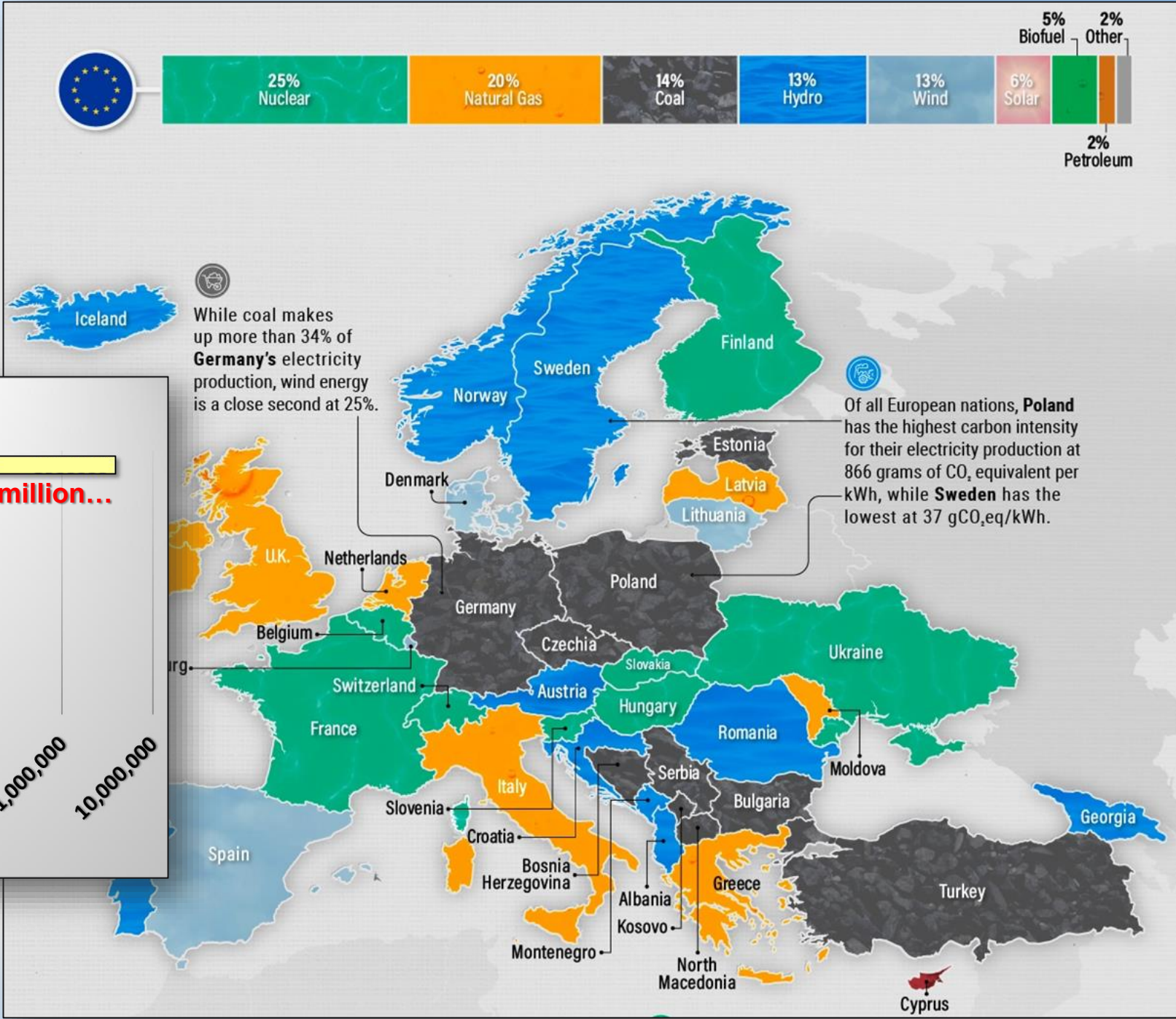
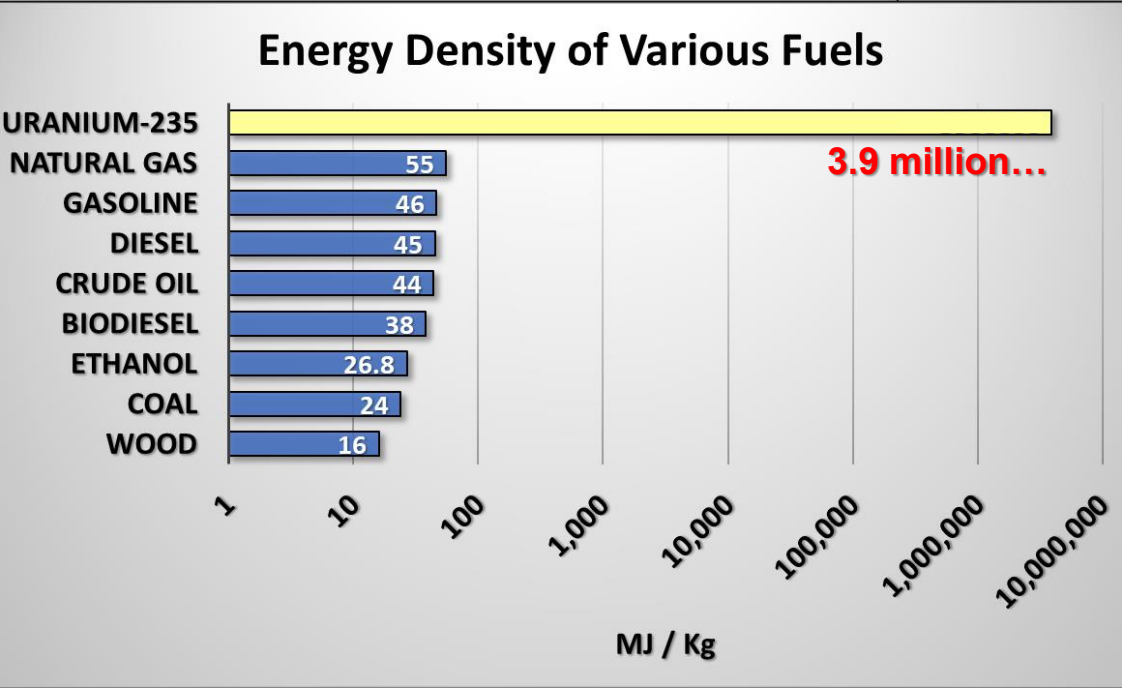
Sources: British Geological Survey (2019),
USGS Mineral Commodity Summaries (2021)

Uranium: Some Context... Global Primary Energy Consumption 1800-2021



Uranium: Why All the Interest?

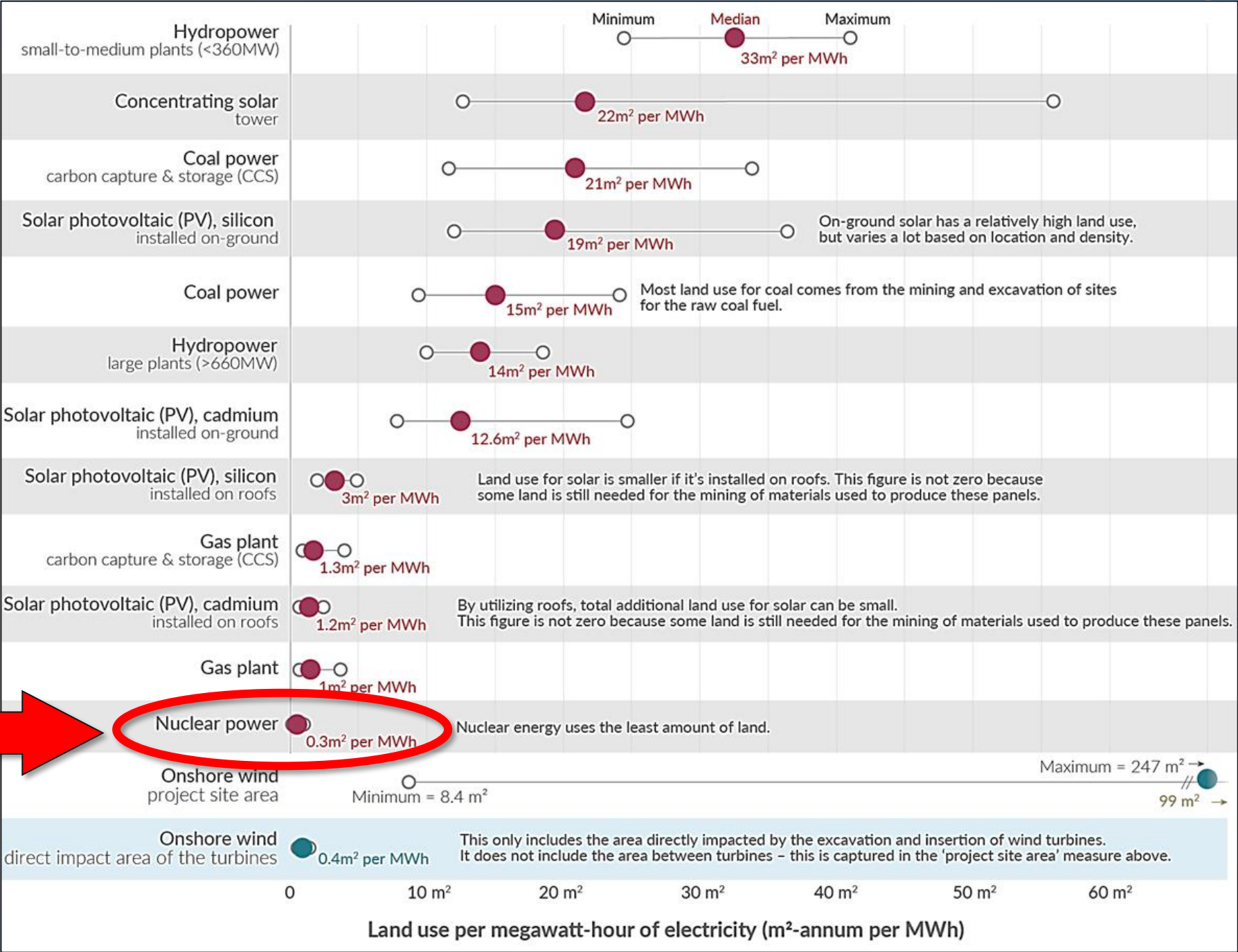
Energy Density and Electricity...



Source: Cote and Parker, Visual Capitalist (2023;
<https://www.visualcapitalist.com/mapped-europes-biggest-sources-of-electricity-by-country/>)

Uranium: Why All the Interest? Land Use...

*Nuclear
power has
the smallest
land use
footprint...*



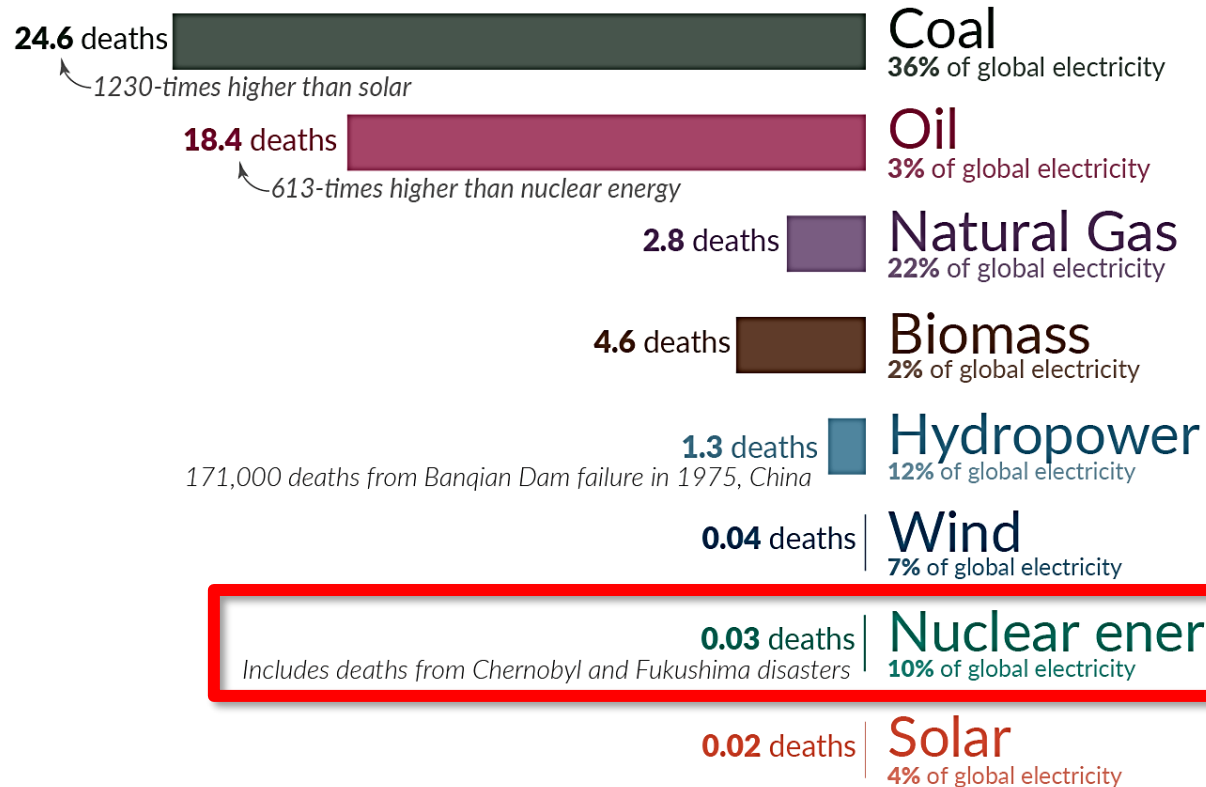
Source: Ritchie, Our World in Data (2022); <https://ourworldindata.org/land-use-per-energy-source>

Uranium: Why All the Interest? Safer and Cleaner...



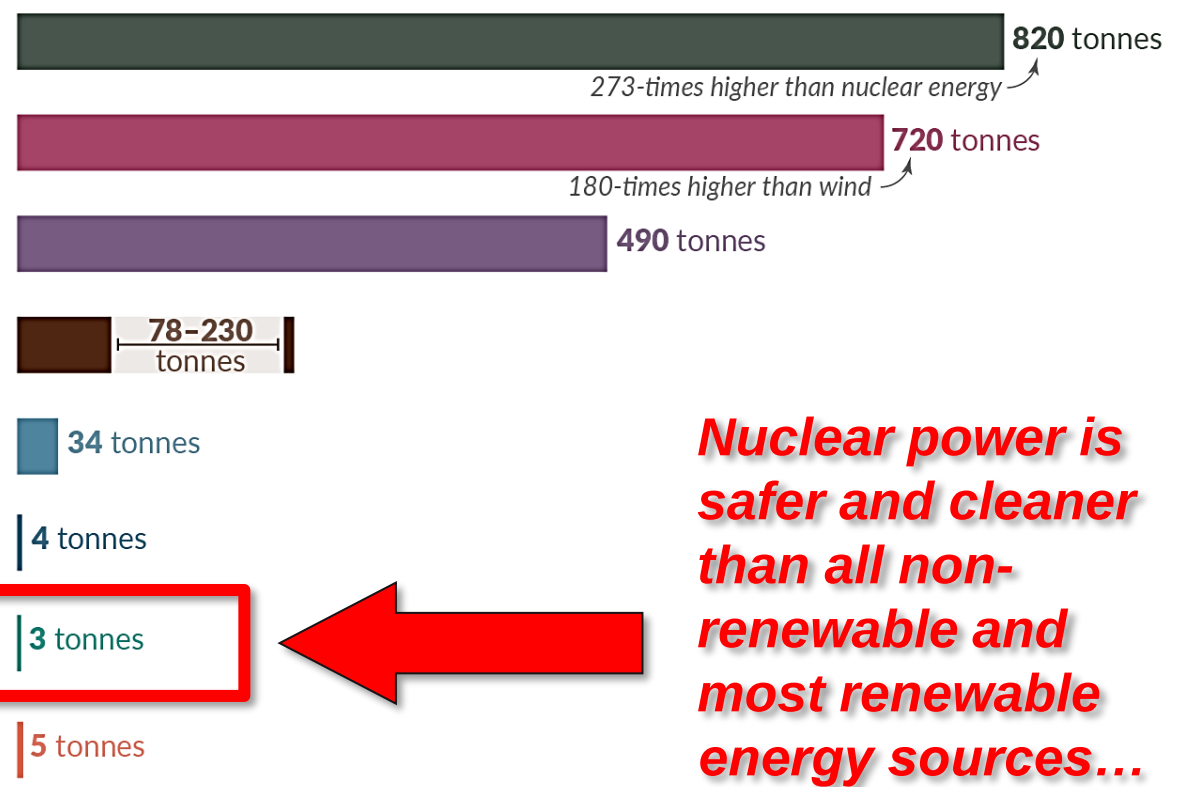
Death rate from accidents and air pollution

Measured as deaths per terawatt-hour of electricity production.
1 terawatt-hour is the annual electricity consumption of 150,000 people in the EU.



Greenhouse gas emissions

Measured in emissions of CO₂-equivalents per gigawatt-hour of electricity over the lifecycle of the power plant.
1 gigawatt-hour is the annual electricity consumption of 150 people in the EU.



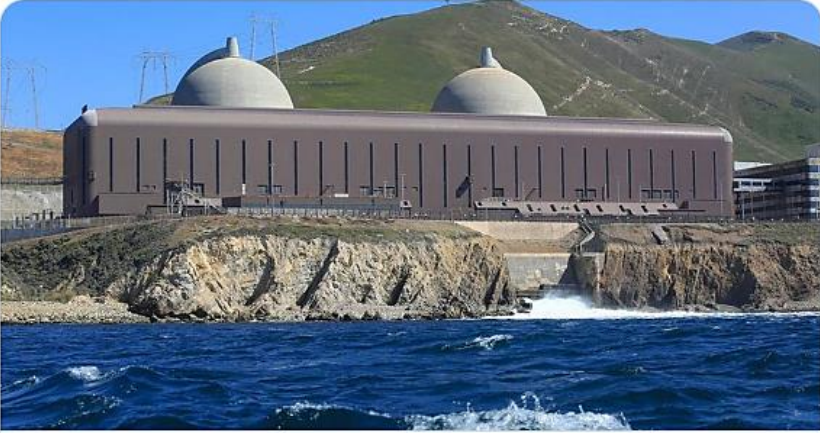
Nuclear power is safer and cleaner than all non-renewable and most renewable energy sources...

The Headlines... Calls to Support Nuclear Energy



TIME @TIME · 11 May

J. Robert Oppenheimer's grandson: "We must get over our cognitive and political bias: Nuclear energy is necessary and safe, and not the same as nuclear weapons"



time.com

Nuclear Energy's Moment Has Come

The grandson of J. Robert Oppenheimer explains why we need to develop and scale nuclear energy to meet the global energy transition

1,814 7,858 49K 7.2M

Elon Musk @elonmusk

The world should increase use of nuclear power!

7:55 pm · 11 May 2023 · 3.6M Views

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Home / News / Energy & Environment / Nuclear / Sweden adopts '100% fossil-free' energy target, easing way for nuclear

Sweden adopts '100% fossil-free' energy target, easing way for nuclear

EURACTIV.com with Reuters · Est. 2min · 21 Jun 2023 (updated: 22 Jun 2023)



"This creates the conditions for nuclear power," Finance Minister Elisabeth Svantesson said. "In order to increase electricity production, we need clean electricity and we need a stable energy system."

NHK WORLD - JAPAN Watch Live

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EXPERTS URGE G7 LEADERS TO DISCUSS NUCLEAR SECURITY

Experts urge G7 leaders to discuss nuclear security

Thursday, May 11, 17:09

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Industry to G7: Back current fleet, speed deployment of advanced units

Tue, Apr 18, 2023, 7:22PM | Nuclear News



Press Release

16 May 2023

Member States call on EU to support ALL low-carbon, fossil free energy sources – including nuclear

Brussels, 16 May 2023: 16th Member States met today in Paris with Commissioner Kadri Simson to discuss cooperation on nuclear energy, further to the recently established 'nuclear alliance'

Declaration in Sapporo, Japan. Seated, left to right, are George Christidis (representing CNA) chief, Tom Greatrex, Yves Desbazeille, and Sama Bilbao y León. (Photo: World Nuclear Association)

nucleareurope Supporting a sustainable future

Press Release

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Member States call on EU to support ALL low-carbon, fossil free energy sources – including nuclear

Brussels, 16 May 2023: 16th Member States met today in Paris with Commissioner Kadri Simson to discuss cooperation on nuclear energy, further to the recently established 'nuclear alliance'

The Headlines... Revival of Nuclear Energy



Bloomberg

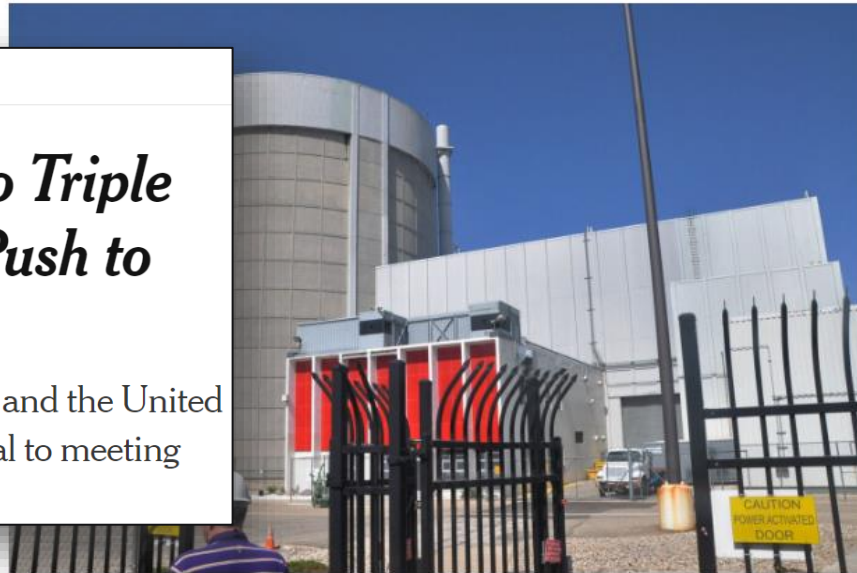
• Live TV Markets ▾ Economics Industries Tech Politics Businessweek Opinion More ▾

Nuclear Energy Revival: Why Fusion Is So Hard | Two Approaches to Fusion | Why Nuclear Is Booming | Future History of

Green
Climate Politics

Once Unthinkable Nuclear Plant Revival Is a Reality in US Shift

Restart of Michigan's Palisades plant could lead to more reopenings.



The Palisades nuclear plant in Covert Township, Michigan, in 2010. Photographer: John Madill/The Herald-Palladium



By [Will Wade](#)

29 April 2024 at 14:00 CEST

Countries launch joint declaration to triple nuclear energy capacity by 2050 at COP28

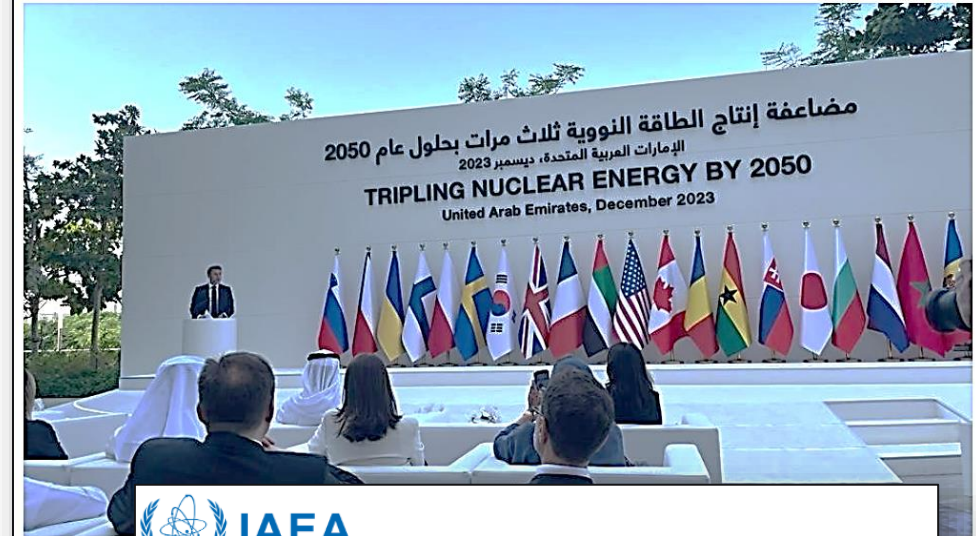
Published date: 2 December 2023 |

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Final COP28 Agreement Calls for Faster Deployment

Nuclear Energy Makes History as Final COP28 Agreement Calls for Faster Deployment

13 Dec 2023

Jeffrey Donovan, IAEA Department of Nuclear Energy

The Headlines... Concerns About a Supply Gap

MINING.COM



Uranium sector 'scrambling' to fill supply gap

Colin McClelland | November 23, 2023 | 4:30 pm [Energy News Asia](#) [Canada](#) [Europe](#) [Russia and Central Asia](#) [Uranium](#)



About 60 nuclear plants currently under construction worldwide...

A uranium supply gap will widen by 2030 as more nuclear plants come online, analysts say.

- Uranium spot price surged past USD\$100 U_3O_8 /lb for the first time since late 2007 (15 January 2024)
- Existing nuclear fuel supplies are being depleted by higher demand
- Global yellowcake (U_3O_8) supply could reach 145 million lb. this year or next...
 - Annual demand is already at 180 million lb.
 - Annual demand expected to nearly double to 300 million lb. by 2040
- Uranium supply gap will widen by 2030 as more nuclear plants come online

The Headlines... Uranium Price: USD \$106/lb U₃O₈



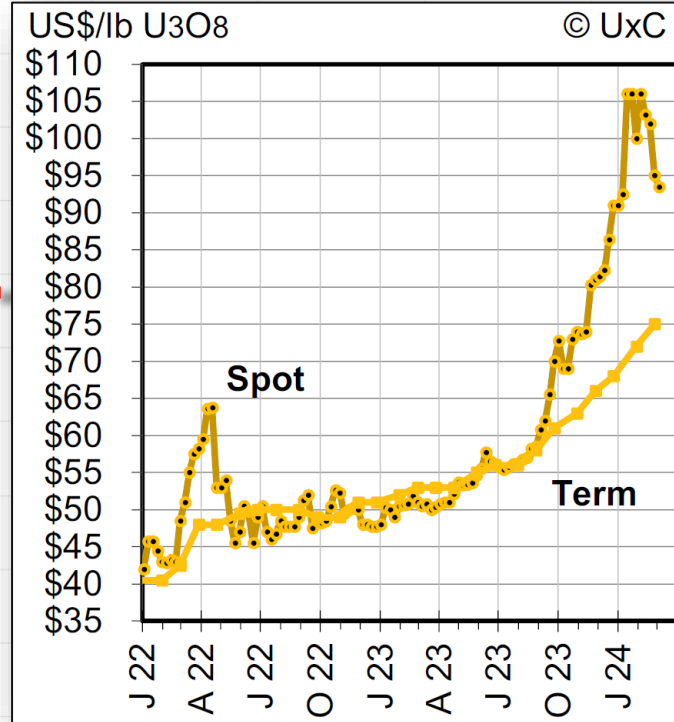
© Trading Economics

~ 24-Year High
So... Uranium
is "Back"?



October
2007

January
2024



2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022 2024

Uranium Supply and Demand Fundamentals

Supply

(Resources in the Ground)



Production

(Resources Extracted)



Demand

(Resources Requirements)



Some Stats... Deposits

DEPOSITS (COUNTS)

Number of uranium-bearing deposits with
>4000 tU (as of 2021, IAEA UDEPO database)



Highest in DEPOSITS

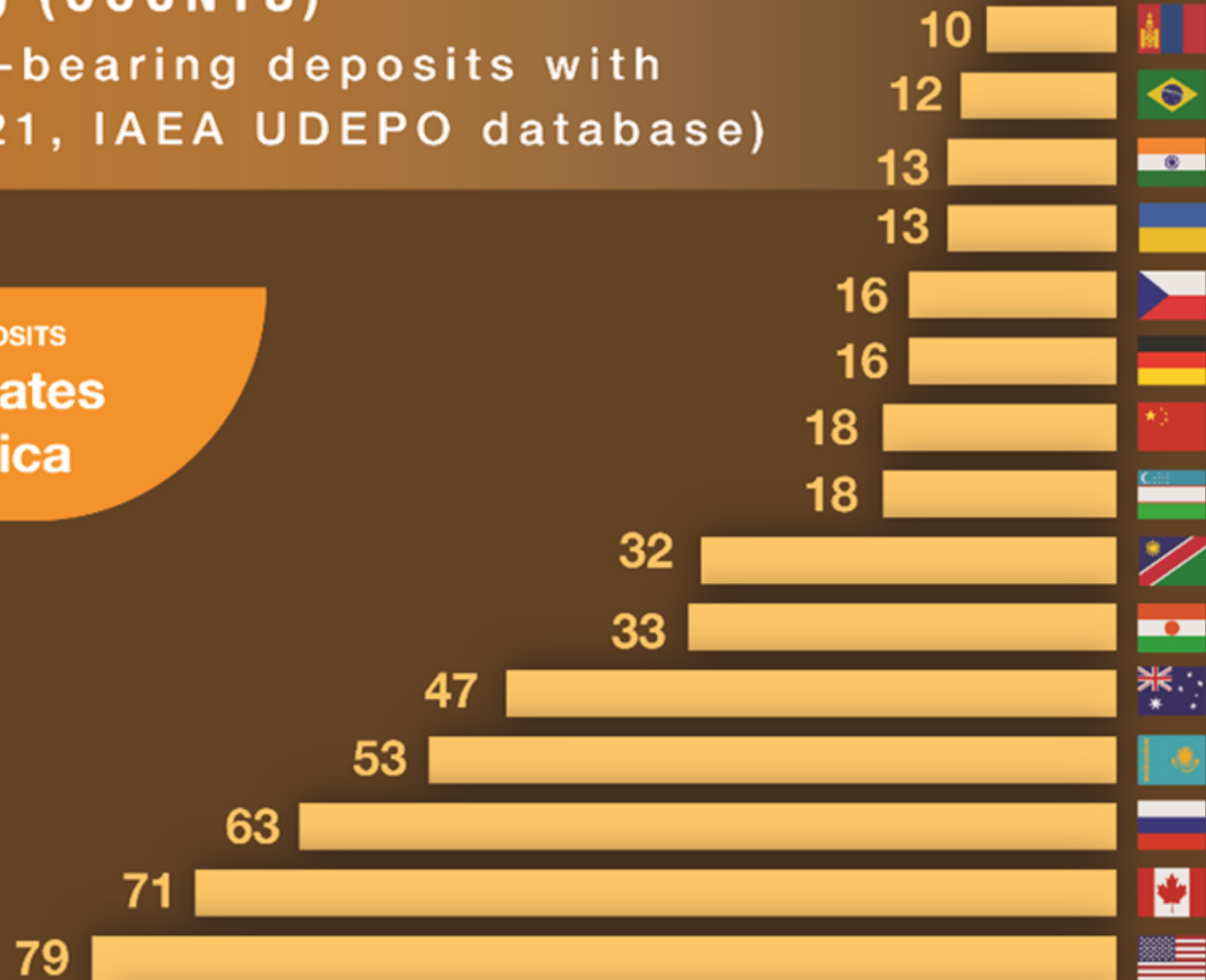
**United States
of America**

#2

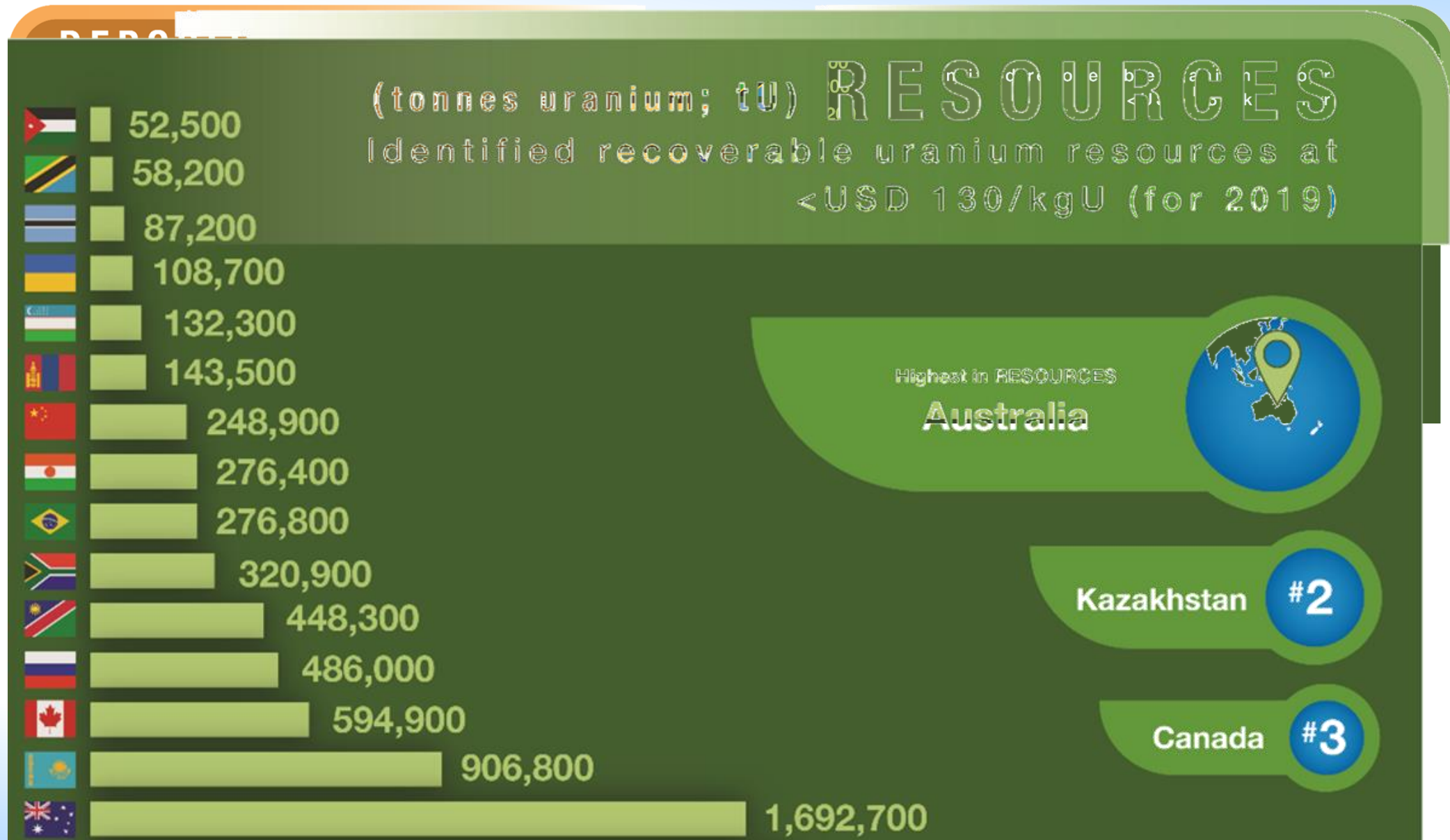
Canada

#3

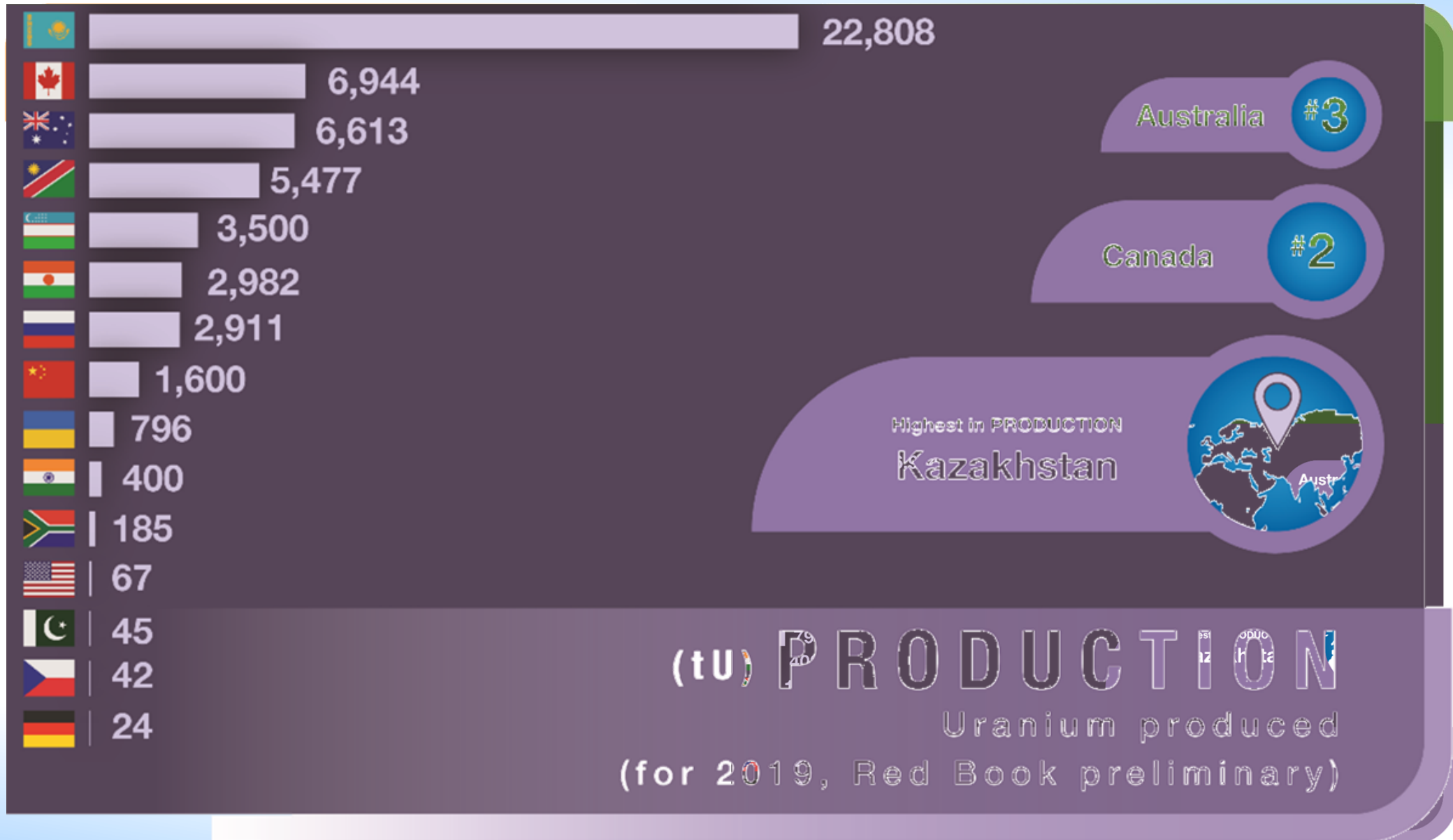
Russia



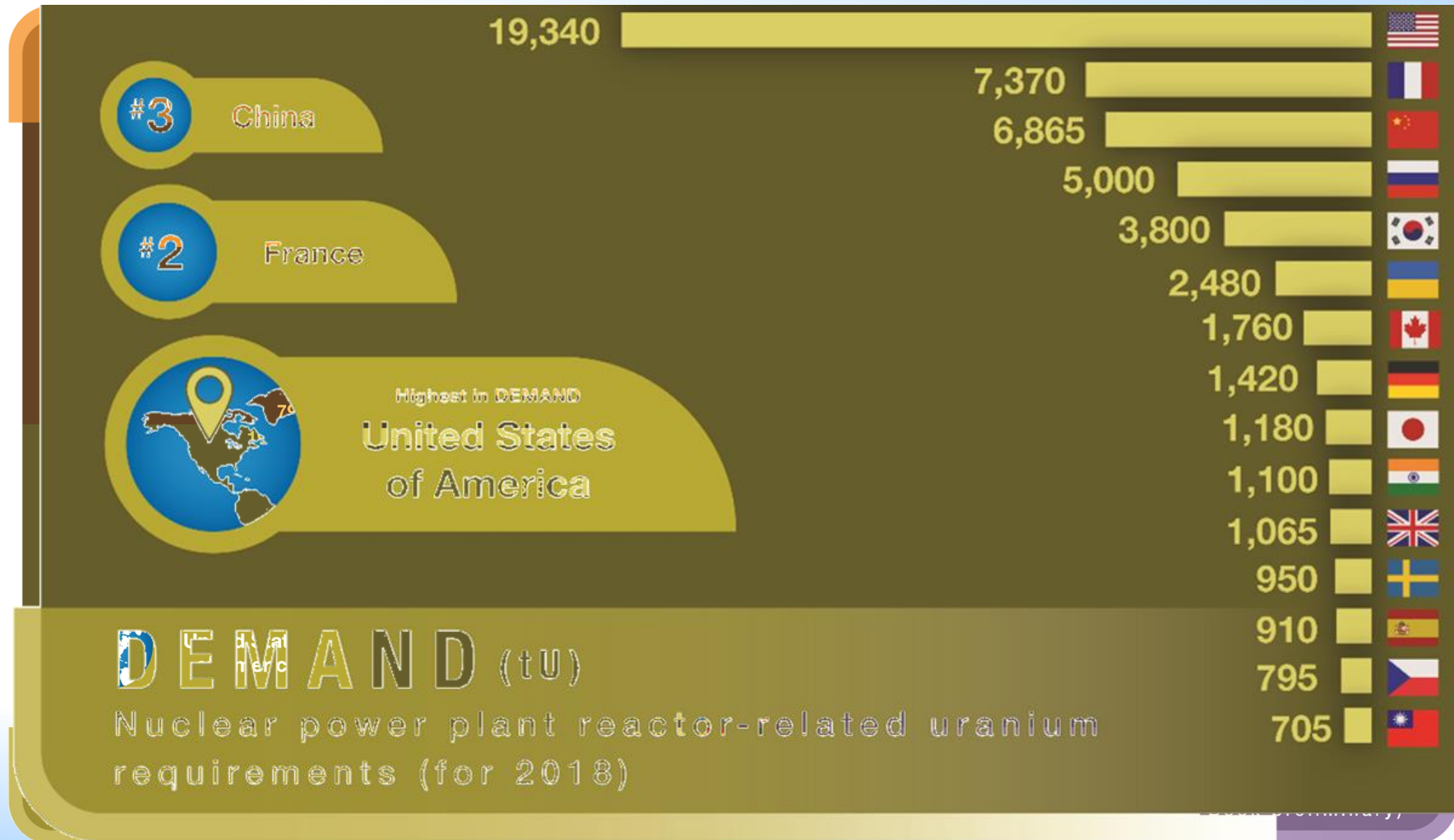
Some Stats... Resources



Some Stats... Production

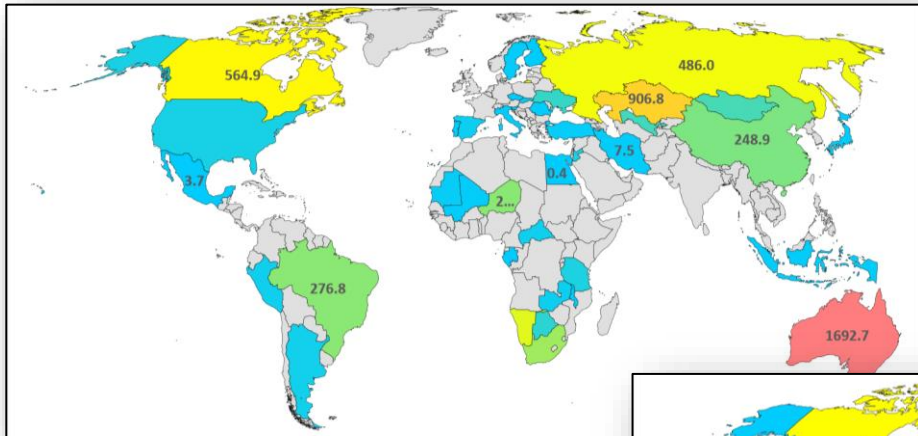


Some Stats... Demand

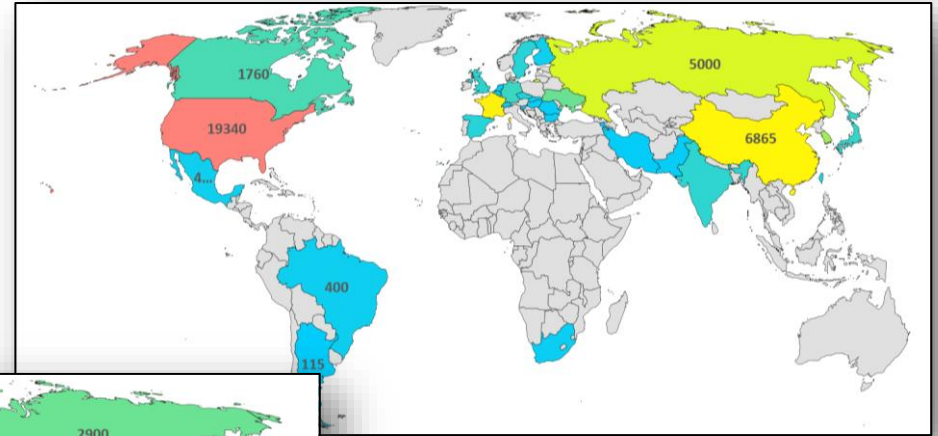


Some Stats... Resources, Production, and Demand

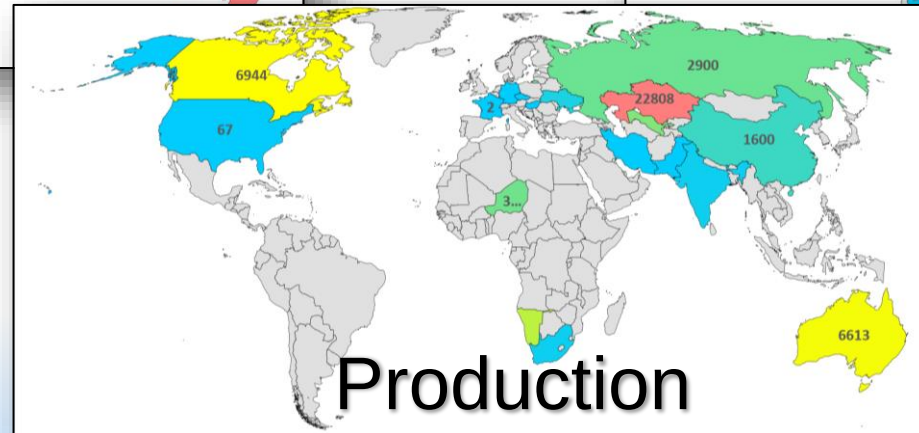
- The countries with abundant uranium resources or large production are not those with high uranium demand/requirements...



Resources



Demand

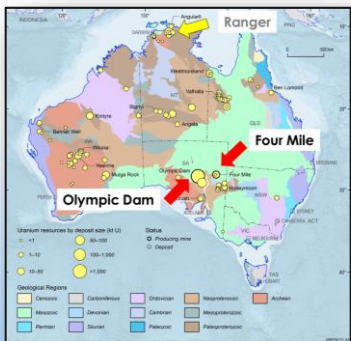


Production

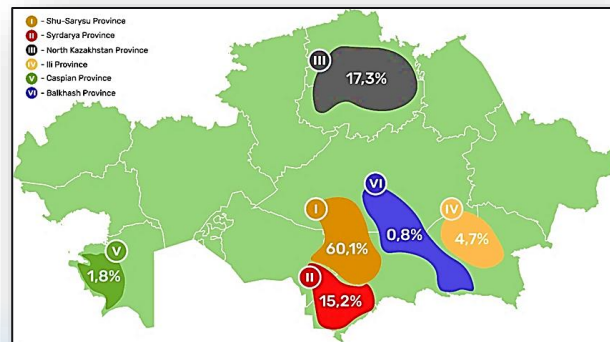
Some Uranium Stats... Overview of Global Projects, Resources/Reserves, and Deposits



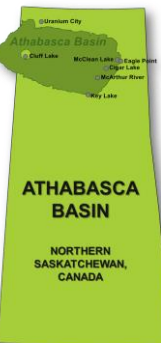
- 166 projects globally with resource or reserve estates
- 72% of global resources and reserves in Australia, Canada, and Kazakhstan...
 - 37% of global resources come from the Olympic Dam, Australia
 - 2% average to nearly 20% highest grade deposits in Canada
- Top 10 uranium deposits by resources...



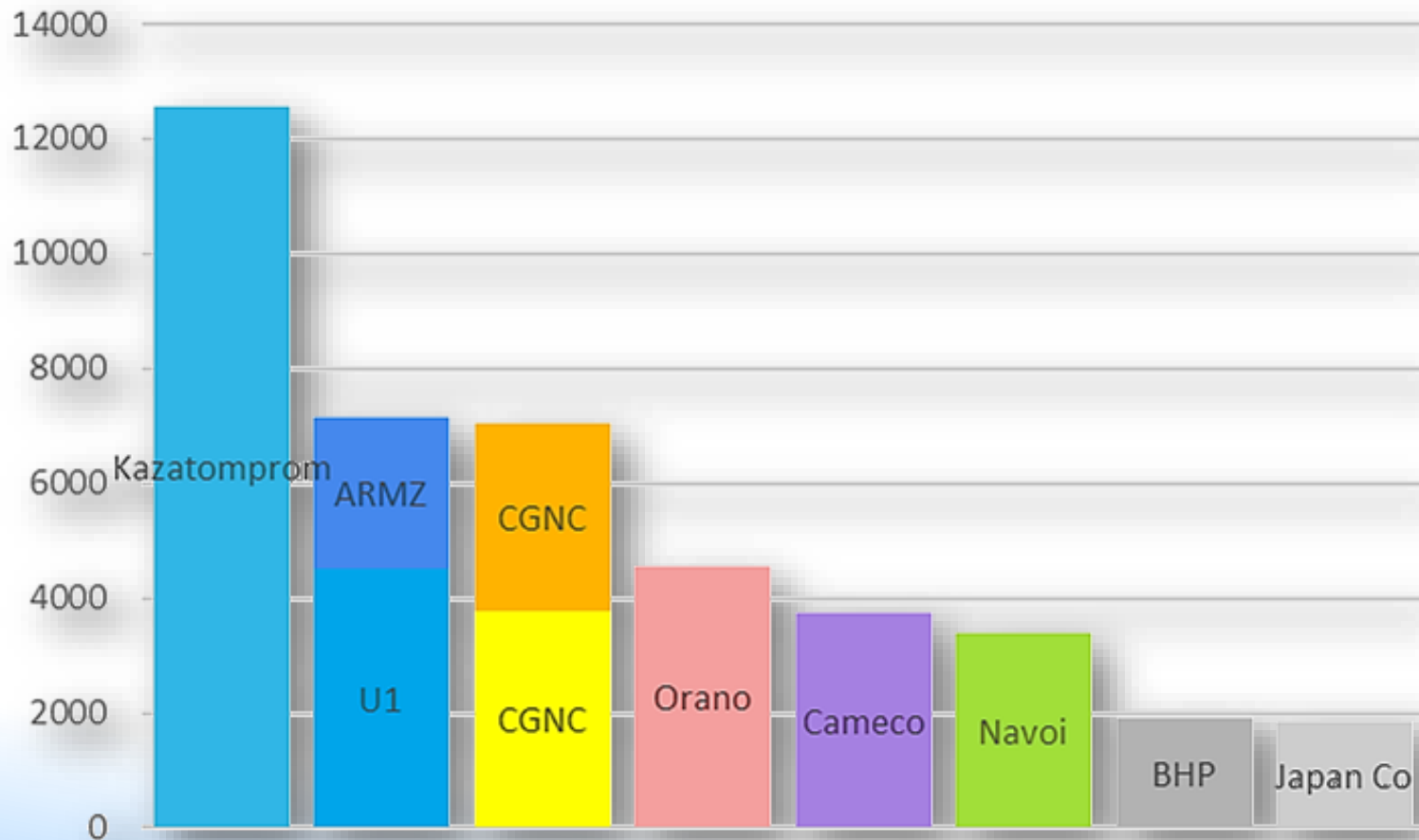
Olympic Dam - Australia
Inkai - Kazakhstan
Imouraren - Niger
Husab - Namibia
Budenovskoye - Kazakhstan



McArthur River - Canada
Arrow - Canada
Jabiluka - Australia
Cigar Lake - Canada
SOMAIR - Niger



Some Uranium Stats... 2021 Top Producing Companies



- 10 major companies produced 85% of world total...
 - 27% Kazatomprom
 - 15% Rosatom...
(Uranium One + ARMZ)
 - 14.8% Chinese companies...
(CNNC + CGNC)

Joint OECD-NEA / IAEA Uranium Group

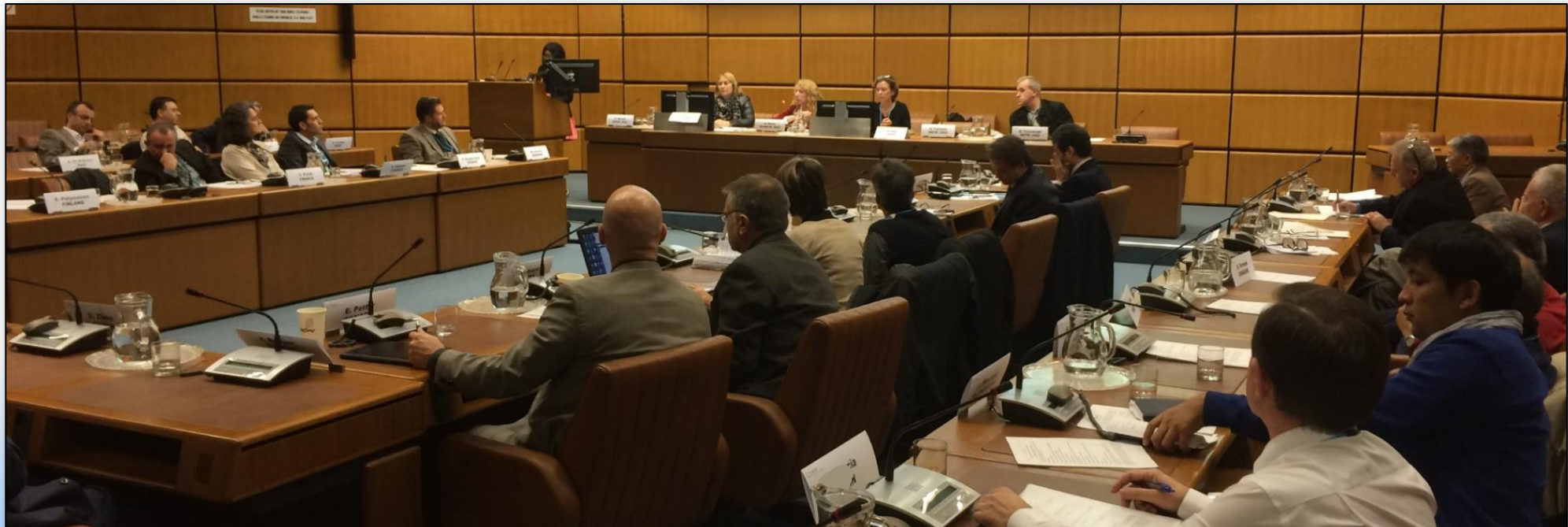


- Long-time collaborative association between the Nuclear Energy Agency (NEA) of the Organisation for Economic Cooperation and Development (OECD) and the International Atomic Energy Agency (IAEA)...
 - Forum for the exchange of information, analysis, and guidance on the uranium market and its role and relationship with respect to the global nuclear fuel cycle
 - Platform for dialogue and cooperation among governments, industry, and other stakeholders on issues related to the uranium market and the nuclear fuel cycle
 - Activities are based on the principles of transparency, objectivity, and impartiality



Joint OECD-NEA / IAEA Uranium Group

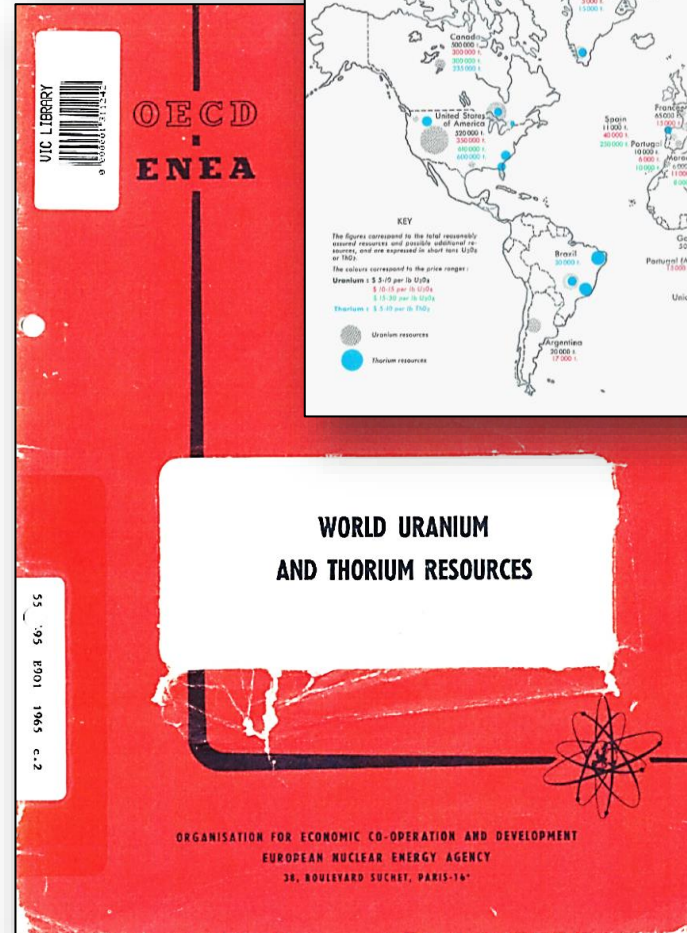
- Multilateral membership...
 - Officially nominated by a government authority
 - Approximately 50+ members from 40+ countries
 - Government officials/representative, functionaries, policy-makers/analysts, geologists, engineers, miners, economists, fuel buyers, etc.



Joint OECD-NEA / IAEA Uranium Group... Red Book

- Responsible for preparation and publication of the “**Red Book**” ...
 - Tracks world and country trends and developments in uranium exploration, resources, production & demand
- Biennial, country-level global survey...
 - More than 100 countries have contributed over its history

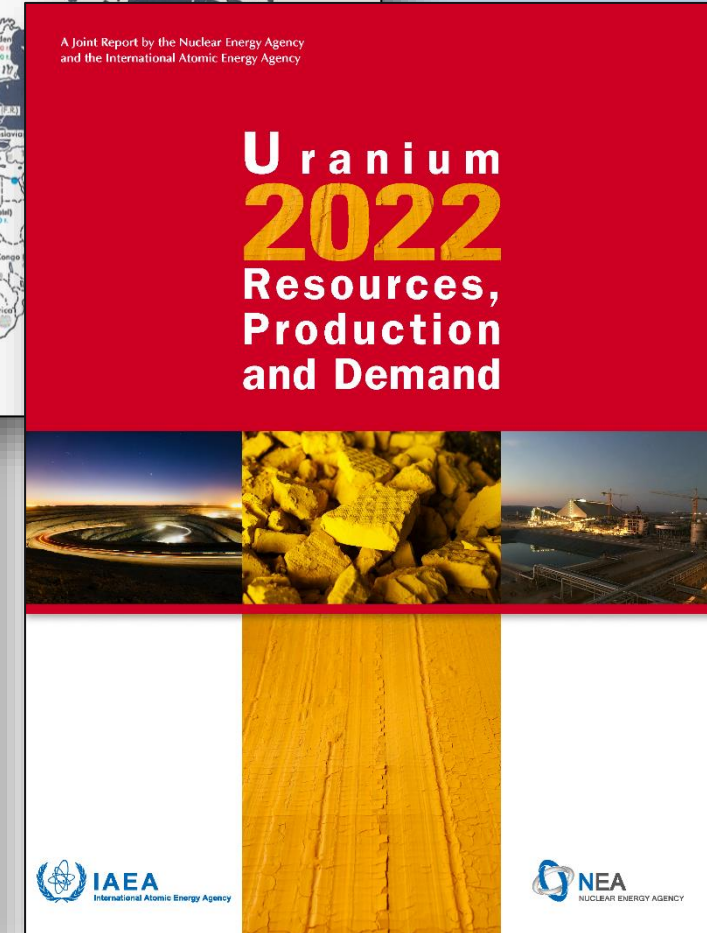
1st edition



1965

OECD / ENEA

29th edition

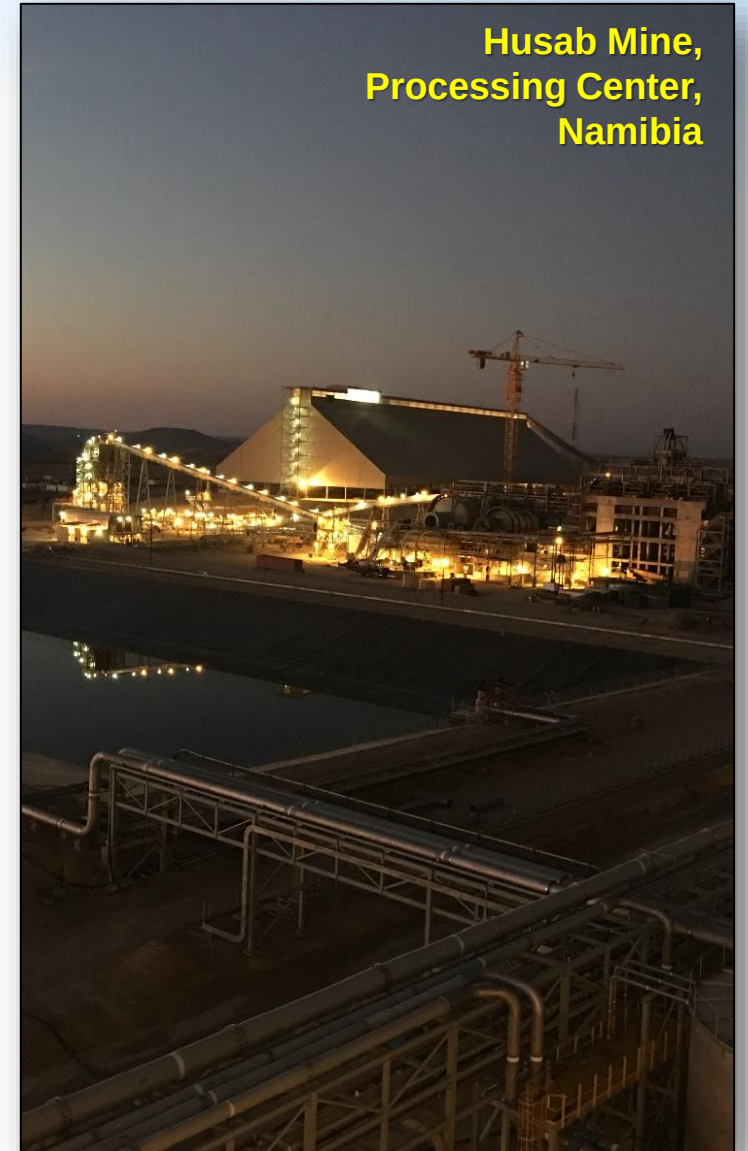


2023

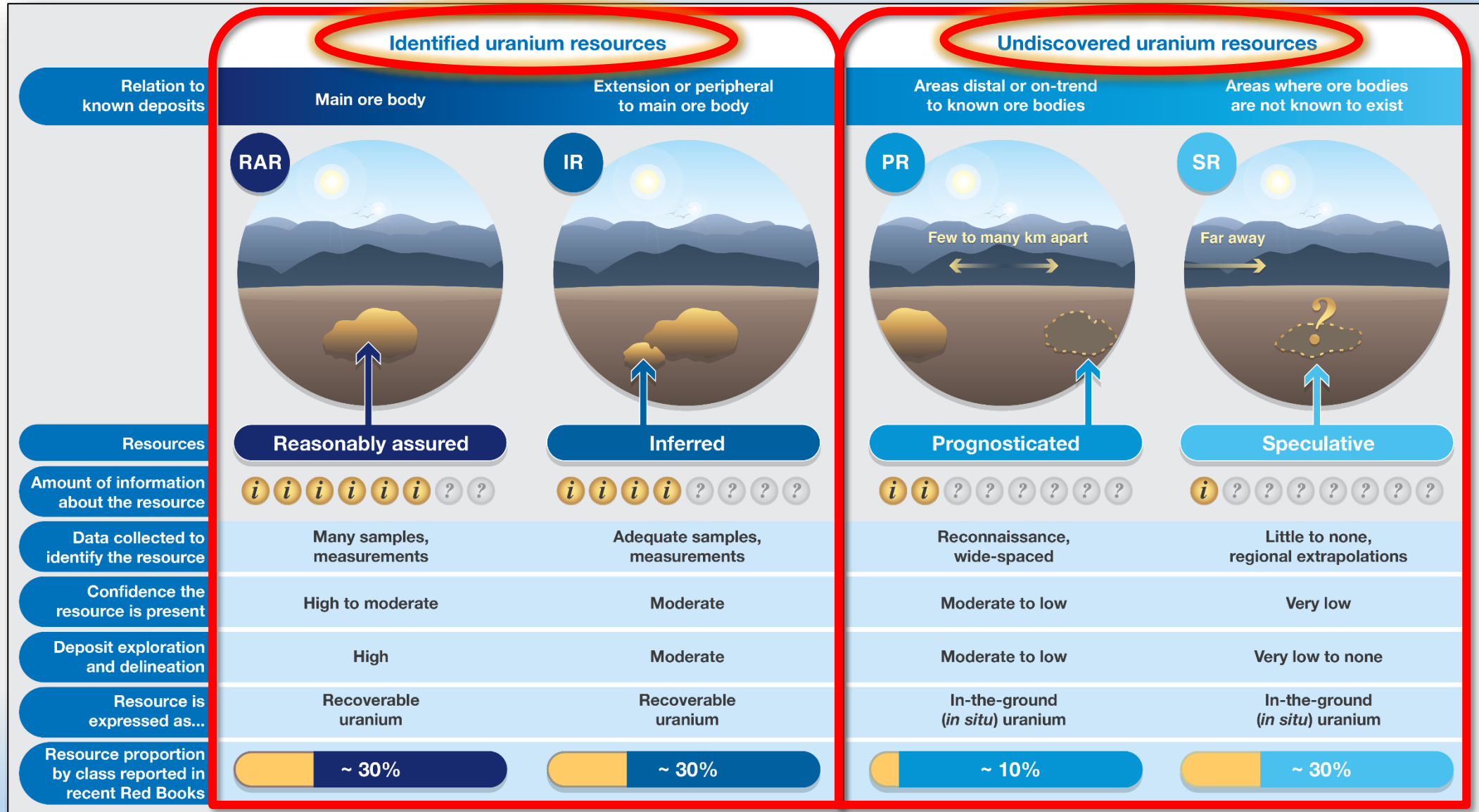
OECD-NEA / IAEA

Red Book... What Is It?

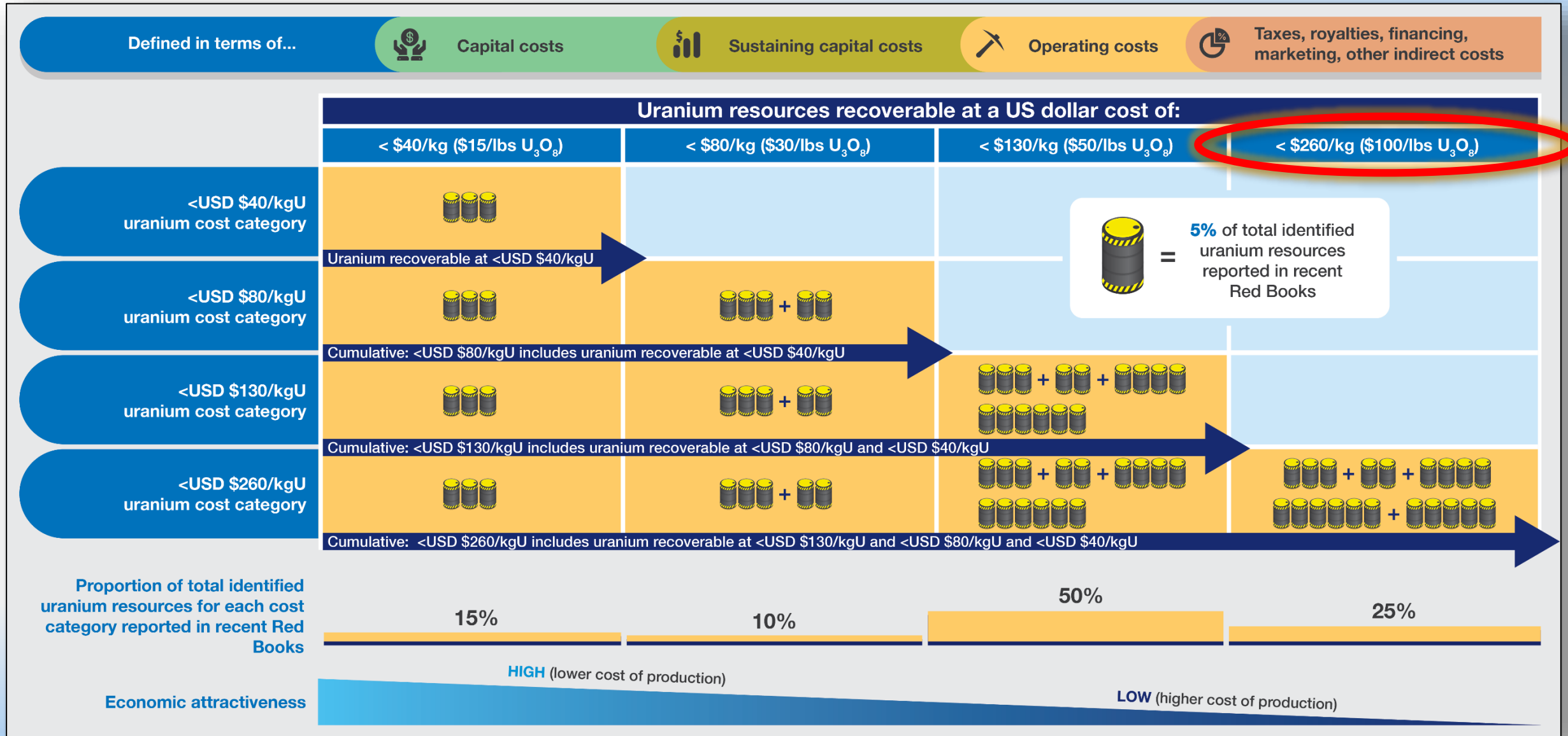
- Authoritative source for uranium resource information...
 - Derived from official government information
 - Valued for its unbiased, non-promotional analysis
- Provides statistics and analyses...
 - Exploration, resources, production, demand
 - Secondary sources, surplus defence material
 - Supply and demand relationships
- Reference manual...
 - Public and private libraries
 - Energy & uranium production companies
 - National and international organizations
 - Universities, research institutes, industry



Red Book... Terminology: Resource Classification



Red Book... Terminology: Cost Categorization

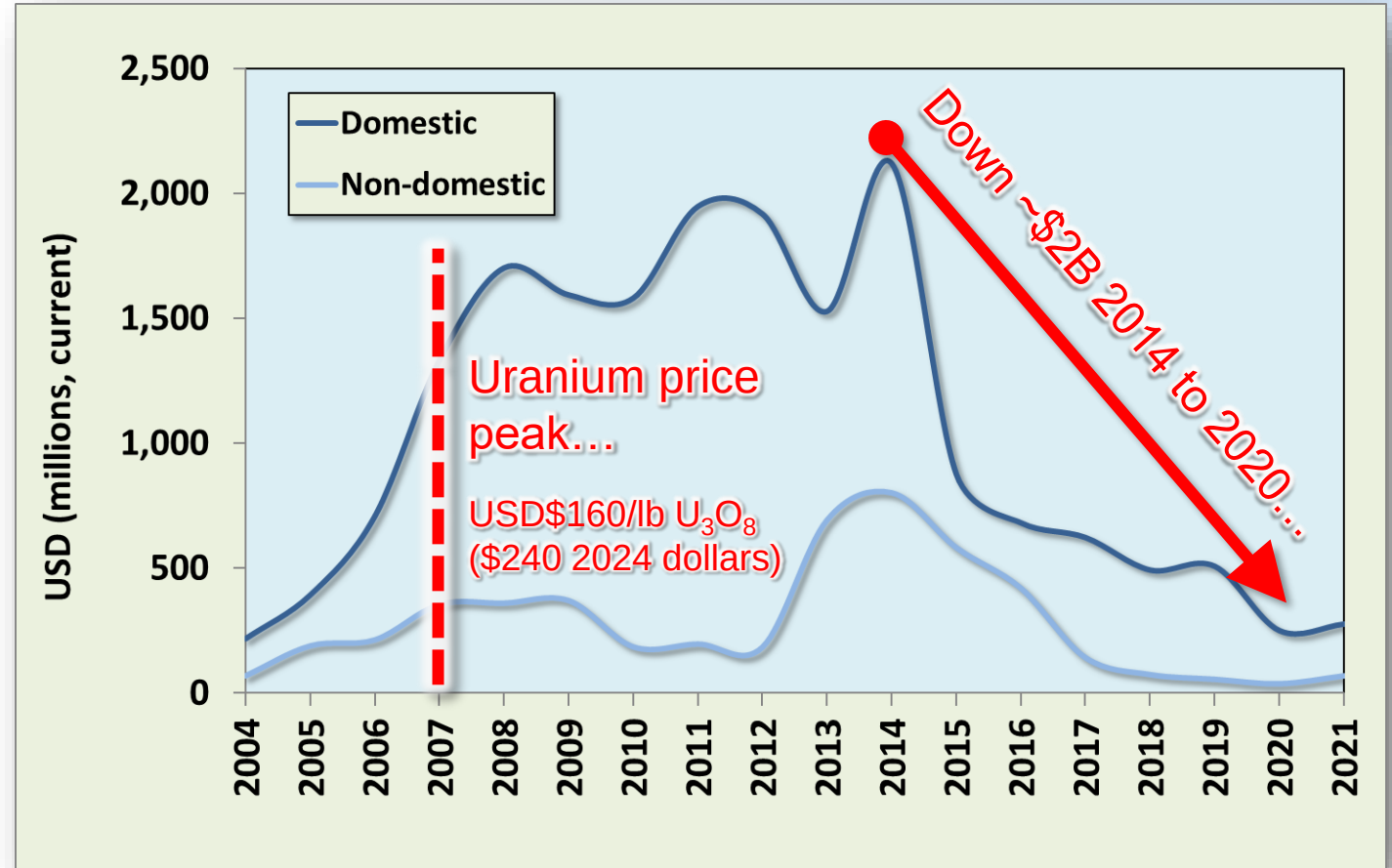


Supply... Uranium Exploration & Mine Development Expenditures, 2004-2021

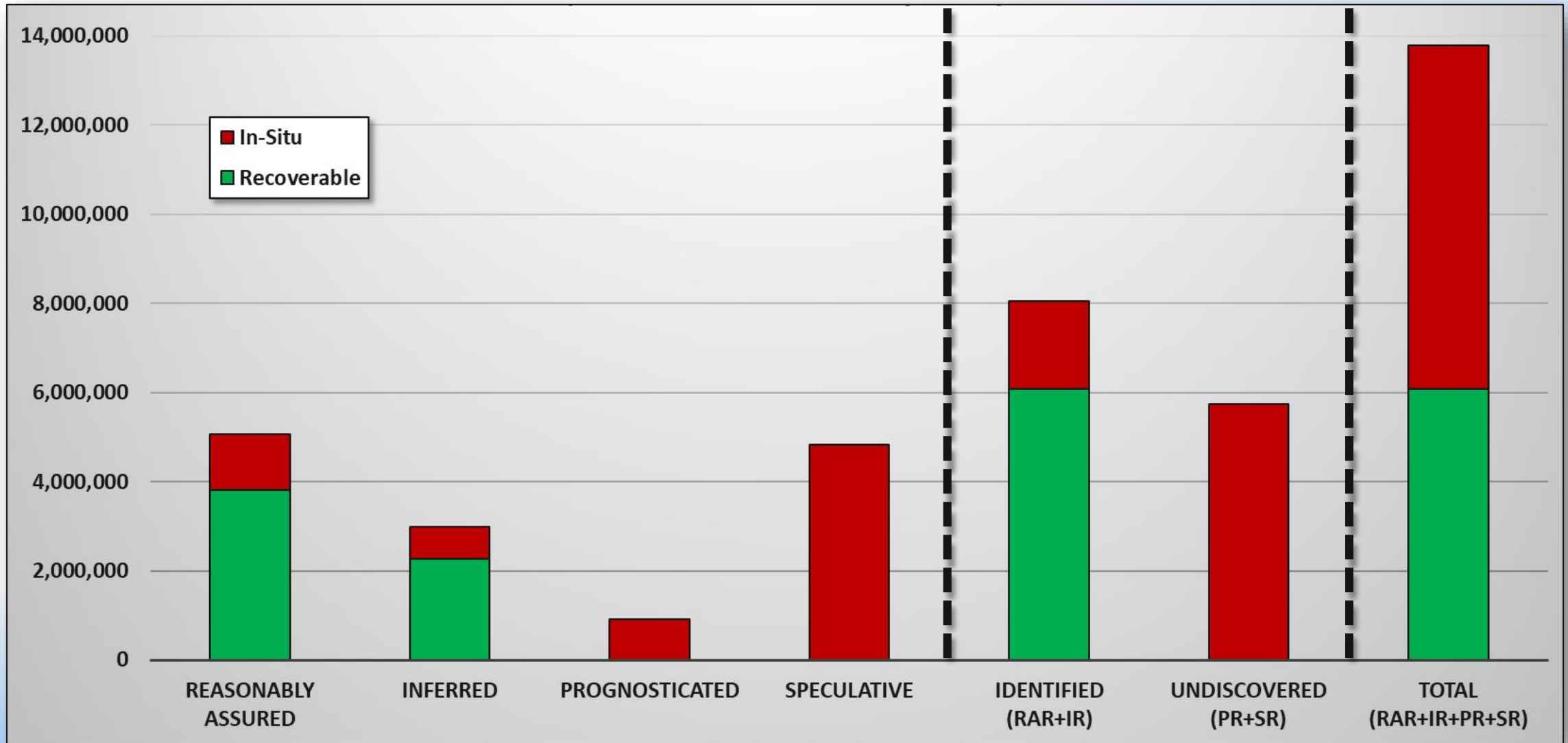
- Decrease of almost USD \$2B from 2014 to 2020

- 2021 expenditures increase slightly, but are expected to dramatically rise in response

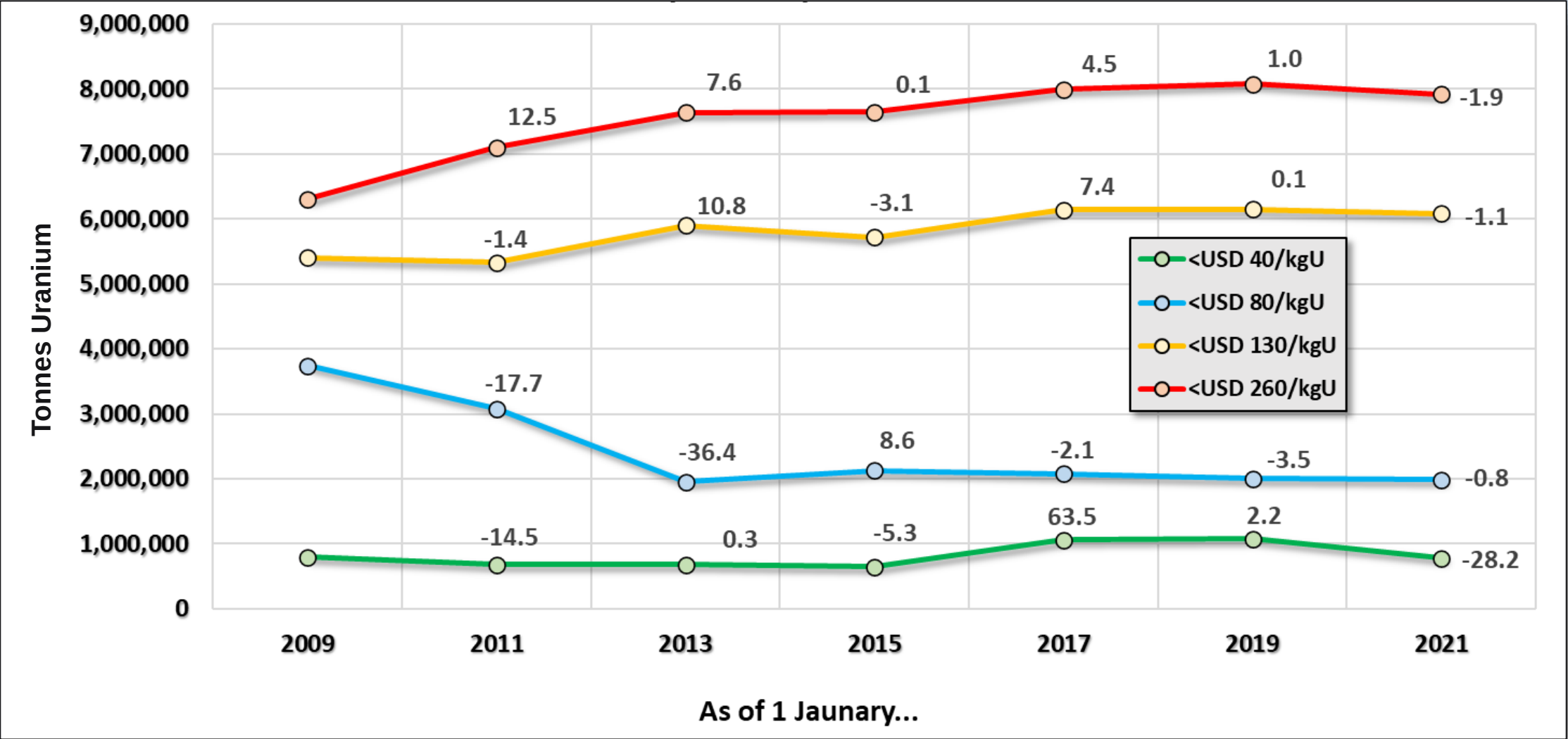
to recent renewed interest in nuclear power generation and the deployment of SMRs



Supply... Resources, Conventional, 1 Jan. 2021, by Resource Classification, at <USD 130/kgU

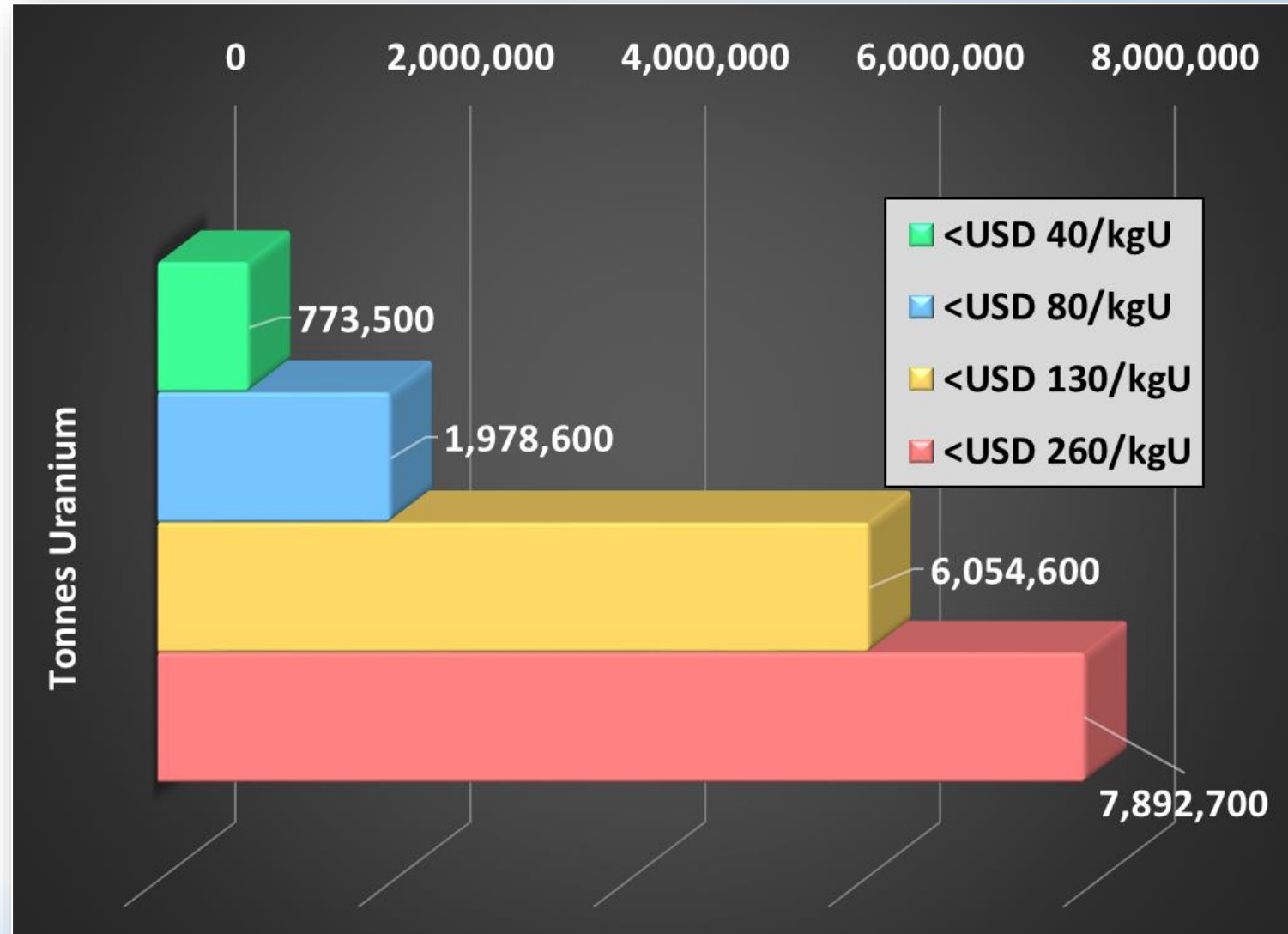


Supply... Resources, Identified Recoverable, 2009-2021 Global Changes, by Cost Category



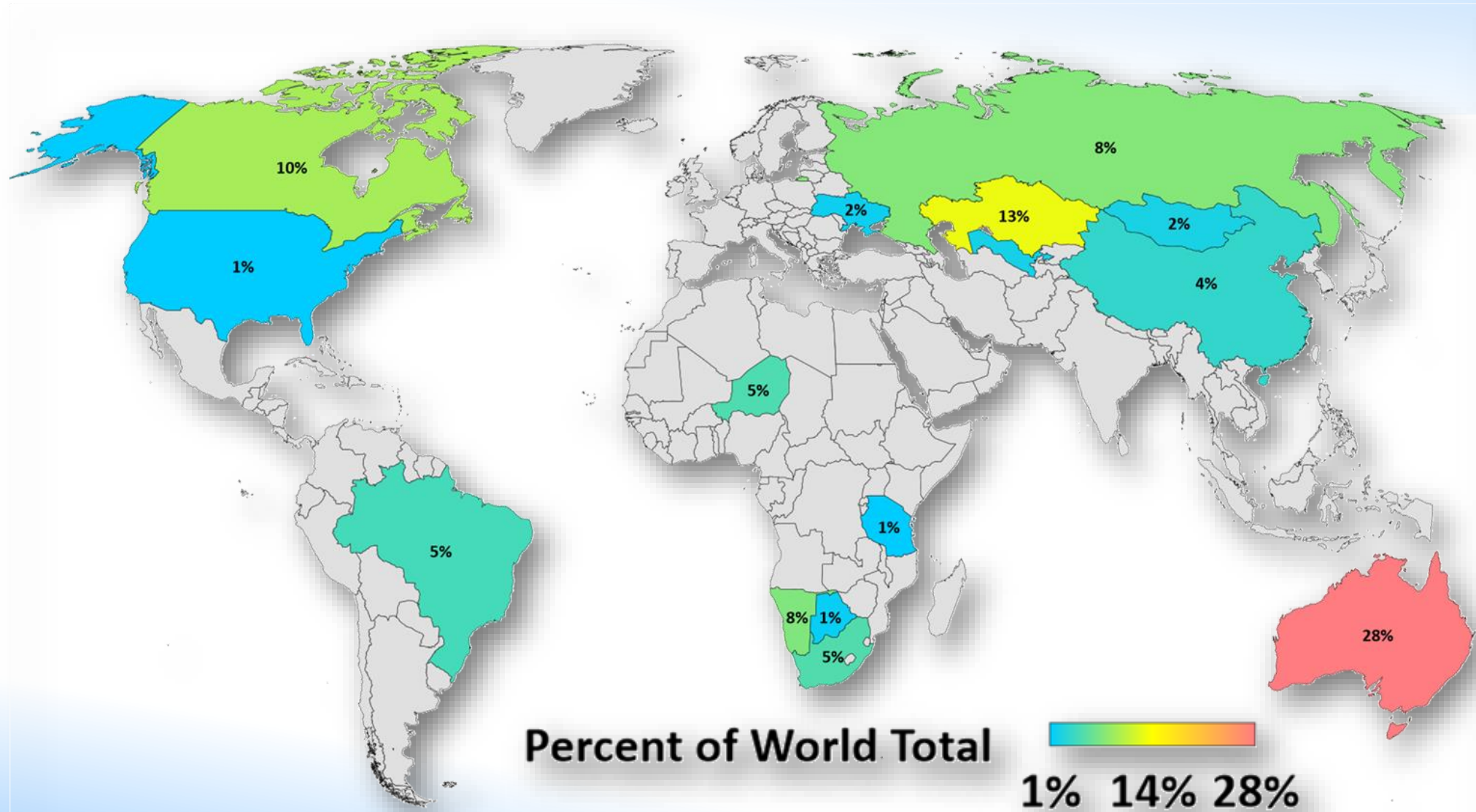
Supply... Resources, Identified Recoverable, 1 Jan. 2021, by Cost Category

- Identified recoverable resources decreased by ~2% from 2019, most notably in lower cost recoverable resources
- Mainly result of mining depletion and cost category re-assignments

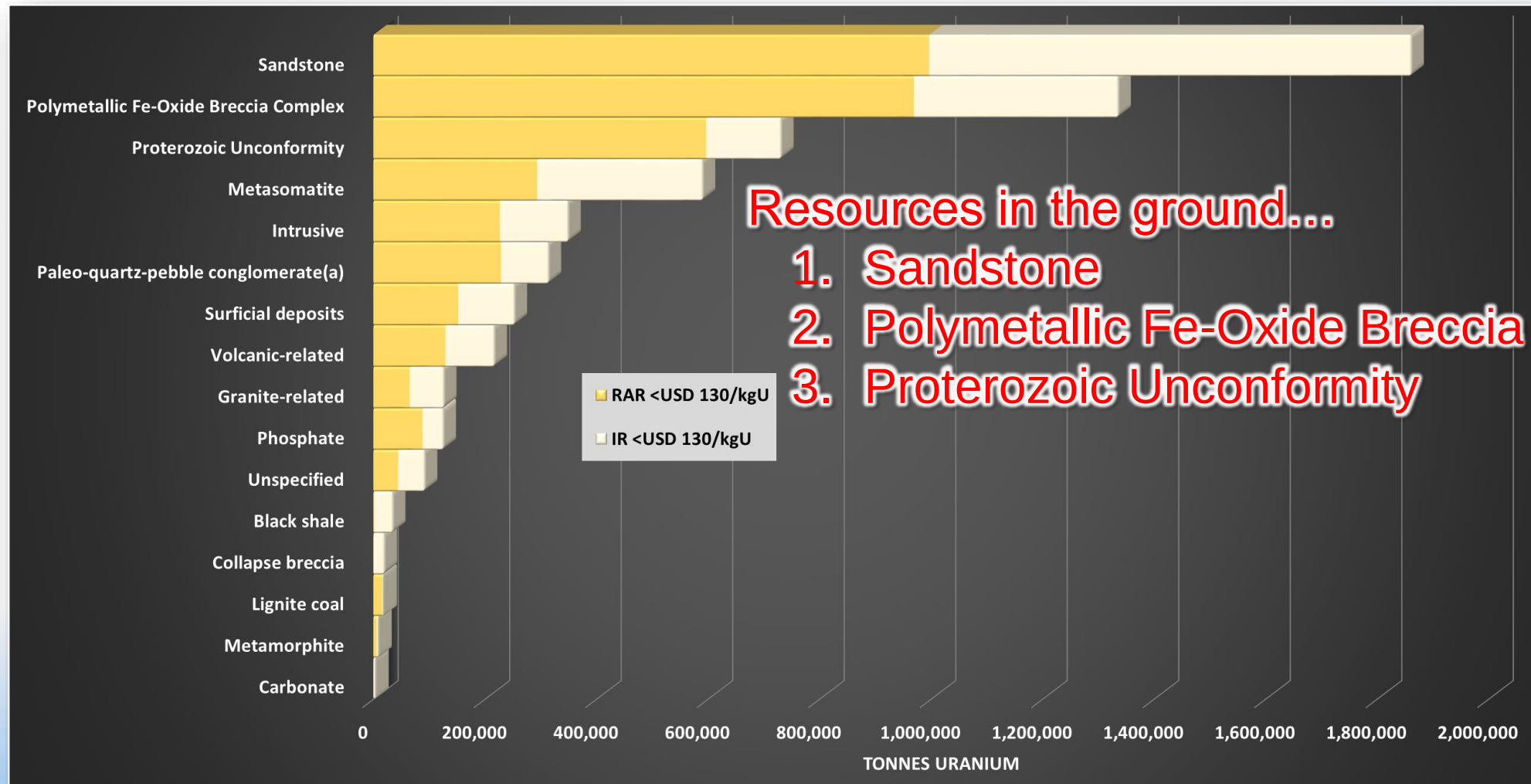


Supply... Resources, Identified Recoverable, 1 Jan. 2021, by Global Distribution, at <USD 130/kgU

Australia	28%
Kazakhstan	13%
Canada	10%
Russia	8%
Namibia	8%
South Africa	5%
Niger	5%
Brazil	5%
China	4%
Mongolia	2%
Uzbekistan	2%
Ukraine	2%
Botswana	1%
United States	1%
Tanzania	1%



Supply... Resources, Identified Recoverable, 1 Jan. 2021, by Deposit Type, at <USD 130/kgU

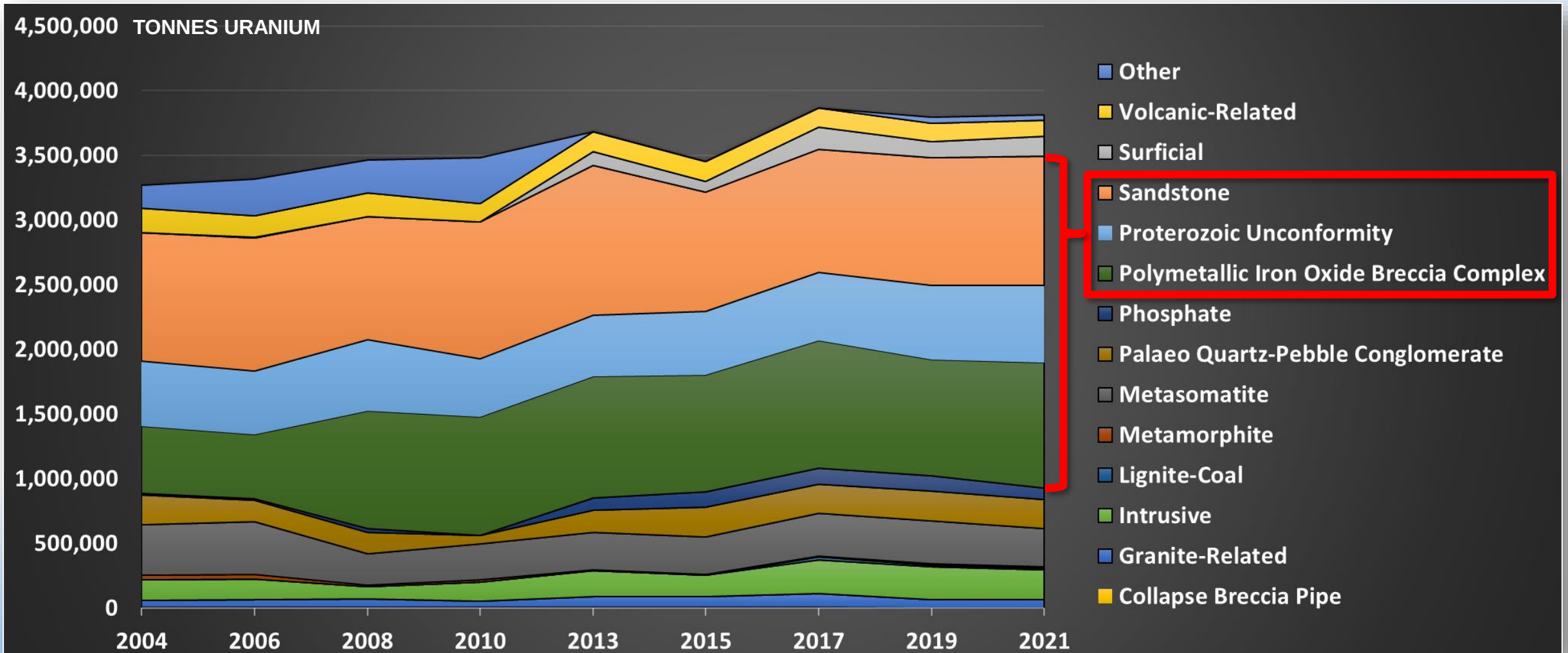


Supply... Resources, RAR Recoverable, 2004-2021

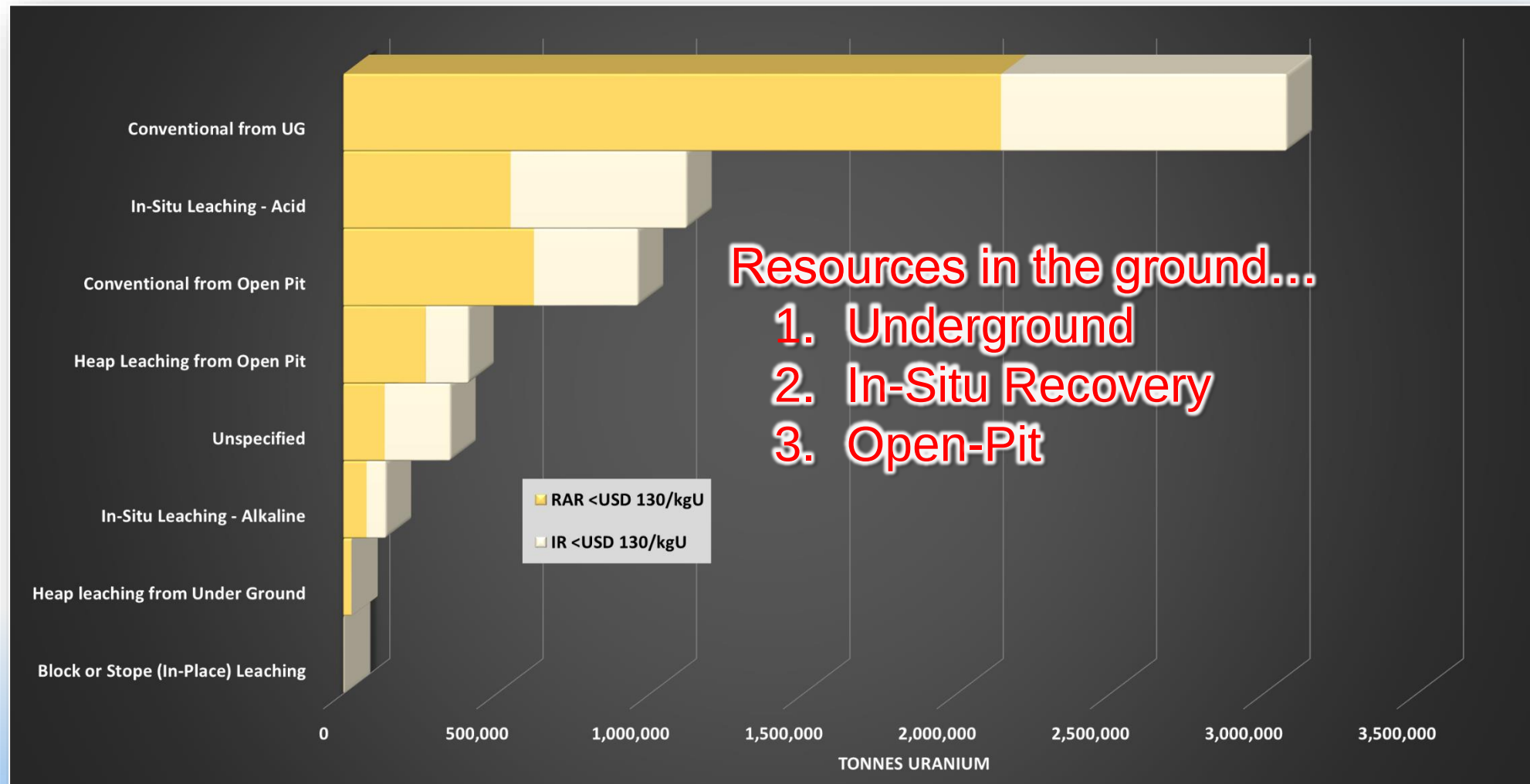
Global Changes, by Deposit Type at <USD 130/kgU



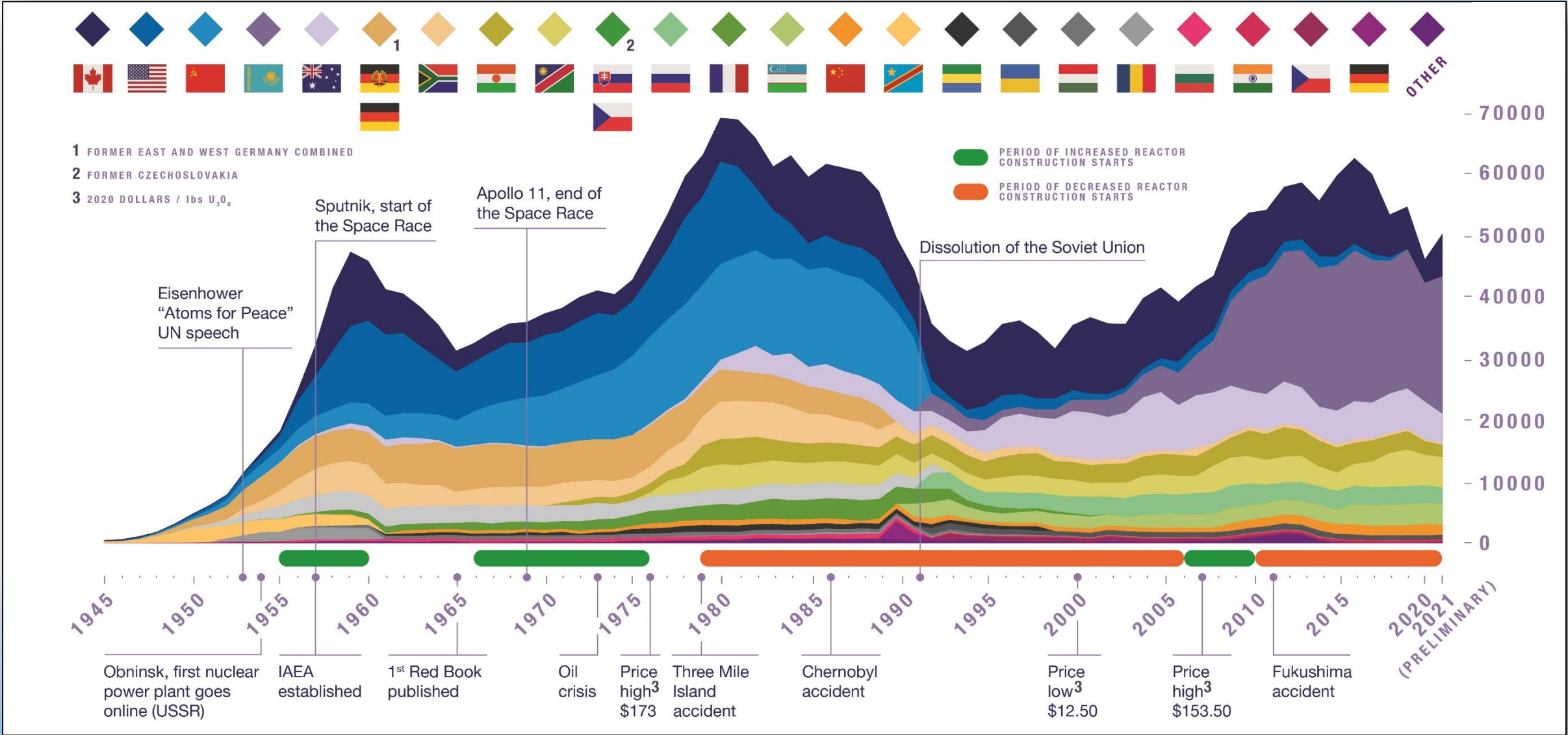
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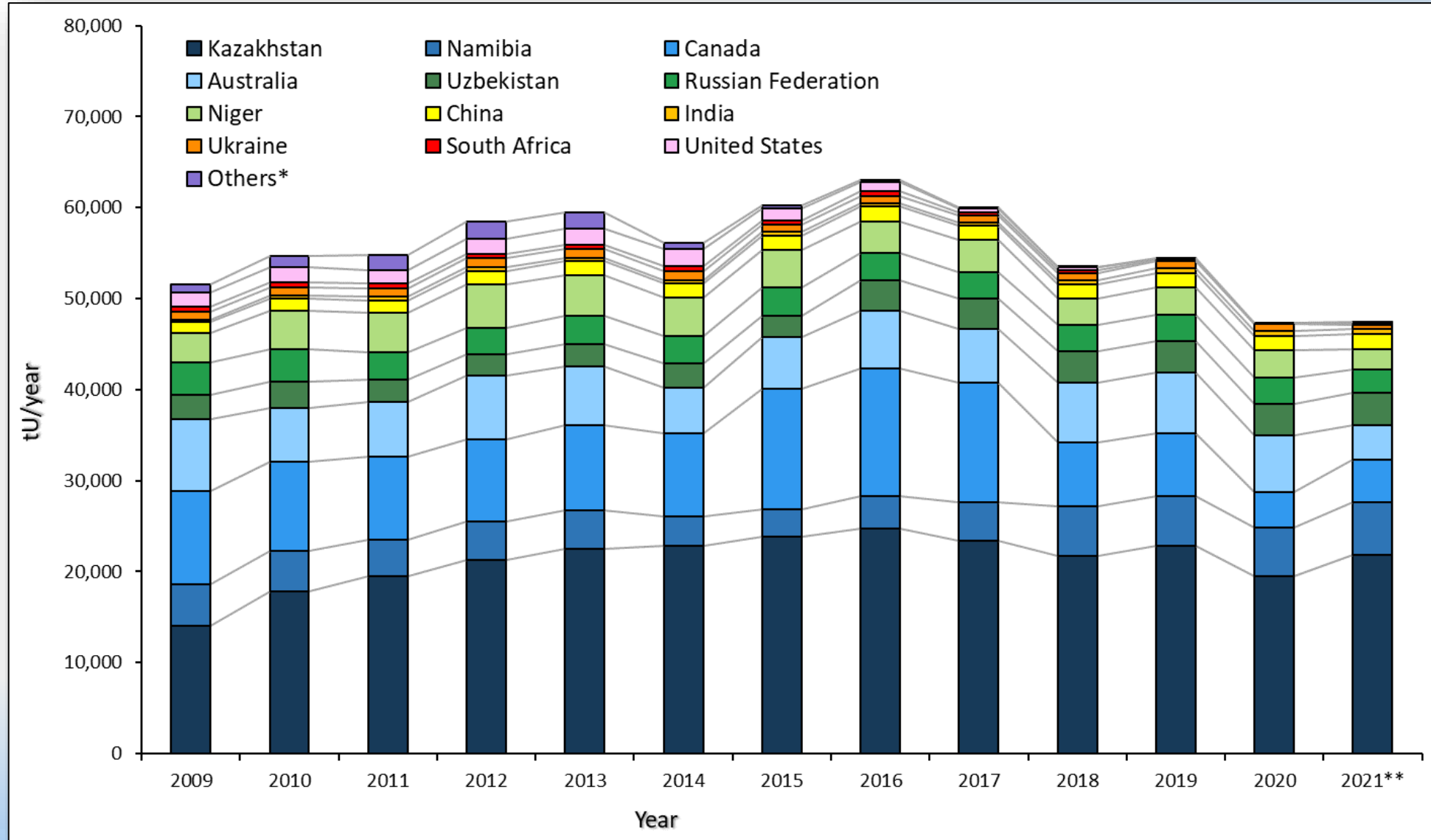
Supply... Resources, Identified Recoverable, 1 Jan. 2021, by Production Type, at <USD 130/kgU



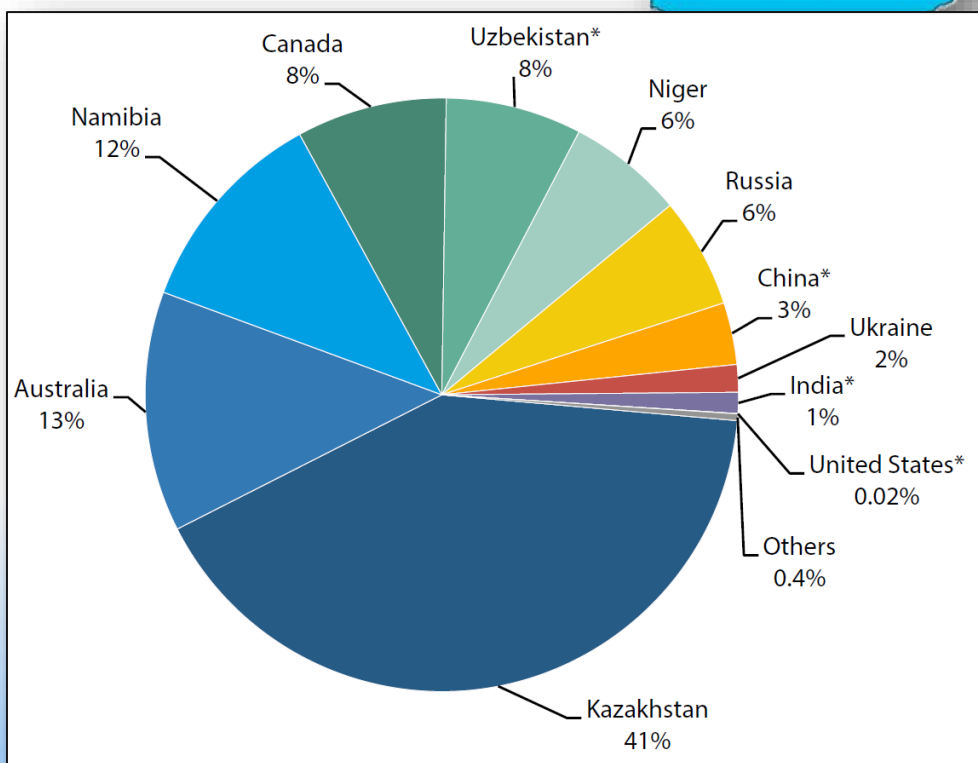
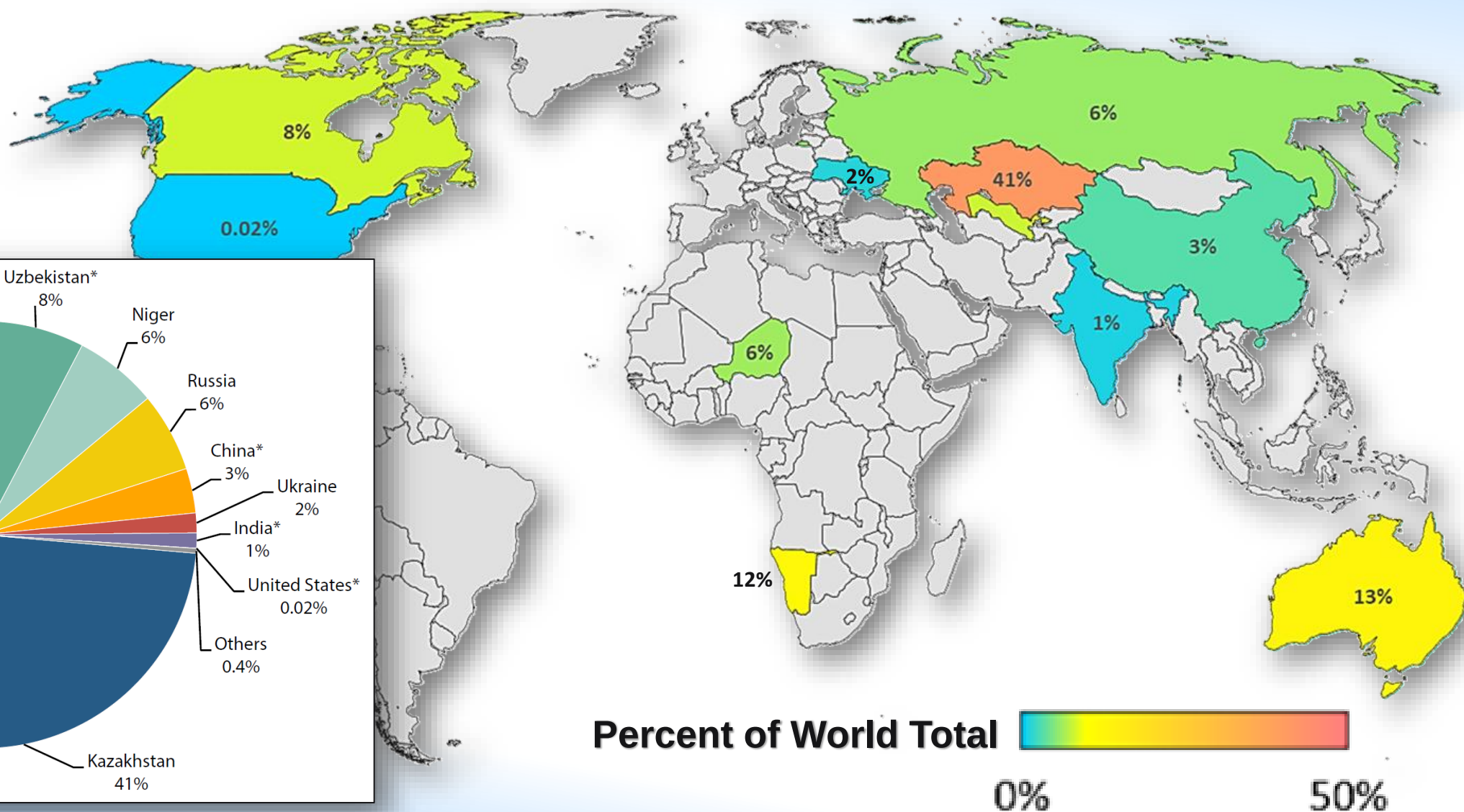
Production... World Total, 1945-2021 (3.14M tU)



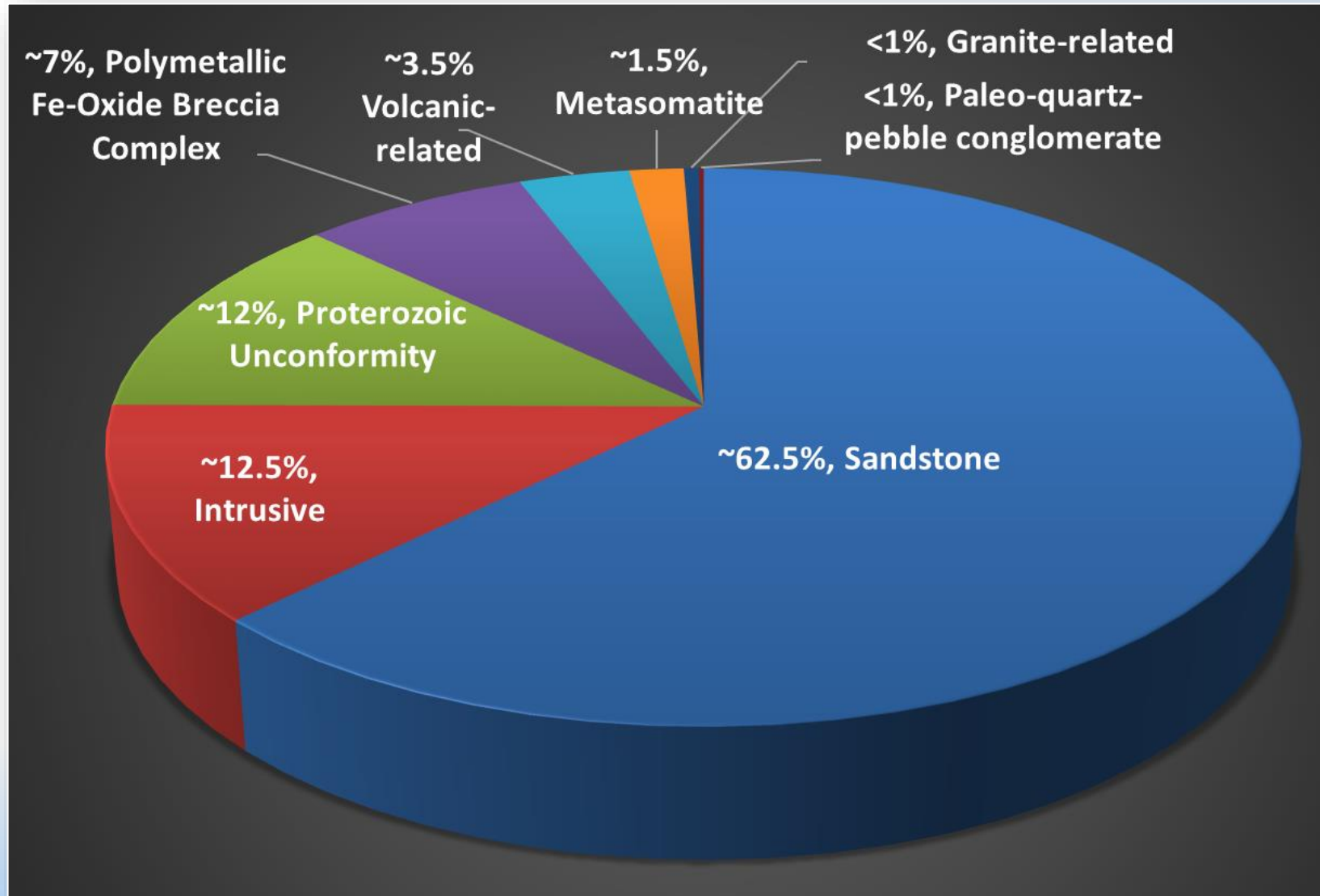
Production... World Total, 2009-2021 (~0.72M tU)



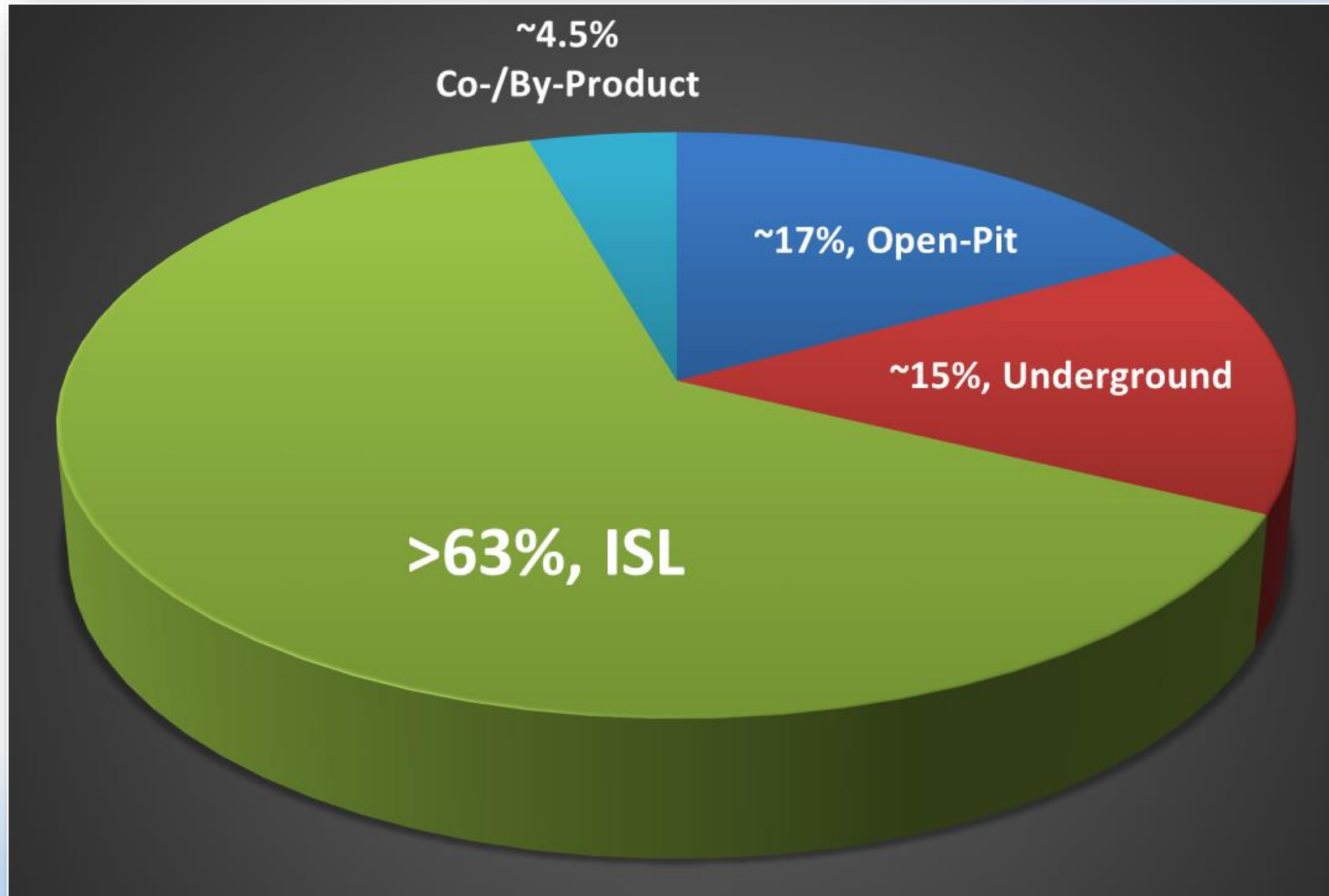
Production... World Total, 1 Jan. 2021 (~47,300 tU)



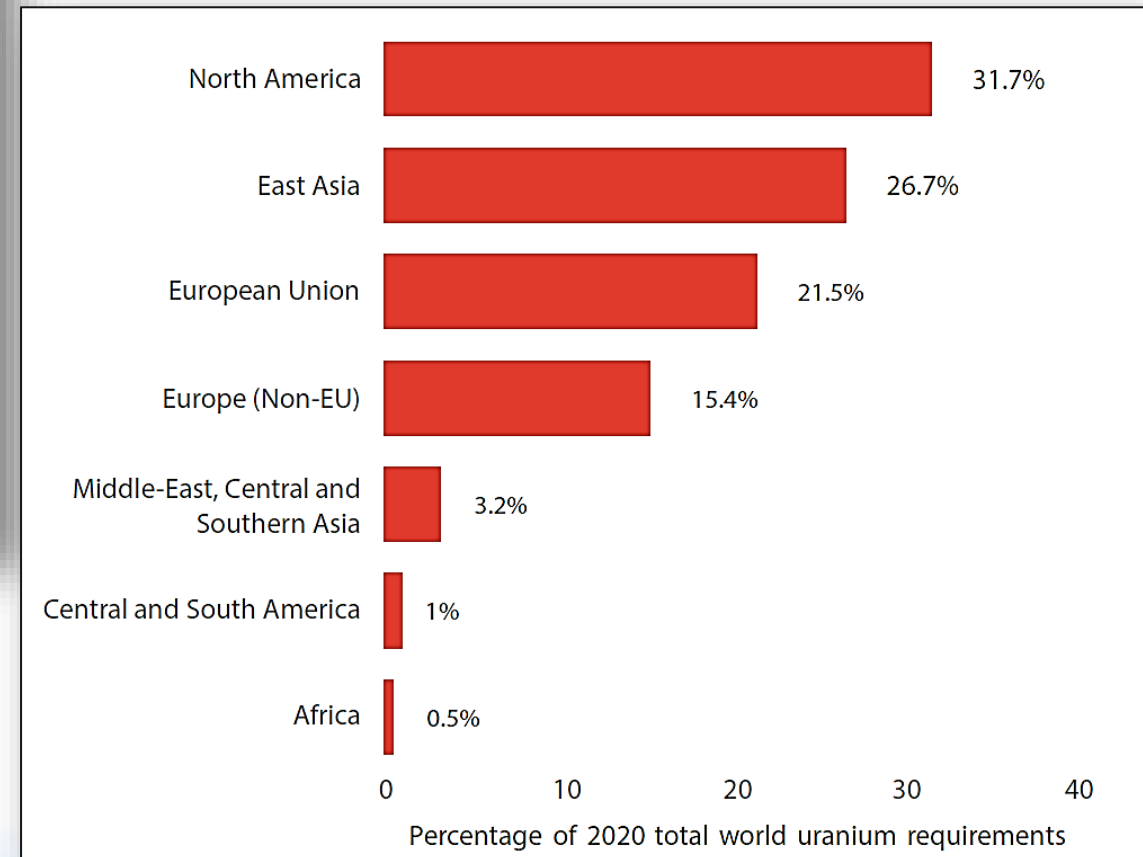
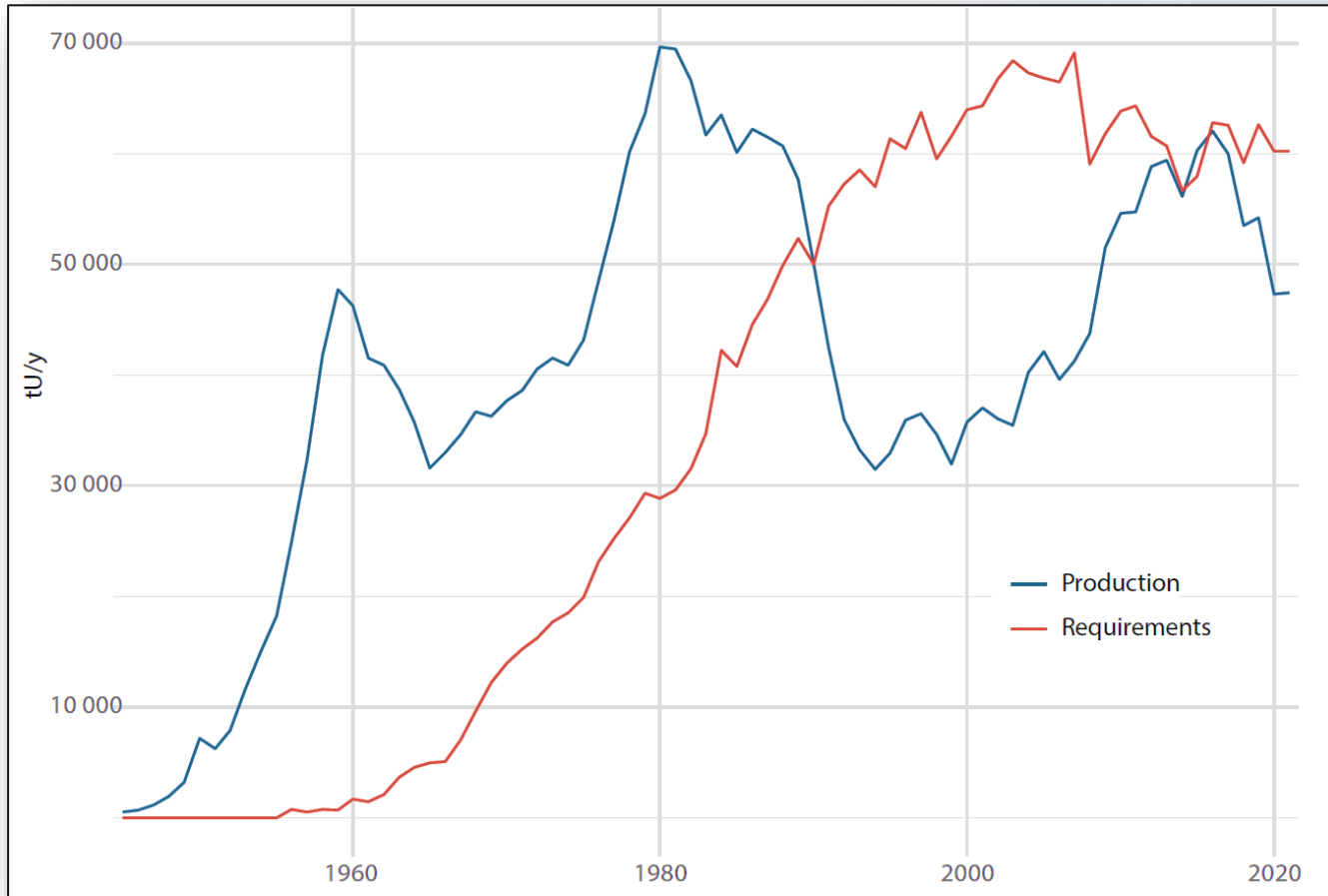
Production... World Total, 1 Jan. 2021, by Deposit Type



Production... World Total, 1 Jan. 2021, by Production Method



Demand... World Uranium Requirements, 1 Jan. 2021

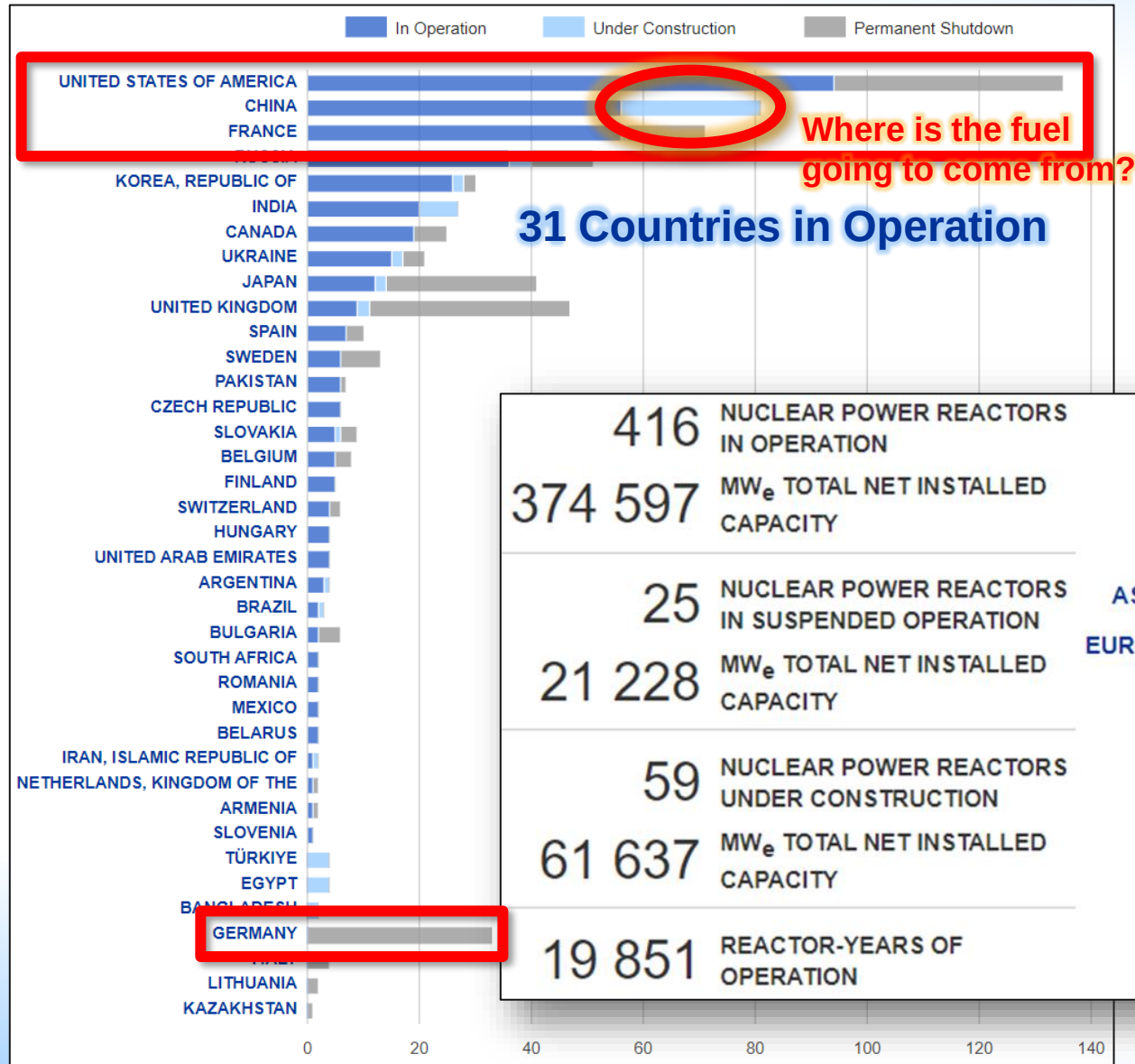


Demand... Commercial Nuclear Power Plants



IAEA

As of May 2024...

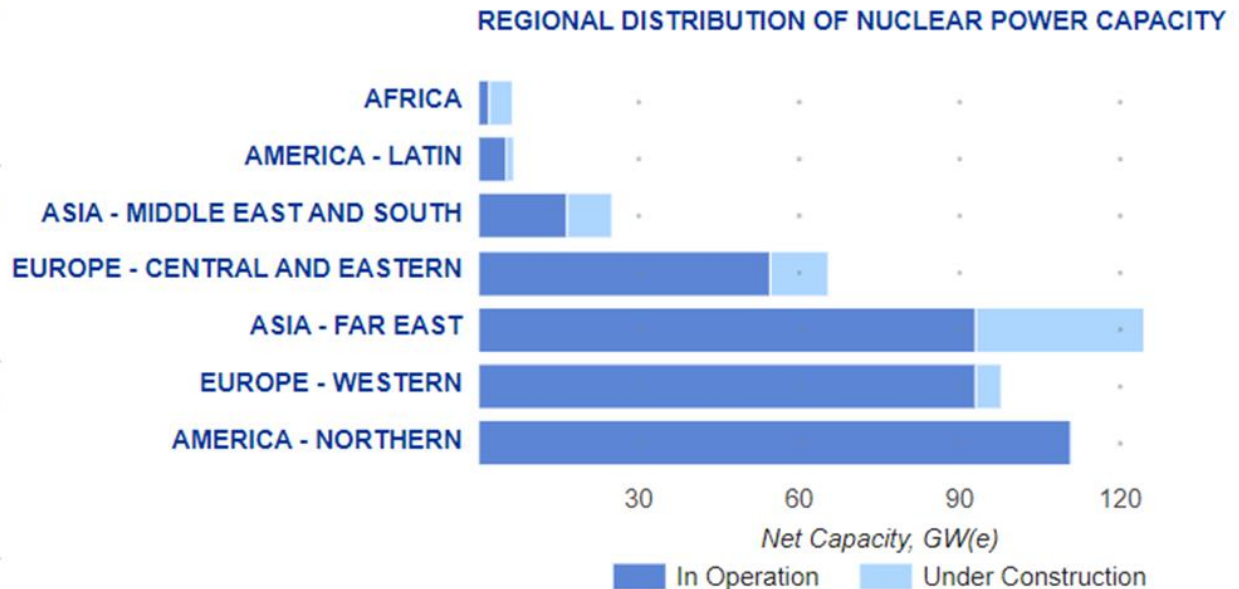


416 NUCLEAR POWER REACTORS IN OPERATION
374 597 MW_e TOTAL NET INSTALLED CAPACITY

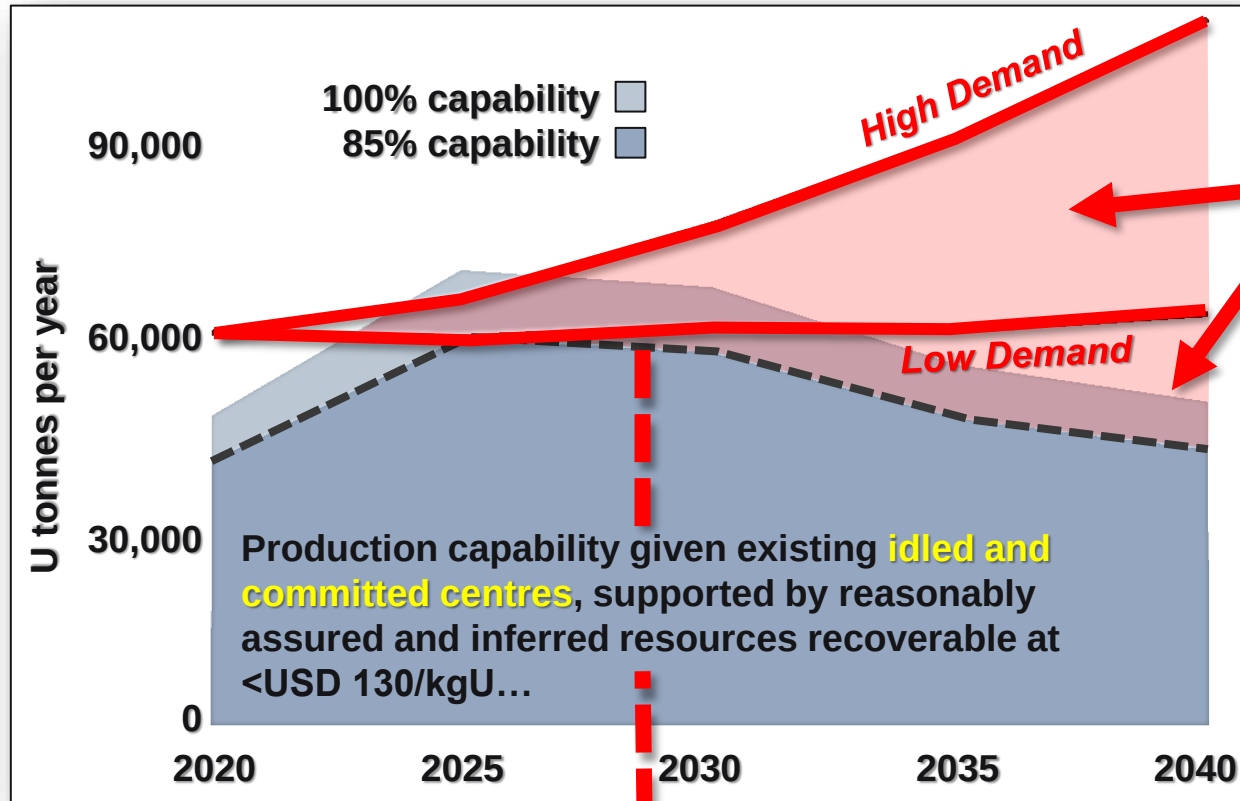
25 NUCLEAR POWER REACTORS IN SUSPENDED OPERATION
21 228 MW_e TOTAL NET INSTALLED CAPACITY

59 NUCLEAR POWER REACTORS UNDER CONSTRUCTION
61 637 MW_e TOTAL NET INSTALLED CAPACITY

19 851 REACTOR-YEARS OF OPERATION



Demand... Uranium Production and Demand Projections to 2040



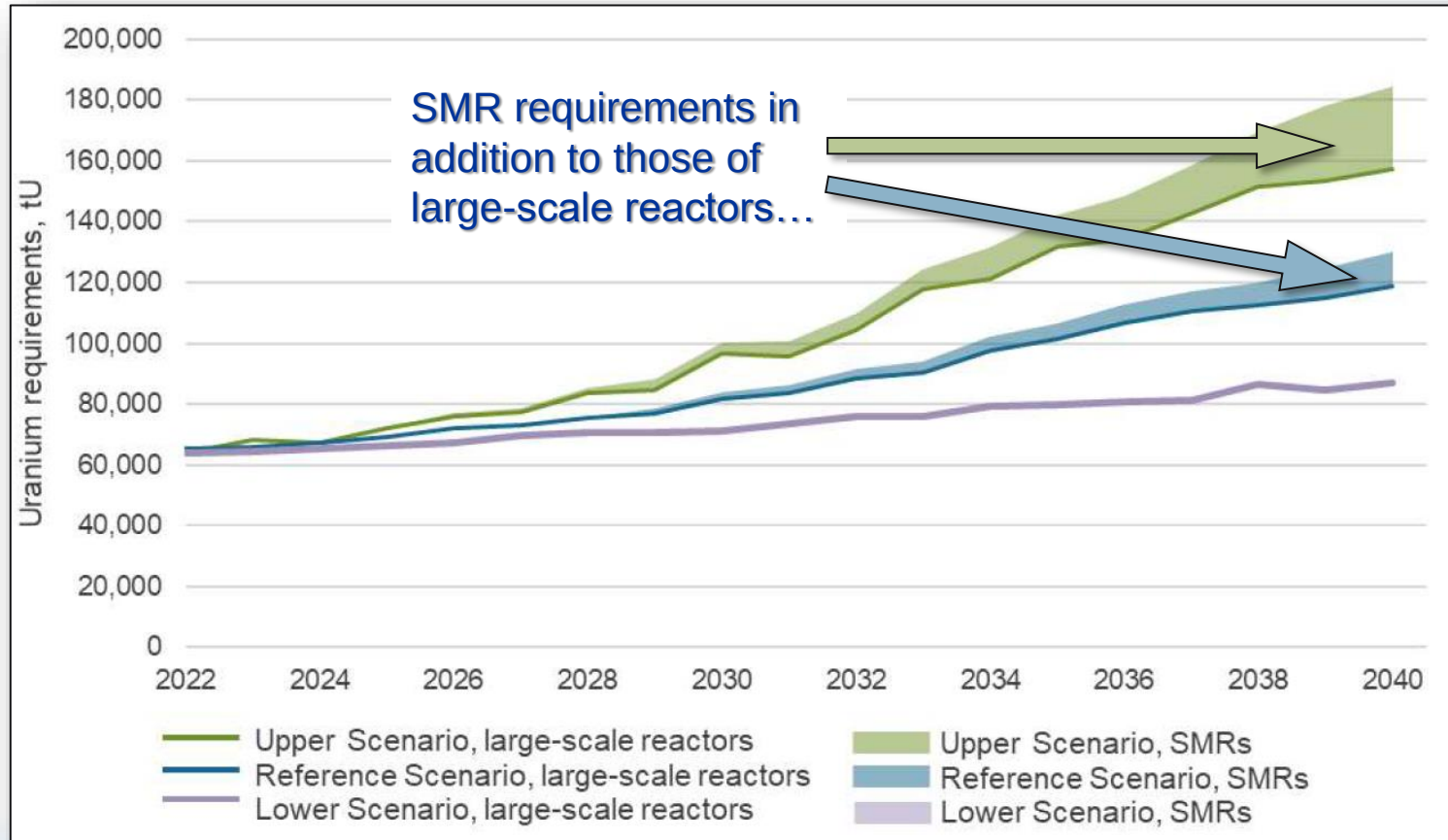
Gaps between uranium demand and 85% capability production...

- *Why 85%... Because actual production seldom, if ever, matches with full production capability*

It is assumed that **secondary supply will fill the gaps** when requirements are greater than primary mine production

Possible start of a supply shortfall for the low demand scenario **in the late 2020s** (sooner for the high demand scenario) from primary mine production if planned and prospective production centres do not come on-line, or **if new deposits are not found and mined**, or if adequate secondary supplies are not available.

Demand... Additional Uranium Reactor Requirements if SMRs Included



Upper Scenario: +26,000 tU/yr

Reference Scenario: +11,000 tU/yr

Lower Scenario: +1,300 tU/yr

**Additional share for
SMRs by 2040:**

In addition to requirements for large-scale reactors, the latest edition of the WNA Fuel Report included a new 'Generic SMR' uranium requirement concept that considers prospective SMRs in three nuclear capacity scenarios: low, reference, and upper demand.

Take-Aways...

- Sufficient uranium resources exist to support nuclear power and significant growth in capacity for electricity generation and other uses (e.g., heat, hydrogen) in the near to long term
- ~8,000,000 tonnes of in-ground uranium resources of economic interest (recoverable at <USD 260/kgU)
- Identified recoverable resources at <USD 260/kgU (equivalent to USD 100/lb U_3O_8), are sufficient for more than 130 years
 - Considering the uranium requirements as of 2020



Take-Aways...

- To turn these resources into refined uranium ready for nuclear fuel production...
 - Favourable prices will need to be further sustained
 - Investment to improve exploration and develop new, more cost-effective extraction techniques
 - Research and technical innovation will be required, particularly for recovery of uranium from low-grade deposits
- Global uranium demand is expected to continue to increase over the next several decades...
 - NPP produce competitively priced, low-carbon baseload electricity
 - Will remain an important component in the mix of green energy



Take-Aways...

- Sufficient resources identified, but...
 - “Pounds in the ground $\neq$ pounds in the drum”
- Supply prone to disruption until capacity increased and diversified
- Security of supply is a key strategic consideration...
 - May drive innovation for recovery of uranium from unconventional resources and high-cost conventional resources



Carnotite Mineralization,
Langer-Hienrich Mine, Namibia

Thank You... Questions?



**Yellowcake Filter Press, UEC
Hobson Processing Plant, Texas**

**Screw Conveyor, UEC Hobson
Processing Plant, Texas**

