A Joint Report by the Nuclear Energy Agency
and the International Atomic Energy Agency

Uranium 2024
Resources, Production and Demand

IAEA
International Atomic Energy Agency

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NUCLEAR ENERGY AGENCY

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NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1 February 1958. Current NEA membership consists of 34 countries: Argentina, Australia, Austria, Belgium, Bulgaria, Canada, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, Romania, Russia (suspended), the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, the United Kingdom and the United States. The European Commission and the International Atomic Energy Agency also take part in the work of the Agency.

The mission of the NEA is:

- to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for the safe, environmentally sound and economical use of nuclear energy for peaceful purposes.
- to provide authoritative assessments and to forge common understandings on key issues as input to government decisions on nuclear energy policy and to broader OECD analyses in areas such as energy and the sustainable development of low-carbon economies.

Specific areas of NEA competence include the safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

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Executive summary

Uranium 2024: Resources, Production and Demand presents the most recent review of world uranium market fundamentals and offers a statistical profile of the uranium industry. It contains 62 country reports on uranium exploration, resources, production and reactor-related requirements, 48 of which were prepared from officially reported government data and narratives, and 14 that were prepared by the secretariats of the Nuclear Energy Agency (NEA) and International Atomic Energy Agency (IAEA). The report includes projections for nuclear generating capacity and reactor-related uranium requirements through 2050, as well as a discussion of long-term uranium supply and demand issues.

The data reporting period for *Uranium 2024: Resources, Production and Demand* (also known as the "Red Book") covers 1 January 2021 to 1 January 2023 (calendar years 2021 and 2022), although some relevant information for 2023 and 2024 is also included in the discussions.

Resources

Total global uranium resources are largely unchanged compared to the previous edition of the Red Book, with total identified recoverable resources at <USD 260/kgU of just over 7.9 million tU, comprised of 60% reasonably assured resources (1% increase from the previous edition) and 40% inferred resources. At <USD 130/kgU, total identified recoverable resources of 5.9 million tU decreased (-3%) compared to 2021, with decreases more pronounced (-6%; -14%) at <USD 80/kgU and <USD 40/kgU, respectively. Decreases resulted primarily from comprehensive re-evaluations of Brazil and Uzbekistan uranium resources. A trend of re-assignment of resources to higher cost categories continued with this edition, and as of 1 January 2023, only four countries reported any resources in the <USD 40/kgU cost category with 75% of the global total attributed to Kazakhstan.

Globally, Australia continues to dominate the world's uranium resources with 28% of the total identified recoverable resources at <USD 130/kgU and 24% of identified resources at <USD 260/kgU. Fully 68% of Australia's uranium resource endowment, and 17% of global identified resources, are attributed to a single site, the Olympic Dam deposit, where uranium is mined as a co-product of copper. Kazakhstan's (14%) and Canada's (10%) approximate share of worldwide identified resources at <USD 130/kgU (11% each at <USD 260/kgU), remain similar as reported in the previous edition. The top 15 countries represent approximately 95% of the world's total identified resources at the <USD 130/kgU cost category and more than 90% at <USD 260/kgU.

Comprehensive reviews and reassessments of Brazil's and Uzbekistan's uranium resources resulted in the removal of approximately 170 000 tU of high-cost resources. These and smaller magnitude decreases from mining depletion in Australia and Canada and from an updated resource estimate in Zambia were, at the <USD 130/kgU cost category, partially offset by increases from China, Namibia, Niger, Türkiye and the United States, primarily resulting from ongoing exploration activities. Additionally, at <USD 260/kgU, increased resources primarily from the addition of new or previously not included resources for Bulgaria, Cameroon, Egypt, India, Pakistan and Saudi Arabia, partially offset by decreases associated with revised estimates at deposits in the Central African Republic and Niger, resulted in the essentially unchanged global identified resources.

With respect to the lower cost categories (<USD 40/kgU, <USD 80/kgU), readers are cautioned regarding both these resource estimates (particularly <USD 40/kgU), since Australia does not report resources in either of these cost categories, most countries do not report in the <USD 40/kgU category, and some countries that have never (or have not recently) hosted uranium mining may be underestimating mining costs.

Although resources in this publication are primarily reported as recoverable resources (the potential amount of uranium after deducting for losses from mining and processing), also reporting *in situ* resources estimates at times provides a view of the full available resource base in the ground, and by quantifying the average recovery (and non-recovered portion) gives an indication of how the available uranium could vary with changes in mining and processing methods. Total identified in situ resources of 10.7 million tU at <USD 260/kgU are largely unchanged compared with the previous edition. The overall average recovery factor from this in situ estimate to recoverable resources is 74%, or 26% mining and processing losses.

Future additions to the conventional resource base could come from undiscovered (prognosticated and speculative) resources of just over 7.9 million tU (7% increase from the previous edition), coincidentally the same value as total identified resources. Unconventional resources are another source of potential future supply and, as reported in the IAEA's World Distribution of Uranium and Thorium Deposits (UDEPO) 1 database in approximately 210 deposits, currently amount to about 57 million tU. It is important to note that in some cases, including several major producing countries with significant identified resource inventories, estimates of undiscovered resources and unconventional resources are either not reported or have not been updated for several years.

The uranium resource figures presented in this edition are a snapshot of the situation as of 1 January 2023, as reported mainly from official government sources. Readers should keep in mind that resource figures are dynamic and related to commodity prices.

Exploration and mining development

The overall picture of worldwide domestic exploration and mine development expenditures is dramatically changed compared to previous recent editions of the Red Book, as a persistent downward trend of several years came to an end. Annual expenditures, which decreased to approximately USD 380 million in 2020 from more than USD 1.5 billion in the years prior to the downturn, recovered to USD 800 million in 2022. Preliminary data for 2023 expenditures suggest a further increase to USD 840 million. Non-domestic figures, a subset of global exploration and development expenditures, increased from close to USD 50 million in 2020 to approximately USD 70 million in 2022 and USD 80 million expected for 2023 (preliminary data). Total expenditures reflect a response to the depressed uranium market that lasted from mid-2011, and a recent recovery that started in late-2020.

From 2008 to 2014, total domestic expenditures ranged from USD 1.5 to 2.1 billion annually, before steadily declining from USD 876 million in 2015 to USD 377 million in 2020, less than 25% of the prior annual expenditures. Decreased expenditures from 2015 to 2020 were due to persistently low uranium prices that slowed exploration and mine development projects, other than the previously committed development of the Husab mine in Namibia. Conversely, rising uranium prices and increased interest in nuclear energy since 2020 reversed the trend, and expenditures more than doubled from the 2020 low, to USD 803 million in 2022 and to more than USD 840 million expected for 2023, based on preliminary data.

Total exploration and mine development expenditures for 2021, 2022 and 2023 (preliminary estimates) amongst the 27 reporting countries (7 which reported only for 2021 and 2022) amounted to USD 2.1 billion, with Canada, China, Russia, India, Namibia and Uzbekistan leading the way. Expenditures in these six countries together accounted for 90% of the total, with Canada alone accounting for 34%.

1. IAEA (2018), World Distribution of Uranium and Thorium Deposits, https://infcis.iaea.org/UDEPO/Report/statistics.

The total quantity of exploration and development drilling for the 22 reporting countries increased by 46%, from 2 704 km in 2020 to 3 955 km in 2022. For 2022, Kazakhstan, China and Uzbekistan each accounted for 27%, 26%, and 18% respectively, with India, Canada, United States, and Namibia accounting for most of the remainder.

Production

Global uranium mine production increased by 4% from 2020 to 2022. After five years of declining production as major producing countries, including Canada and Kazakhstan, limited production in response to a depressed uranium market, production levels in 2022 began to increase in response to a strong uranium price recovery, a trend that has continued in 2023 and 2024. With 7 400 tU annual capacity of previously idled mines back in production, as of 1 January 2023, the annual production capacity of idled mines had come down to 22 000 tU and a further 5 200 tU of this capacity has since been restarted or committed for restart. The remaining 16 800 tU of idled annual capacity presents further opportunity; however, many of the remaining idled operations face additional complicating factors such as substantial capital requirements, technical issues and a resource base that may only support significantly less than the stated production capacity.

In 2022, 17 countries produced uranium, with the global total amounting to 49 490 tU. Kazakhstan remained by far the world's largest producer, at 43% of global production, even as production continued at scaled-back levels. Kazakhstan's production alone in 2022 amounted to more than the combined production from Canada, Namibia, Australia and Uzbekistan, respectively the second, third, fourth and fifth largest producers of uranium that year. Just six countries accounted for 90% of the world's uranium production in 2022, and nine countries accounted for 99%, with Russia, Niger, China, and India the sixth, seventh, eighth and ninth largest producers, respectively.

In situ leaching (ISL) remained the dominant production technology throughout the reporting period, accounting for nearly 60% of total global uranium production in 2022 and approximately 55% in 2023, as the McArthur River mine restart in Canada began to bring back previously idled underground production.

Overall, the downturn in world uranium production reached its low point in 2020 and 2021 at 47 588 tU and 47 361 tU, respectively, subsequently increasing 5% to 49 490 tU in 2022 and a further 10% to 54 345 tU in 2023. Production for 2023 was still just 86% of the 2016 peak production of almost 63 000 tU, reached before broad-based production cuts brought about the five-year period of declining production from 2016 to 2021. Within OECD countries, the 2016 to 2021 decline was even more dramatic, primarily due to idling of mines in Canada and the United States in response to the persistently low uranium price market conditions, COVID-19 production suspensions in 2020 and 2021, and the winding down of operations at Australia's Ranger mine before closing in early 2021. OECD production saw a remarkable drop of 60% from the 2016 high through the 2021 low.

Environmental and social aspects of uranium exploration and production

With uranium production projected to expand to meet global demand over the medium term, efforts are being made to develop safe mining practices and to continue to minimise environmental impacts. The country reports provide some updates about the environmental and social aspects of uranium mining, including site remediation and decommissioning projects, which highlight the progress that the uranium industry has made on environmental stewardship.

Although the focus of this publication remains uranium resources, production and demand, the environmental and social aspects of the uranium production cycle are of great importance and, as in the last few editions, updates on activities in this area have been included in the country reports. With a need for increased uranium production to meet demand, the continued development of transparent, safe and well-regulated operations that minimise environmental impacts is crucial, particularly for those countries hosting uranium production for the first time.

For this edition, 32 countries provided information on activities related to the environmental aspects of the uranium production cycle, including ongoing work related to closed facilities and policy/regulatory-related issues.

Additional information on the environmental aspects of uranium production may be found in *Managing Environmental and Health Impacts of Uranium Mining* (NEA, 2014[2]), which outlines the significant improvements made in these areas since the early strategic period of uranium mining. The IAEA Bulletin, *Uranium: From Exploration to Remediation* (IAEA, 2018[3]), and the IAEA Nuclear Energy Series, *Milestones in the Development of National Infrastructure for the Uranium Production Cycle* (IAEA, 2023[4]), include some information on this topic. More recently, the NEA published a comprehensive overview of the experiences in the uranium mining industry of working with Indigenous people and local communities to maximise overall benefits for all stakeholders in *Maximising Uranium Mining's Social and Economic Benefits: A Guide for Stakeholders* (NEA, 2023[5]).

Uranium demand

Global nuclear capacity is expected to increase in the coming years as energy demand grows.. Reactor-related uranium needs vary significantly by region, largely reflecting projected nuclear capacity growth, with East Asia anticipated to have the highest annual uranium demand by 2050. Security of supply will be essential for further nuclear capacity expansion and will, in turn, result in greater uranium demand.

As of 1 January 2023, a total of 438 commercial nuclear reactors were operational globally, with a net generating capacity of 394 GWe requiring about 59 000 tU annually. Taking into account changes in policies announced in several countries and nuclear programmes as of 1 January 2023, world nuclear capacity by 2050 is projected to increase to 574 GWe in the low demand case, and to 900 GWe in the high demand case, an increase compared to 2022 capacity of around 45% and 130% respectively. Accordingly, world annual reactor-related uranium requirements are projected to rise to between around 90 000 tU/y and 142 000 tU/y by 2050. These projections mark a significant upward revision of demand projections compared to the 2022 edition of the Red Book.

Nuclear capacity projections vary considerably from region to region. East Asia is projected to experience the largest increase, which, by the year 2050, could result in total capacity of between 212 GWe and 354 GWe in the low and high cases, respectively, representing an additional capacity of between 90% and 220% of the 111 GWe capacity existing at the end of 2022. While representing a significant regional capacity increase, countries of this region (e.g. China) have consistently demonstrated the ability to build multiple reactors within the set budgets and schedules.

Other regions projected to experience significant nuclear capacity growth by 2050 include the Middle East as well as Central and South Asia, for which the low and high cases project capacity of 67 GWe and 102 GWe, compared to 15 GWe at the end of 2022. In Europe, nuclear capacity in non-EU member countries is projected to increase in the high-case scenario to 124 GWe by 2050, more than doubling 2022 capacity. Even in the low-case scenario, nuclear capacity of non-EU member countries in Europe is projected to reach around 104 GWe by 2050, nearly doubling 2022 capacity.

2. NEA (2014), *Managing Environmental and Health Impacts of Uranium Mining*, OECD Publishing, Paris, www.oecd-nea.org/jcms/pl_14766.
3. IAEA (2018), *Uranium: From Exploration to Remediation*, IAEA Bulletin, Volume 59-2, June 2018, Vienna, www.iaea.org/bulletin/59-2.
4. IAEA (2023), *Milestones in the Development of National Infrastructure for the Uranium Production Cycle,* IAEA Nuclear Energy Series No. NF-G-1.1, www.iaea.org/publications/15010.
5. NEA (2023), *Maximising Uranium Mining's Social and Economic Benefits: A Guide for Stakeholders,* OECD Publishing, Paris, www.oecd-nea.org/jcms/pl_72776.

For the European Union, however, nuclear capacity in 2050 is projected to decrease by 17% in the low case and increase by 33% in the high case with respect to 2022 capacity. Modest growth in capacity is projected in Africa (between 11 and 20 GWe in 2050, for the low and high cases respectively), Central and South America (between 7 and 17 GWe in 2050) and South-eastern Asia (7 GWe in the high case, in 2050).

For North America, the projections see nuclear generating capacity in 2050 decreasing by 18% in the low case and increasing by 31% in the high case, from 2022 capacity of 108 GWe, depending largely on future electricity demand, lifetime extensions of existing reactors, and government policies.

As in the case of nuclear capacity, and directly related to it, uranium requirements vary considerably from region to region, reflecting projected capacity increases and possible inventory building. By 2050, annual uranium requirements are projected to be largest in the East Asia region, driven by an increase in installed nuclear generating capacity, particularly in China.

The key factors shaping the future of nuclear energy capacity include growing electricity demand, the economic competitiveness of nuclear power plants, innovative financing solutions for these capital-intensive projects, resilient supply chains, robust waste management strategies, public acceptance, and alignment with national energy security objectives.

In response to the growing demand for reliable energy amid rising geopolitical uncertainties and the pressing need for climate action, many countries have recently shifted their policies to favour nuclear energy. Notable examples include the reversal of planned phase-outs in Belgium, France and Korea; clean energy incentives in the United States to support the continued operation of existing plants and the construction of new conventional, advanced and small modular reactors; the establishment of regional alliances such as the European Nuclear Alliance; and plans or considerations by several countries, including Ghana, Kazakhstan, Kenya, Poland, Saudi Arabia, Uganda and Uzbekistan, to develop their first nuclear reactors.

Supply and demand adequacy

The current uranium resource base is sufficient to meet even high-demand projections through 2050, but achieving this will require timely investments to convert resources into active production. Meeting high-demand needs through 2050 alone would consume approximately 35% of the currently identified recoverable resource base at a cost of under USD 260/kgU (USD 100/lb U_3O_8). Beyond 2050, sustaining both high-growth and even low-growth demand scenarios into the second half of this century – a timeframe aligned with the operational lifespan of new reactors – will make investment in uranium exploration and new production centres essential to replenish depleted reserves.

In 2022, global uranium production met approximately 85% of world reactor requirements, an increase from around 79% in 2020. The remaining demand was met through secondary sources, including excess government and commercial inventories, spent fuel reprocessing, underfeeding at enrichment plants, re-enrichment of depleted uranium tails, and uranium inventory derived from blending down highly enriched uranium

Declining uranium market prices from 2011 to 2021, coupled with uncertainty around nuclear power development in some countries, led to reduced uranium demand, depressed prices, and a slowdown in mine production and development. The current Red Book reporting period (2021-2022) marks the beginning of a long-awaited recovery. After reaching USD 25/lb U_3O_8 in 2020, uranium spot prices rose to USD 30/lb U_3O_8 (USD 80/kg U) at the start of 2021, climbing further to USD 50/lb U_3O_8 (USD 130/kg U) by early 2023, and reaching a high of USD 106/lb U_3O_8 (USD 275/kg U) in January 2024. The rise in uranium prices over the past few years can be attributed to two key factors: the growing global interest in nuclear energy, which has increased expectations for higher uranium demand, and heightened geopolitical risks arising from the Russia-Ukraine war, among others, which have exacerbated concerns over fuel supply security and caused significant shifts in uranium market dynamics.

Improved market conditions have already spurred a supply-side response, with several idled mines reactivated and delayed projects advancing toward final investment decisions to support a growing global nuclear fleet. While the global uranium mining network remains sparse, posing potential supply risks, utilities have built substantial inventories in recent years at low prices, providing a buffer against short-term disruptions.

Meeting high-demand growth requirements by 2050 would use approximately 50% of the currently identified recoverable resource base at costs below USD 130/kgU and about 35% at costs below USD 260/kgU. Beyond 2050, however, even if nuclear capacity remains at 2050 levels, cumulative uranium requirements would surpass 100% of the current total identified resource base in the highest cost category by the 2080s under high demand or by the 2110s under low demand.

In the near term, if existing and committed mines operate near their stated production capacity, primary production is expected to meet low-demand scenarios through 2031. However, under high-demand scenarios, a production shortfall is anticipated by around 2027. While secondary sources will continue to supply a portion of uranium demand, it is crucial to bring new facilities online from planned and prospective production centres and to sustain exploration efforts to identify additional resources.

Bringing these resources to market will require substantial investment and technical expertise. Producers must navigate significant, often unpredictable challenges in launching new production facilities, including geopolitical and local factors, technical hurdles, and complex legal and regulatory frameworks. Sustained strong market conditions will be essential to drive the necessary industrial investment.

In the long term, developing and implementing alternative fuel cycles that move away from the default once-through approach used by most countries – especially by closing the fuel cycle – could have a substantial impact on the uranium market

Conclusions

The currently identified uranium resources are sufficient to meet both low- and high-growth nuclear capacity needs through 2050 and beyond. However, these resources will require further development for production. In both scenarios, even if nuclear capacity remains stable at 2050 levels through the end of the century, cumulative demand could exceed the current identified uranium resource base of nearly 8 million tonnes by the 2080s under the low-growth demand scenario and by the 2110s under the high-growth demand scenario outlined in this edition.

Historically, strong market signals have driven significant investment in uranium exploration, leading to the discovery and production of economically viable resources. However, various factors affect the timing and feasibility of resource recovery, including political stability, jurisdictional mining policies, and local experience with uranium mining.

To bring in-ground resources into production, market conditions must offer confidence in project returns. Poor market conditions delay not only new supply but also exploration investments, which impacts long-term resource development. For sustained uranium supply, both consumers and producers must ensure a stable framework for uranium exploration, mining, and transportation, supported by pricing mechanisms that encourage long-term investments. Sustained, adequate uranium prices are essential to support both new projects and ongoing exploration, as global uranium demand could more than double by 2050 in a high-demand scenario and increase by 45% in a low-demand case.

Following a decade-long downturn, the uranium market began to recover in 2021, with prices rising from USD 30/lb U_3O_8 at the start of 2021 to a high of USD 106/lb U_3O_8 in January 2024. In response, exploration and mine development activities have increased, with some previously stalled projects nearing final investment decisions. About half of previously idled production capacity has returned to production, although remaining capacity may require higher prices to restart.

Ongoing geopolitical tensions are reshaping the uranium market, prompting some nuclear-generating countries to build up domestic supplies or prioritise imports from allied or neutral countries. Increasing global momentum for nuclear energy, driven by climate goals and commitments like the call by over 20 countries to triple global nuclear energy by 2050, which was first announced at the 28th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP28), suggests a positive outlook for uranium demand, particularly as small modular reactors (SMRs) gain traction.

In the longer term, advanced reactor designs and closed fuel cycles with recycling capabilities, if successfully developed, may have the potential to exploit existing uranium resources for at least several centuries, ensuring the long-term sustainability of nuclear energy. Additionally, unconventional uranium sources, such as phosphate deposits and black shales, could further extend uranium availability, particularly with the emergence of new technologies

In conclusion, while sufficient uranium resources exist to meet demand for nuclear power generation in both low- and high-growth scenarios through 2050 and beyond, substantial investment in new mining projects will be essential. Given the long lead times for project development, identifying and advancing new projects in the near to medium term is crucial to avoid potential supply disruptions. Sustained adequate uranium prices will be required to drive new production, support exploration to replace depleting resources, and justify investment in innovative extraction techniques for unconventional uranium sources.

Chapter 1. Uranium supply

This chapter summarises the status of worldwide uranium resources, exploration and production. The data reporting period for this edition of the Red Book covers 1 January 2021 to 1 January 2023 (i.e. the calendar years 2021 and 2022). However, some important information for 2023 and 2024 has also been included when needed to provide some timely context.

Uranium resources

Uranium resources are classified by a scheme (based on geological certainty and costs of production) developed to combine resource estimates from a number of different countries into harmonised global figures. **Identified resources** (which include **reasonably assured resources**, or RAR, and **inferred resources**, or IR) refer to uranium deposits delineated by sufficient direct measurement to conduct pre-feasibility and sometimes feasibility studies. For **reasonably assured resources**, high confidence in estimates of grade and tonnage are generally compatible with mining decision-making standards. **Inferred resources** are not defined with such a high degree of confidence and generally require further direct measurement prior to making a decision to mine. **Undiscovered resources** (which include **prognosticated resources**, or PR, and **speculative resources**, or SR) refer to resources that are expected to exist based on geological knowledge of previously discovered deposits and regional geological mapping. **Prognosticated resources** refer to those expected to exist in known uranium provinces, generally supported by some direct evidence. **Speculative resources** refer to those expected to exist in geological provinces that may host uranium deposits. Both **prognosticated** and **speculative resources** require significant amounts of exploration before their existence can be confirmed and grades and tonnages can be defined. **Unconventional resources** are defined as very low-grade resources or those from which uranium is only recoverable as a minor by-product or co-product. For a more detailed description, see Appendix 3.

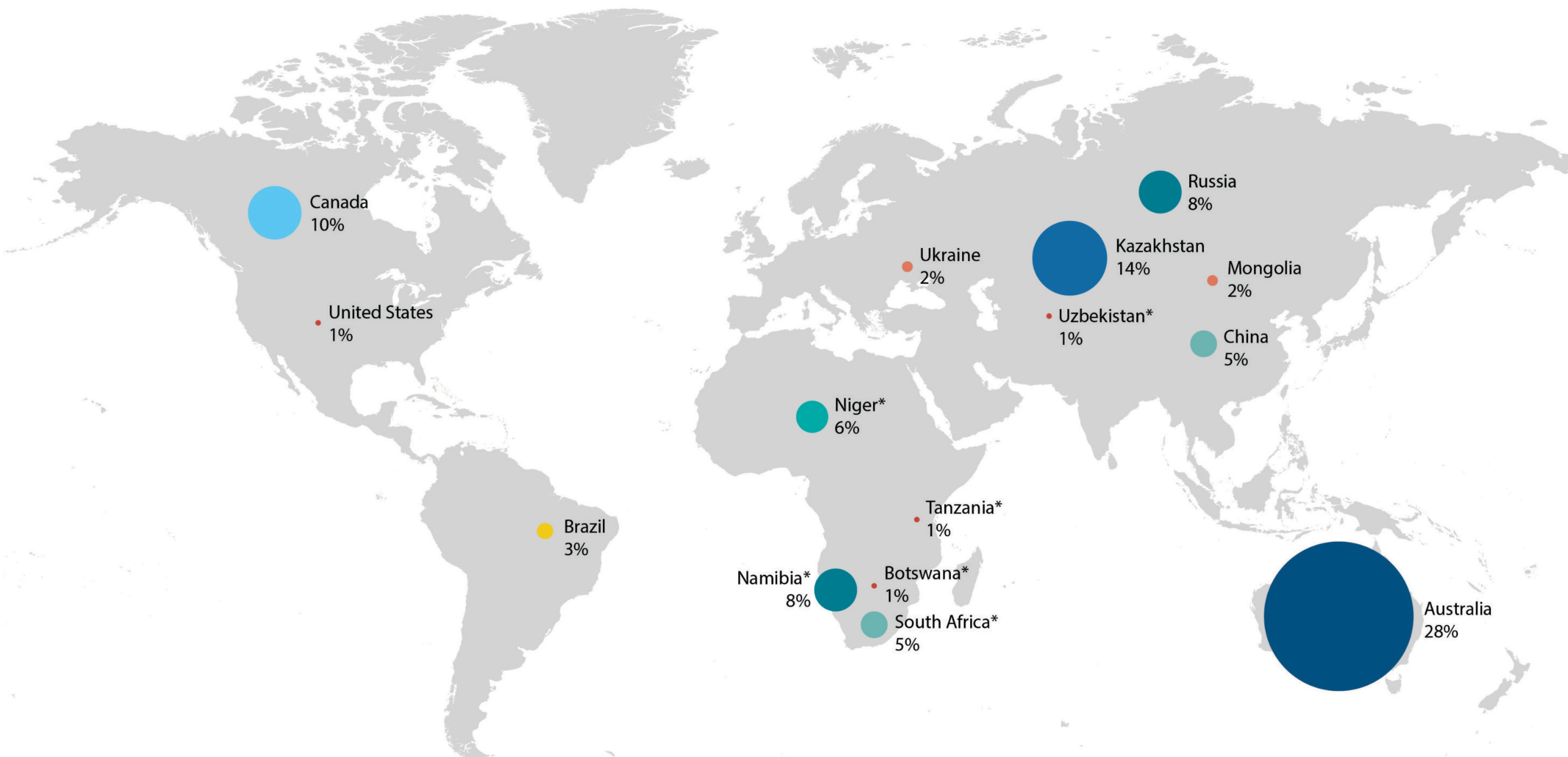
Identified conventional resources

The global distribution of identified conventional resources, recoverable at a cost of less than USD 130/kgU, is shown in Figure 1.1. Identified resources consist of *reasonably assured resources* (RAR) plus *inferred resources* (IR) recoverable at a cost of less than USD 260/kgU (USD 100/lb U_3O_8; see Appendix 3). Unless otherwise noted, resource figures in this report refer exclusively to recoverable resources; that is, the potential amount of uranium recovered after losses from mining and processing are deducted. In situ resources are also presented at times in this report, referring to the estimated amount of uranium in the ground, and are clearly indicated as such (see Appendix 3).

Relative changes in different resource and cost categories of global identified recoverable resources between this edition and the 2022 edition of the Red Book are summarised in Table 1.1 (note that resources of a given cost category also include resources from lower cost categories – in other words, the resource amounts are cumulative from lowest to highest cost category; see Appendix 3 about how to read and interpret cost category resource figures).

Figure 1.1. **Global distribution of identified recoverable conventional uranium resources**

(<USD 130/kgU as of 1 January 2023)



The global distribution of identified recoverable conventional uranium resources in the <USD 130/kgU cost category among 15 countries, which are either major uranium producers or have significant plans for growth of nuclear generating capacity, illustrates the widespread distribution of these resources. Together, these 15 countries are endowed with over 95% of the global resource base as specified above (the remaining resources in this cost category are distributed among another 23 countries). The widespread distribution of uranium resources is an important geographic aspect of nuclear energy in light of security of energy supply.

* Secretariat estimate or partial estimate.

Table 1.1. **Changes in identified recoverable resources 2021-2023**

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes*)

Resource category	2021	2023	Change[(a)]	% change
Total Identified resources				
<USD 260/kgU	7 917 500	7 934 500	17 000	0.2
<USD 130/kgU	6 078 500	5 925 700	-152 800	-2.5
<USD 80/kgU[(b)]	1 990 800	1 881 100	-109 700	-5.5
<USD 40/kgU[(b)]	775 900	666 900	-109 000	-14.0
Reasonably assured resources				
<USD 260/kgU	4 688 300	4 778 700	90 400	1.9
<USD 130/kgU	3 814 500	3 868 800	54 300	1.4
<USD 80/kgU[(b)]	1 211 300	1 180 700	-30 600	-2.5
<USD 40/kgU[(b)]	457 200	364 700	-92 500	-20.2
Inferred resources				
<USD 260/kgU	3 229 200	3 155 700	-73 500	-2.3
<USD 130/kgU	2 263 900	2 056 900	-207 000	-9.1
<USD 80/kgU[(b)]	779 600	700 400	-79 200	-10.2
<USD 40/kgU[(b)]	318 700	302 200	-16 500	-5.2

* Totals may not sum exactly, or exactly match totals reported in other tables of this report, due to rounding.

(a) Changes might not equal differences between 2021 and 2023 because of independent rounding. (b) Totals for <USD 40/kgU and <USD 80/kgU cost ranges should be regarded with some caution as certain countries do not report low-cost resource estimates, whereas other (non-producing) countries may underestimate mining costs.

From 1 January 2021 to 1 January 2023 there was almost no change in global identified recoverable conventional uranium resources at the <USD 260/kgU cost category, which again totalled over 7.9 million tU, an increase of just 0.2% (17 000 tU) from 2021. However, at all other cost categories the overall picture is one of decreasing identified conventional resources with the relative decrease greatest (-14%; 109 000 tU) in the lowest cost category (<USD 40/kgU) and less pronounced (-6%; -3%) at the <USD 80/kgU and <USD 130/kgU cost categories, respectively. Low-cost (<USD 40/kgU) RAR declined most significantly on a relative basis (-20%; 92 000 tU) whereas at all other cost categories RAR changes were more favourable by 2% to 4% than the changes in total identified resources at that same cost category. At the lowest cost category (<USD 40/kgU) most of the decrease in identified resources resulted from the RAR change and IR decreased only 16 000 tU (-5%), whereas at all other cost categories the IR decreases contributed most or all the decrease in identified resources.

The overall decrease in the lowest cost category (<USD 40/kgU) of identified conventional resources is principally the result of the removal of over 51 000 tU from this cost category for Brazil and over 52 000 tU for Uzbekistan as part of comprehensive reviews and reassessments of their uranium resources. Notably, neither Argentina nor Uzbekistan reported any resources in the lowest cost category (as they had in previous editions) and as of 1 January 2023, only Brazil (86 800 tU), China (73 200 tU), Kazakhstan (498 800 tU), and Spain (8 100 tU) reported recoverable uranium resources in the lowest cost category (<USD 40/kgU). At the higher cost categories (<USD 130/kgU and <USD 260/kgU), the comprehensive reviews and reassessments of Brazil's and Uzbekistan's uranium resources resulted in the removal of approximately 100 000 tU and 70 000 tU, respectively, of high-cost resources. These, and smaller magnitude decreases, from mining depletion in Australia and Canada, and from an updated resource estimate of the Mutanga project in Zambia, were, at the <USD 130/kgU cost category, partially offset by increases from China, Namibia, Niger, Türkiye and, to a lesser extent, the United States, primarily resulting from ongoing exploration activities. Additionally, at the <USD 260/kgU cost category, increased resources primarily from the addition of new or previously not included resources for Bulgaria, Cameroon, Egypt, India, Pakistan and Saudi Arabia, partially offset by decreases associated with new estimates of the Imouraren deposit in Niger and the Bakouma deposits in the Central African Republic, resulted in the small increase of global identified resources.

Current estimates of identified resources, RAR and IR, on a country-by-country basis, are presented in Tables 1.2, 1.3 and 1.4, and graphically summarised in Figures 1.2 and 1.3. Table 1.5 summarises major changes in resources between 2021 and 2023 in selected countries.

Table 1.2a. **Identified recoverable resources**

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Algeria[a,b]	0	0	0	19 500
Argentina	0	19 300	34 300	35 300
Australia	0	0	1 671 200	1 935 200
Bolivia[a,b]	0	0	0	1 300
Botswana*[b]	0	0	87 200	87 200
Brazil [a]	86 800	86 800	167 800	177 800
Bulgaria[a,b,d]	0	0	0	5 100
Cameroon[a,b]	0	0	0	21 000
Canada	0	287 900	582 000	852 200
Central African Republic*[a]	0	0	0	29 200
Chad*[a,b,c]	0	0	0	2 400
Chile*[b]	0	0	0	1 400
China[a]	73 200	175 800	270 500	291 300
Congo, Dem. Rep.*[a,b,c]	0	0	0	2 700
Czechia	0	0	800	119 100
Denmark (Greenland)[a,b]	0	0	0	114 000
Egypt[a]	0	0	400	12 100
Finland[a,b,f]	0	0	1 200	1 200
Gabon[b,c]	0	0	4 800	5 800
Germany [b]	0	0	0	7 000
Greece[b,c]	0	0	0	7 000
Guyana[a,b]	0	0	0	4 600
Hungary[a]	0	0	0	16 700
India[a,d]	0	0	0	252 500
Indonesia[a]	0	1 500	8 600	8 600
Iran, Islamic Republic of*[a]	0	0	7 400	7 400
Italy[b,c]	0	6 100	6 100	6 100
Japan[b]	0	0	6 600	6 600
Jordan[a]	0	0	0	49 000
Kazakhstan[a]	498 700	730 800	813 900	873 400
Malawi	0	0	15 900	18 600
Mali*[a,b]	0	0	8 900	8 900
Mauritania*	0	0	18 200	25 500
Mexico[a]	0	500	4 500	5 100

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Table 1.2a. **Identified recoverable resources** *(cont'd)*

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Mongolia	0	16 900	144 600	144 600
Namibia*	0	33 200	497 900	550 800
Niger*	0	31 700	336 000	454 000
Pakistan(a)	0	0	0	22 500
Paraguay*(a,e)	0	0	4 300	4 300
Peru*(a,b)	0	33 400	33 400	33 400
Portugal(a,b)	0	3 400	5 300	5 300
Romania*(b,c)	0	0	6 600	6 600
Russia	0	32 400	476 600	652 500
Saudi Arabia(a,g)	0	0	0	46 100
Senegal*(a)	0	0	0	4 700
Slovak Republic(a,b)	0	12 700	15 500	15 500
Slovenia(a,b)	0	5 400	9 200	9 200
Somalia*(a,b,c)	0	0	0	7 600
South Africa*	0	228 000	320 900	436 400
Spain(a)	8 100	28 500	28 500	28 500
Sweden*(a,b,c)	0	0	9 600	9 600
Tanzania*	0	46 800	57 700	57 700
Türkiye(a)	0	0	27 100	36 000
Ukraine	0	71 500	106 700	184 800
United States(a,h)	0	0	67 800	121 400
Uzbekistan*(a)	0	28 500	45 000	63 600
Viet Nam(a,b)	0	0	0	3 800
Zambia	0	0	23 000	23 000
Zimbabwe(a,b)	0	0	0	2 000
Total(i)	**666 900**	**1 881 100**	**5 925 700**	**7 934 500**

† Totals may not sum exactly, or exactly match totals reported in other tables of this report, due to rounding.

* Secretariat estimate.

(a) In situ resources were adjusted by the Secretariat to estimate recoverable resources using recovery factors provided by countries or estimated by the Secretariat according to the expected production method (Appendix 3).

(b) Assessment not made within the last five years.

(c) Not reported in 2023 responses, data from Red Book 2022.

(d) Cost data not provided, therefore resources are reported in the <USD 260/kgU category.

(e) Recovery factors partially adjusted by Secretariat.

(f) Finland also reports unconventional identified recoverable resources of ~11 800 tU (8 600 tU RAR + 3 200 tU inferred) for the Talvivaara black schist-hosted Ni-Zn-Cu-Co deposit.

(g) Categorised as unconventional resources. Resources are for the Ghurayyah polymetallic (Th-U-Nb-Ta and REE-bearing minerals) deposit and Jabal Sayid U-Th prospect.

(h) Secretariat estimate for other than the <USD 260/kgU category total, since other cost data and distribution of resources by production method data withheld, for confidentiality of company data concerns.

(i) Totals for <USD 40/kgU and <USD 80/kgU cost ranges should be regarded with some caution as certain countries do not report low-cost resource estimates, whereas other (non-producing) countries may underestimate mining costs.

Table 1.2b. **Identified in situ resources**

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Algeria(b)	0	0	0	26 000
Argentina(a)	0	25 300	46 000	47 500
Australia(a)	0	0	2 644 900	3 032 900
Bolivia(b)	0	0	0	1 700
Botswana*(a,b)	0	0	140 600	140 600
Brazil	133 600	133 600	236 300	250 500
Bulgaria(b,d)	0	0	0	7 900
Cameroon(b)	0	0	0	28 000
Canada(a)	0	331 000	668 900	979 500
Central African Republic*	0	0	0	36 500
Chad*(b,c)	0	0	0	3 200
Chile*(a,b)	0	0	0	1 900
China	104 600	249 900	378 000	405 700
Congo, Dem. Rep.*(b,c)	0	0	0	3 600
Czechia(a)	0	0	1 300	197 300
Denmark (Greenland)(b)	0	0	0	228 000
Egypt	0	0	500	16 100
Finland(b,f)	0	0	1 500	1 500
Gabon(a,b,c)	0	0	6 400	7 700
Germany(a,b)	0	0	0	9 300
Greece(a,b,c)	0	0	0	9 300
Guyana(b)	0	0	0	6 200
Hungary	0	0	0	22 200
India(d)	0	0	0	335 000
Indonesia	0	2 000	11 500	11 500
Iran, Islamic Republic of*	0	0	9 900	9 900
Italy(a,b,c)	0	8 100	8 100	8 100
Japan(a,b)	0	0	7 800	7 800
Jordan	0	0	0	63 000
Kazakhstan	560 400	821 700	917 900	989 500
Malawi(a)	0	0	19 600	24 200
Mali*(b)	0	0	11 800	11 800
Mauritania*(a)	0	0	22 700	32 500
Mexico	0	700	6 000	6 800
Mongolia(a)	0	22 500	192 200	192 200
Namibia*(a)	0	41 500	622 400	688 500

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Table 1.2b. **Identified in situ resources** *(cont'd)*

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Niger*(a)	0	39 100	415 400	567 900
Pakistan	0	0	0	30 000
Paraguay*(e)	0	0	5 100	5 100
Peru*(b)	0	47 700	47 700	47 700
Portugal(b)	0	4 500	7 000	7 000
Romania*(a,b,c)	0	0	8 800	8 800
Russia(a)	0	43 200	584 500	835 200
Saudi Arabia(g)	0	0	0	61 500
Senegal*	0	0	0	6 200
Slovak Republic(b)	0	15 800	19 300	19 300
Slovenia(b)	0	7 200	12 200	12 200
Somalia*(b,c)	0	0	0	10 100
South Africa* (a)	0	304 000	426 400	589 600
Spain	9 800	34 400	34 400	34 400
Sweden*(b,c)	0	0	12 800	12 800
Tanzania*(a)	0	58 500	72 200	72 200
Türkiye	0	0	33 500	45 400
Ukraine(a)	0	81 600	121 400	210 300
United States(h)	0	0	96 600	168 200
Uzbekistan*	0	40 800	64 300	90 900
Viet Nam(b)	0	0	0	5 200
Zambia(a)	0	0	27 900	27 900
Zimbabwe(b)	0	0	0	2 700
Total(i)	**808 300**	**2 313 000**	**7 943 700**	**10 714 400**

† Totals may not sum exactly, or exactly match totals reported in other tables of this report, due to rounding.

* Secretariat estimate.

(a) Recoverable resources were adjusted by the Secretariat to estimate in situ resources using recovery factors provided by countries or estimated by the Secretariat according to the expected production method (Appendix 3).

(b) Assessment not made within the last five years.

(c) Not reported in 2023 responses, data from Red Book 2022.

(d) Cost data not provided, therefore resources are reported in the <USD 260/kgU category.

(e) Recovery factors partially adjusted by Secretariat.

(f) Finland also reports unconventional identified in situ resources of ~26 200 tU (19 200 tU RAR + 7 000 tU inferred) for the Talvivaara black schist-hosted Ni-Zn-Cu-Co deposit.

(g) Categorised as unconventional resources. Resources are for the Ghurayyah polymetallic (Th-U-Nb-Ta and REE-bearing minerals) deposit and Jabal Sayid U-Th prospect.

(h) Secretariat estimate for other than the <USD 260/kgU category total, since other cost data and distribution of resources by production method data withheld, for confidentiality of company data concerns.

(i) Totals for <USD 40/kgU and <USD 80/kgU cost ranges should be regarded with some caution as certain countries do not report low-cost resource estimates, whereas other (non-producing) countries may underestimate mining costs.

Table 1.2c. **Comparison of identified resources reported as in situ versus recoverable***

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Identified resources	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Total in situ	808 300	2 313 000	7 943 700	10 714 400
Total recoverable	666 900	1 881 100	5 925 700	7 934 500
Difference	141 400	431 900	2 018 000	2 779 900
Difference %	17.5	18.7	25.4	25.9
Recovery %	82.5	81.3	74.6	74.1

(as of 1 January 2021, tonnes U; Red Book 2022)

Identified resources	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Total in situ	931 100	2 416 900	8 046 300	10 671 800
Total recoverable	775 900	1 990 800	6 078 500	7 917 500
Difference	155 200	426 100	1 967 800	2 754 300
Difference %	16.7	17.6	24.5	25.8
Recovery %	83.3	82.4	75.5	74.2

(as of 1 January 2019, tonnes U; Red Book 2020)

Identified resources	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Total in situ	1 268 400	2 456 300	8 070 300	10 584 500
Total recoverable	1 080 500	2 007 600	6 147 800	8 070 900
Difference	187 900	448 700	1 922 500	2 513 600
Difference %	14.8	18.3	23.8	23.7
Recovery %	85.2	81.7	76.2	76.3

(as of 1 January 2017, tonnes U; Red Book 2018)

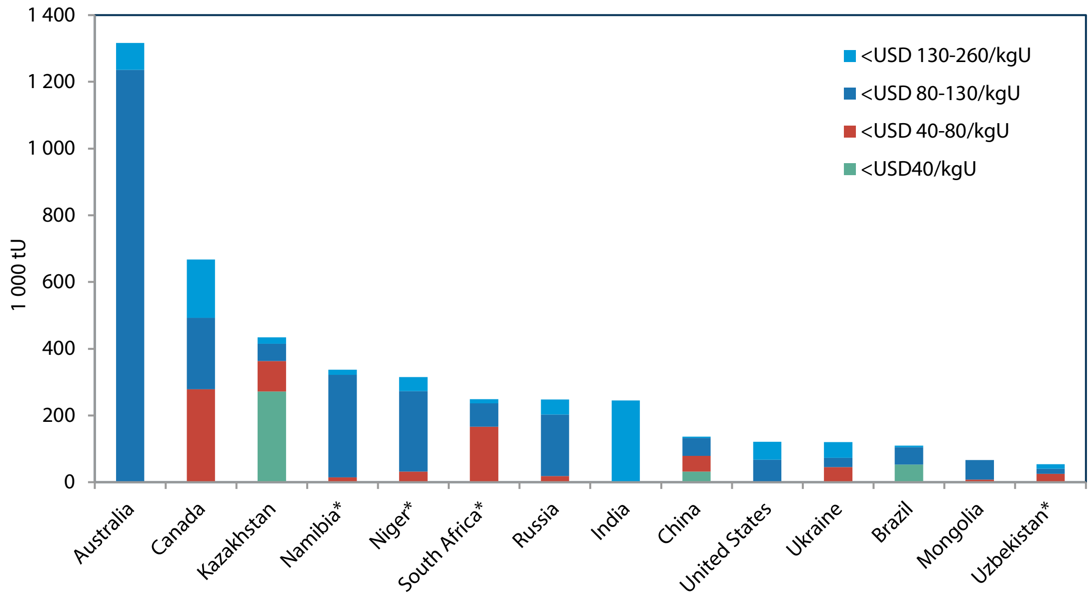
Identified resources	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Total in situ	1 294 700	2 618 000	8 122 100	10 652 900
Total recoverable	1 057 700	2 079 500	6 142 200	7 988 600
Difference	237 000	538 500	1 979 900	2 664 300
Difference %	18.3	20.6	24.4	25.0
Recovery %	81.7	79.4	75.6	75.0

† Totals may not sum exactly, or exactly match totals reported in other tables of this report, due to rounding.

* In Red Book 2018 and 2020, the percent difference and percent recovery are in error, and were corrected in Red Book 2022.

Figure 1.2. **Distribution of reasonably assured recoverable conventional uranium resources among select countries with a significant share of resources**

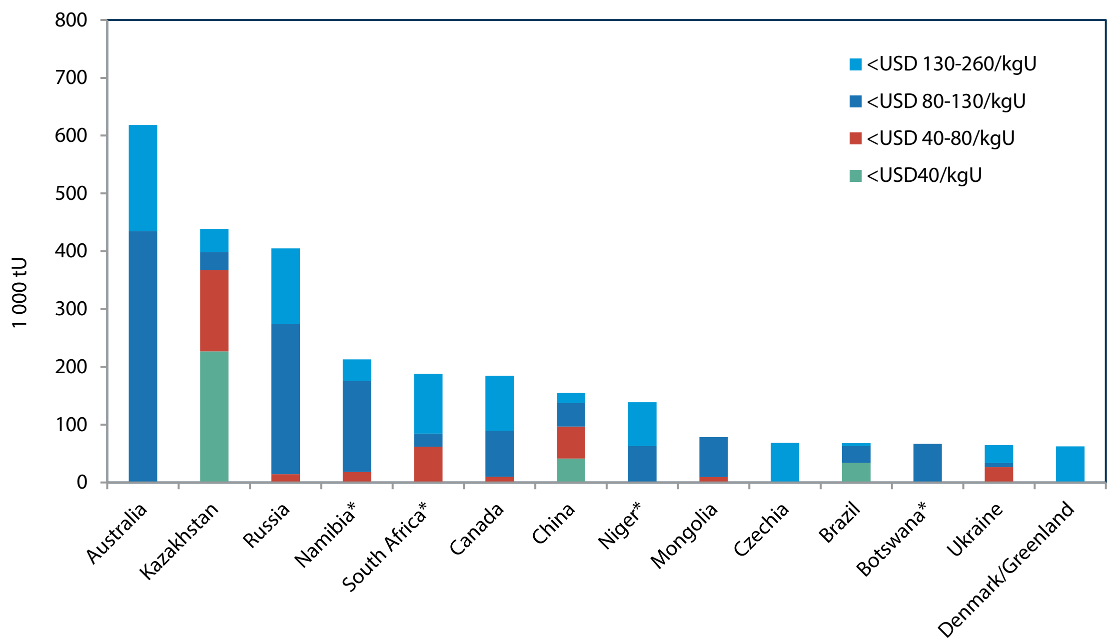
(1 000 tonnes U)



* Secretariat estimate or partial estimate.

Figure 1.3. **Distribution of inferred recoverable conventional uranium resources among select countries with a significant share of resources**

(1 000 tonnes U)



* Secretariat estimate or partial estimate.

Table 1.3a. **Reasonably assured recoverable resources**

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Algeria[a,b]	0	0	0	19 500
Argentina	0	7 000	10 500	10 500
Australia	0	0	1 236 200	1 317 000
Botswana*[b]	0	0	20 400	20 400
Brazil [a]	53 000	53 000	104 600	110 000
Canada	0	278 200	492 700	667 400
Chile*[b]	0	0	0	600
China[a]	31 800	79 200	132 800	136 300
Congo, Dem. Rep.*[a,b,c]	0	0	0	1 400
Czechia	0	0	800	50 800
Denmark (Greenland)[a,b]	0	0	0	51 400
Finland[a,b,f]	0	0	1 200	1 200
Gabon[b,c]	0	0	4 800	4 800
Germany [b]	0	0	0	3 000
Greece[b,c]	0	0	0	1 000
Guyana[a,b]	0	0	0	2 400
India[a,d]	0	0	0	244 600
Indonesia[a]	0	1 500	5 500	5 500
Iran, Islamic Republic of*[a]	0	0	3 200	3 200
Italy[b,c]	0	4 800	4 800	4 800
Japan[b]	0	0	6 600	6 600
Jordan[a]	0	0	0	5 400
Kazakhstan[a]	271 800	363 400	414 800	434 500
Malawi	0	0	11 600	13 800
Mali*[a,b]	0	0	5 000	5 000
Mauritania*	0	0	9 100	9 400
Mexico[a]	0	0	2 500	2 500
Mongolia	0	7 600	66 200	66 200
Namibia*	0	14 800	322 000	337 600
Niger*	0	31 700	273 100	315 200
Paraguay*[a,e]	0	0	2 900	2 900
Peru*[a,b]	0	14 000	14 000	14 000
Portugal[a,b]	0	3 400	4 500	4 500
Romania*[b,c]	0	0	3 000	3 000

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Table 1.3a. **Reasonably assured recoverable resources** *(cont'd)*

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Russia	0	18 200	202 300	247 700
Saudi Arabia[a,g]	0	0	0	6 000
Slovak Republic[a,b]	0	8 800	8 800	8 800
Slovenia[a,b]	0	1 700	1 700	1 700
Somalia*[a,b,c]	0	0	0	5 000
South Africa*	0	166 300	236 000	248 400
Spain[a]	8 100	19 100	19 100	19 100
Sweden*[a,b,c]	0	0	4 900	4 900
Tanzania*	0	38 300	40 400	40 400
Türkiye[a]	0	0	3 700	3 700
Ukraine	0	44 800	72 900	120 000
United States[a,h]	0	0	67 800	121 400
Uzbekistan*[a]	0	24 900	40 200	54 200
Viet Nam[a,b]	0	0	0	800
Zambia	0	0	18 400	18 400
Zimbabwe[a,b]	0	0	0	2 000
Total[i]	**364 700**	**1 180 700**	**3 868 800**	**4 778 700**

† Totals may not sum exactly, or exactly match totals reported in other tables of this report, due to rounding.

* Secretariat estimate.

(a) In situ resources were adjusted by the Secretariat to estimate recoverable resources using recovery factors provided by countries or estimated by the Secretariat according to the expected production method (Appendix 3).

(b) Assessment not made within the last five years.

(c) Not reported in 2023 responses, data from Red Book 2022.

(d) Cost data not provided, therefore resources are reported in the <USD 260/kgU category.

(e) Recovery factors partially adjusted by Secretariat.

(f) Finland also reports unconventional reasonably assured recoverable resources of ~ 8 600 tU for the Talvivaara black schist-hosted Ni-Zn-Cu-Co deposit.

(g) Categorised as unconventional resources. Resources are for the Ghurayyah polymetallic (Th-U-Nb-Ta and REE-bearing minerals) deposit and Jabal Sayid U-Th prospect.

(h) Secretariat estimate for other than the <USD 260/kgU category total, since other cost data and distribution of resources by production method data withheld, for confidentiality of company data concerns.

(i) Totals for <USD 40/kgU and <USD 80/kgU cost ranges should be regarded with some caution as certain countries do not report low-cost resource estimates, whereas other (non-producing) countries may underestimate mining costs.

Table 1.3b. **Reasonably assured in situ resources**

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Algeria(b)	0	0	0	26 000
Argentina(a)	0	9 600	14 400	14 400
Australia(a)	0	0	1 960 100	2 085 800
Botswana*(a,b)	0	0	32 900	32 900
Brazil	81 600	81 600	146 800	154 500
Canada(a)	0	319 800	566 300	767 100
Chile*(a,b)	0	0	0	700
China	45 400	112 700	185 600	190 300
Congo, Dem. Rep.*(b,c)	0	0	0	1 900
Czechia(a)	0	0	1 300	83 700
Denmark (Greenland)(b)	0	0	0	102 800
Finland(b,f)	0	0	1 500	1 500
Gabon(a,b,c)	0	0	6 400	6 400
Germany(a,b)	0	0	0	4 000
Greece(a,b,c)	0	0	0	1 300
Guyana(b)	0	0	0	3 200
India(d)	0	0	0	324 500
Indonesia	0	2 000	7 400	7 400
Iran, Islamic Republic of*	0	0	4 300	4 300
Italy(a,b,c)	0	6 400	6 400	6 400
Japan(a,b)	0	0	7 800	7 800
Jordan	0	0	0	6 800
Kazakhstan	305 300	408 600	467 600	491 200
Malawi(a)	0	0	14 300	18 000
Mali*(b)	0	0	6 700	6 700
Mauritania*(a)	0	0	11 400	11 800
Mexico	0	0	3 300	3 300
Mongolia(a)	0	10 100	88 200	88 200
Namibia*(a)	0	18 500	402 400	422 000
Niger*(a)	0	39 100	337 200	389 100
Paraguay*(e)	0	0	3 400	3 400
Peru*(b)	0	20 000	20 000	20 000
Portugal(b)	0	4 500	6 000	6 000
Romania*(a,b,c)	0	0	4 000	4 000

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Table 1.3b. **Reasonably assured in situ resources** *(cont'd)*

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Russia(a)	0	24 300	251 800	321 700
Saudi Arabia(g)	0	0	0	8 100
Slovak Republic(b)	0	11 000	11 000	11 000
Slovenia(b)	0	2 200	2 200	2 200
Somalia*(b,c)	0	0	0	6 700
South Africa* (a)	0	221 800	314 100	330 400
Spain	9 800	23 000	23 000	23 000
Sweden*(b,c)	0	0	6 500	6 500
Tanzania*(a)	0	47 900	50 500	50 500
Türkiye	0	0	4 300	4 300
Ukraine(a)	0	51 400	83 200	136 400
United States(h)	0	0	96 600	168 200
Uzbekistan*	0	35 600	57 400	77 500
Viet Nam(b)	0	0	0	1 200
Zambia(a)	0	0	22 100	22 100
Zimbabwe(b)	0	0	0	2 700
Total(i)	**442 100**	**1 450 000**	**5 228 200**	**6 469 800**

† Totals may not sum exactly, or exactly match totals reported in other tables of this report, due to rounding.

* Secretariat estimate.

(a) Recoverable resources were adjusted by the Secretariat to estimate in situ resources using recovery factors provided by countries or estimated by the Secretariat according to the expected production method (Appendix 3).

(b) Assessment not made within the last five years.

(c) Not reported in 2023 responses, data from Red Book 2022.

(d) Cost data not provided, therefore resources are reported in the <USD 260/kgU category.

(e) Recovery factors partially adjusted by Secretariat.

(f) Finland also reports unconventional reasonably assured in situ resources of ~19 200 tU for the Talvivaara black schist-hosted Ni-Zn-Cu-Co deposit.

(g) Categorised as unconventional resources. Resources are for the Ghurayyah polymetallic (Th-U-Nb-Ta and REE-bearing minerals) deposit and Jabal Sayid U-Th prospect.

(h) Secretariat estimate for other than the <USD 260/kgU category total, since other cost data and distribution of resources by production method data withheld, for confidentiality of company data concerns.

(i) Totals for <USD 40/kgU and <USD 80/kgU cost ranges should be regarded with some caution as certain countries do not report low-cost resource estimates, whereas other (non-producing) countries may underestimate mining costs.

Table 1.4a. **Inferred recoverable resources**

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Argentina	0	12 300	23 800	24 800
Australia	0	0	435 000	618 300
Bolivia(a,b)	0	0	0	1 300
Botswana*(b)	0	0	66 800	66 800
Brazil (a)	33 800	33 800	63 200	67 800
Bulgaria(a,b,d)	0	0	0	5 100
Cameroon(a,b)	0	0	0	21 000
Canada	0	9 700	89 300	184 800
Central African Republic*(a)	0	0	0	29 200
Chad*(a,b,c)	0	0	0	2 400
Chile*(b)	0	0	0	900
China(a)	41 400	96 600	137 700	155 000
Congo, Dem. Rep.*(a,b,c)	0	0	0	1 300
Czechia	0	0	0	68 300
Denmark (Greenland)(a,b)	0	0	0	62 600
Egypt(a)	0	0	400	12 100
Gabon(b,c)	0	0	0	1 000
Germany (b)	0	0	0	4 000
Greece(b,c)	0	0	0	6 000
Guyana(a,b)	0	0	0	2 200
Hungary(a)	0	0	0	16 700
India(a,d)	0	0	0	8 000
Indonesia(a)	0	0	3 000	3 000
Iran, Islamic Republic of*(a)	0	0	4 200	4 200
Italy(b,c)	0	1 300	1 300	1 300
Jordan(a)	0	0	0	43 600
Kazakhstan(a)	227 000	367 300	399 100	438 900
Malawi	0	0	4 300	4 900
Mali*(a,b)	0	0	3 900	3 900
Mauritania*	0	0	9 000	16 100
Mexico(a)	0	500	2 000	2 600
Mongolia	0	9 300	78 400	78 400
Namibia*	0	18 400	175 900	213 100

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Table 1.4a. **Inferred recoverable resources** *(cont'd)*

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Niger*	0	0	62 800	138 800
Pakistan[(a)]	0	0	0	22 500
Paraguay*[(a,e)]	0	0	1 400	1 400
Peru*[(a,b)]	0	19 400	19 400	19 400
Portugal[(a,b)]	0	0	800	800
Romania*[(b,c)]	0	0	3 600	3 600
Russia	0	14 200	274 300	404 800
Saudi Arabia[(a,g)]	0	0	0	40 000
Senegal*[(a)]	0	0	0	4 700
Slovak Republic[(a,b)]	0	3 900	6 700	6 700
Slovenia[(a,b)]	0	3 800	7 500	7 500
Somalia*[(a,b,c)]	0	0	0	2 600
South Africa*	0	61 700	84 800	188 000
Spain[(a)]	0	9 400	9 400	9 400
Sweden*[(a,b,c)]	0	0	4 700	4 700
Tanzania*	0	8 500	17 300	17 300
Türkiye[(a)]	0	0	23 400	32 300
Ukraine	0	26 700	33 800	64 800
Uzbekistan*[(a)]	0	3 600	4 800	9 400
Viet Nam[(a,b)]	0	0	0	3 000
Zambia	0	0	4 600	4 600
Total[(i)]	**302 200**	**700 400**	**2 056 900**	**3 155 700**

† Totals may not sum exactly, or exactly match totals reported in other tables of this report, due to rounding.

* Secretariat estimate.

(a) In situ resources were adjusted by the Secretariat to estimate recoverable resources using recovery factors provided by countries or estimated by the Secretariat according to the expected production method (Appendix 3).

(b) Assessment not made within the last five years.

(c) Not reported in 2023 responses, data from Red Book 2022.

(d) Cost data not provided, therefore resources are reported in the <USD 260/kgU category.

(e) Recovery factors partially adjusted by Secretariat.

(f) Categorised as unconventional resources. Resources are for the Ghurayyah polymetallic (Th-U-Nb-Ta and REE-bearing minerals) deposit and Jabal Sayid U-Th prospect.

(g) Totals for <USD 40/kgU and <USD 80/kgU cost ranges should be regarded with some caution as certain countries do not report low-cost resource estimates, whereas other (non-producing) countries may underestimate mining costs.

Table 1.4b. **Inferred in situ resources**

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Argentina[(a)]	0	15 700	31 700	33 100
Australia[(a)]	0	0	684 800	947 100
Bolivia[(b)]	0	0	0	1 700
Botswana*[(a,b)]	0	0	107 700	107 700
Brazil	52 000	52 000	89 500	96 000
Bulgaria[(b,d)]	0	0	0	7 900
Cameroon[(b)]	0	0	0	28 000
Canada[(a)]	0	11 200	102 600	212 400
Central African Republic*	0	0	0	36 500
Chad*[(b,c)]	0	0	0	3 200
Chile*[(a,b)]	0	0	0	1 200
China	59 200	137 300	192 400	215 400
Congo, Dem. Rep.*[(b,c)]	0	0	0	1 700
Czechia[(a)]	0	0	0	113 500
Denmark (Greenland)[(b)]	0	0	0	125 100
Egypt	0	0	500	16 100
Gabon[(a,b,c)]	0	0	0	1 300
Germany[(a,b)]	0	0	0	5 300
Greece[(a,b,c)]	0	0	0	8 000
Guyana[(b)]	0	0	0	2 900
Hungary	0	0	0	22 200
India[(d)]	0	0	0	10 500
Indonesia	0	0	4 100	4 100
Iran, Islamic Republic of*	0	0	5 500	5 500
Italy[(a,b,c)]	0	1 700	1 700	1 700
Jordan	0	0	0	56 200
Kazakhstan	255 000	413 000	450 300	498 300
Malawi[(a)]	0	0	5 400	6 200
Mali*[(b)]	0	0	5 200	5 200
Mauritania*[(a)]	0	0	11 300	20 700
Mexico	0	700	2 700	3 400
Mongolia[(a)]	0	12 400	104 100	104 100
Namibia*[(a)]	0	23 000	219 900	266 400

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Table 1.4b. **Inferred in situ resources** *(cont'd)*

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Niger*(a)	0	0	78 200	178 800
Pakistan	0	0	0	30 000
Paraguay*(e)	0	0	1 600	1 600
Peru*(b)	0	27 700	27 700	27 700
Portugal(b)	0	0	1 000	1 000
Romania*(a,b,c)	0	0	4 800	4 800
Russia(a)	0	18 900	332 700	513 500
Saudi Arabia(f)	0	0	0	53 400
Senegal*	0	0	0	6 200
Slovak Republic(b)	0	4 900	8 400	8 400
Slovenia(b)	0	5 000	10 000	10 000
Somalia*(b,c)	0	0	0	3 500
South Africa*(a)	0	82 200	112 200	259 200
Spain	0	11 400	11 400	11 400
Sweden*(b,c)	0	0	6 300	6 300
Tanzania*(a)	0	10 600	21 700	21 700
Türkiye	0	0	29 200	41 100
Ukraine(a)	0	30 200	38 200	73 900
Uzbekistan*	0	5 200	6 900	13 500
Viet Nam(b)	0	0	0	4 000
Zambia(a)	0	0	5 800	5 800
Total(g)	**366 200**	**863 000**	**2 715 400**	**4 244 600**

† Totals may not sum exactly, or exactly match totals reported in other tables of this report, due to rounding.

* Secretariat estimate.

(a) Recoverable resources were adjusted by the Secretariat to estimate in situ resources using recovery factors provided by countries or estimated by the Secretariat according to the expected production method (Appendix 3).

(b) Assessment not made within the last five years.

(c) Not reported in 2023 responses, data from Red Book 2022.

(d) Cost data not provided, therefore resources are reported in the <USD 260/kgU category.

(e) Recovery factors partially adjusted by Secretariat.

(f) Categorised as unconventional resources. Resources are for the Ghurayyah polymetallic (Th-U-Nb-Ta and REE-bearing minerals) deposit and Jabal Sayid U-Th prospect.

(g) Totals for <USD 40/kgU and <USD 80/kgU cost ranges should be regarded with some caution as certain countries do not report low-cost resource estimates, whereas other (non-producing) countries may underestimate mining costs.

Table 1.5. **Major identified recoverable resource changes by country**

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes)

Country	Resource category	2021	2023	Changes	Reasons
Australia	**RAR**				RAR depletion from mining (8 400 tU), closure of Ranger Mine in January 2021 and associated removal of its RAR resources, offset by delineation of new in situ resources at Olympic Dam. Decrease (3.7%) of inferred resources.
	<USD 130/kgU	1 238 700	1 236 200	-2 500	
	<USD 260/kgU	1 317 800	1 317 000	-800	
	Inferred				
	<USD 130/kgU	445 400	435 000	-10 400	
	<USD 260/kgU	642 000	618 300	-23 700	
Brazil	**RAR**				Brazil conducted a comprehensive review and reassessment of uranium resources resulting in major changes to distribution of resources (by production methods, processing methods, deposit types and production cost categories), substantial decrease in recovery factors, and a substantial decrease in the country's estimated identified recoverable uranium resources.
	<USD 40/kgU	138 100	53 000	-85 100	
	<USD 80/kgU	155 900	53 000	-102 900	
	<USD 130/kgU	155 900	104 600	-51 300	
	<USD 260/kgU	155 900	110 000	-45 900	
	Inferred				
	<USD 40/kgU	0	33 800	33 800	
	<USD 80/kgU	73 500	33 800	-39 700	
	<USD 130/kgU	120 900	63 200	-57 700	
	<USD 260/kgU	120 900	67 800	-53 100	
Bulgaria	**Inferred**				First time reported.
	<USD 260/kgU	0	5 100	5 100	
Cameroon	**Inferred**				First time reported.
	<USD 260/kgU	0	21 000	21 000	
Canada	**RAR**				6 600 tU decrease (1%) in total identified resources at <USD 130/kgU due to mining depletion (12 100 tU) exceeding new resources added. At <260/kgU, increase in RAR and decrease in inferred resources resulting in overall decrease of 13 200 tU (1.5%) total identified resources.
	<USD 80/kgU	282 300	278 200	-4 100	
	<USD 130/kgU	489 700	492 700	3 000	
	<USD 260/kgU	649 000	667 400	18 400	
	Inferred				
	<USD 80/kgU	10 000	9 700	-300	
	<USD 130/kgU	98 900	89 300	-9 600	
	<USD 260/kgU	216 400	184 800	-31 600	
Central African Republic	**Inferred**				Further decrease of uranium resources based on 2020 resource estimates (reported in 2022) of the Bakouma Basin deposits.
	<USD 260/kgU	29 200	23 700	-5 500	
China	**RAR**				Increase both in RAR and inferred resources as a result of exploration resource expansion in the Ordos, Yili, Songliao and Erlian Basin sandstone deposits of northern China and modest increase of uranium resources in the deeper parts and on the periphery of the Xiangshan, Miaoershan, southern Zhuguang, and Xiazhuang volcanic and granite-related uranium ore fields in southern China.
	<USD 40/kgU	31 800	31 800	0	
	<USD 80/kgU	55 600	79 200	23 600	
	<USD 130/kgU	107 600	132 800	25 200	
	<USD 260/kgU	111 100	136 300	25 200	
	Inferred				
	<USD 40/kgU	41 400	41 400	0	
	<USD 80/kgU	76 900	96 600	19 700	
	<USD 130/kgU	116 400	137 700	21 300	
	<USD 260/kgU	133 600	155 000	21 400	

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Table 1.5. **Major identified recoverable resource changes by country** *(cont'd)*

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes)

Country	Resource category	2021	2023	Changes	Reasons
Egypt	**Inferred**				Increase of inferred resources due to the reporting of a resource for the Abu Rusheid metamorphite deposit, previously included in prognosticated resources.
	<USD 130/kgU	400	400	0	
	<USD 260/kgU	1 900	12 100	10 200	
India[a]	**RAR**				Increase in RAR due to appreciable resource additions in the contiguous area of the stratabound deposit in the southern part of the Cuddapah Basin and the extension of areas of known deposits in the Singhbhum Shear Zone, Bhima Basin, and North Delhi Fold Belt.
	<USD 260/kgU	213 000	244 600	31 600	
	Inferred				
	<USD 260/kgU	8 000	8 000	0	
Kazakhstan	**RAR**				Total identified recoverable resources decreased insignificantly by 1 300 tU as resource depletion (43 100 tU) from mining was largely offset by the exploration resources additions at sites No. 6 and No. 7 of the Budenovskoye deposit and site No. 1 of the Inkai deposit.
	<USD 40/kgU	252 000	271 800	19 800	
	<USD 80/kgU	316 400	363 400	47 000	
	<USD 130/kgU	367 800	414 800	47 000	
	<USD 260/kgU	387 400	434 500	47 100	
	Inferred				
	<USD 40/kgU	250 000	227 000	-23 000	
	<USD 80/kgU	415 700	367 300	-48 400	
	<USD 130/kgU	447 500	399 100	-48 400	
	<USD 260/kgU	487 300	438 900	-48 400	
Namibia	**RAR**				41 200 tU net increase in total identified recoverable resources resulting from additional resources identified at Tumas, Wings, and Koppies deposits, significantly greater than mining depletion (11 400 tU) at Husab and Rössing mines.
	<USD 80/kgU	11 800	14 800	3 000	
	<USD 130/kgU	307 200	322 000	14 800	
	<USD 260/kgU	322 800	337 600	14 800	
	Inferred				
	<USD 80/kgU	7 900	18 400	10 500	
	<USD 130/kgU	162 900	175 900	13 000	
	<USD 260/kgU	186 700	213 100	26 400	
Niger	**RAR**				14 000 tU decrease of total identified recoverable resources primarily due to mining depletion (4 300 tU), a 57 700 tU decrease of Imouraren deposit resources following new resources estimate, partially offset by a 17 800 tU increase of resources for underground mining at the Dasa deposit and new resources associated with the Takardeit project (6 300 tU).
	<USD 80/kgU	14 600	31 700	17 100	
	<USD 130/kgU	257 500	273 100	15 600	
	<USD 260/kgU	334 800	315 200	-19 600	
	Inferred				
	<USD 130/kgU	53 600	62 800	9 200	
	<USD 260/kgU	133 200	138 800	5 600	
Pakistan	**Inferred**				New identified resources. Pakistan resources were not previously reported.
	<USD 260/kgU	0	22 500	22 500	
Saudi Arabia	**RAR**				Inclusion of Saudi Arabia resources for Jabal Sayid U-Th prospect (JORC compliant) and Ghurayyah polymetallic deposit (uranium, thorium, niobium, tantalum, zirconium, hafnium, tin, and REEs, of which U is considered to be a co-product of the Ta and Nb).
	<USD 260/kgU	0	6 000	6 000	
	Inferred				
	<USD 260/kgU	0	40 000	40 000	

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Table 1.5. **Major identified recoverable resource changes by country** *(cont'd)*

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes)

Country	Resource category	2021	2023	Changes	Reasons
Türkiye	**RAR**				Additional inferred resources identified, including 14 600 tU at the Avanos-Gülşehir deposit, and 7 800 tU at the Malatya-Kuluncak area.
	<USD 130/kgU	3 000	3 700	700	
	<USD 260/kgU	3 000	3 700	700	
	Inferred				
	<USD 130/kgU	8 700	23 400	14 700	
	<USD 260/kgU	9 700	32 300	22 600	
United States(b)	**RAR**				8% increase in reported recoverable identified resources.
	<USD 80/kgU	9 000	0	-9 000	
	<USD 130/kgU	59 400	67 800	8 400	
	<USD 260/kgU	112 200	121 400	9 200	
Uzbekistan	**RAR**				Increase of 5 000 tU RAR and decrease of 72 700 tU inferred recoverable resources due primarily to write-off of high cost (above USD 260/kgU) inferred resources (approximately 30 800 tU of black shales and 31 500 tU of sandstone type resources), mining depletion (7 100 tU), offset by some addition of resources from favourable exploration results, and conversion of inferred resources into RAR.
	<USD 40/kgU	27 200	0	-27 200	
	<USD 80/kgU	27 200	24 900	-2 300	
	<USD 130/kgU	49 200	40 200	-9 000	
	<USD 260/kgU	49 200	54 200	5 000	
	Inferred				
	<USD 40/kgU	24 900	0	-24 900	
	<USD 80/kgU	24 900	3 600	-21 300	
	<USD 130/kgU	82 100	4 800	-77 300	
	<USD 260/kgU	82 100	9 400	-72 700	
Zambia	**RAR**				Increase of 5 600 tU RAR and decrease of 13 600 tU inferred recoverable resources resulting from a new resource estimate of the Mutanga project.
	<USD 130/kgU	12 800	18 400	5 600	
	<USD 260/kgU	12 800	18 400	5 600	
	Inferred				
	<USD 130/kgU	18 200	4 600	-13 600	
	<USD 260/kgU	18 200	4 600	-13 600	

(a) Cost data not provided, therefore resources are reported in the <USD 260/kgU category.

(b) Secretariat estimate for other than the <USD 260/kgU category total, since other cost data withheld, for confidentiality of company data concerns.

Reasonably assured resources amount to 60% of the identified resource total, a 1% increase compared to the previous report. As of 1 January 2023, low-cost RAR and IR comprised <8% and <10% respectively of total RAR and IR, declining by 2.2% and 0.3% respectively from 2021.

Australia reported marginally decreased RAR and decreased IR due to depletion from mining, removal of Ranger Mine resources upon closure, offset by delineation of new resources at Olympic Dam (resulting in a shift from IR to RAR). Brazil reported substantially decreased RAR (all cost categories) and IR (other than an increase at <USD 40/kgU) arising from comprehensive reassessment of uranium resources that resulted in major changes to the distribution of resources, decrease in recovery factors, and re-alignment of expected costs. High-cost (<USD 260/kgU) IR were included for the first time for Bulgaria and Cameroon, based on review of historical information. Canada reported a small decrease in low-cost (<USD 80/kgU) RAR and a modest increase in higher-cost RAR (<USD 130/kgU, <USD 260/kgU) more than offset by decreased IR owing to mining depletion exceeding resources added. The Central African Republic reported decreased high-cost (<USD 260/kgU) IR, resulting from further reassessment of resources at the Bakouma deposit. China reported significantly increased RAR and IR due to

exploration resource expansion primarily at the sandstone deposits in northern China, with modest increases in the deeper and peripheral parts of the volcanic and granite-related uranium ore fields in the south. In Egypt, additional high-cost (<USD 260/kgU) IR were added for the Abu Rusheid deposit, upgraded from the previously reported prognosticated resources. In India, ongoing exploration efforts led to a 15% increase in high-cost (<USD 260/kgU) RAR compared to 2021. Kazakhstan reported increased RAR and decreased IR at all cost categories, as resource depletion from mining was offset by exploration resource additions and delineation upgrades. Ongoing exploration in Namibia boosted RAR and IR resource totals in all cost categories from additional resources identified at Tumas, Wings, and Koppies prospective deposits, significantly greater than mining depletion at existing mines. In Niger, new resource estimates for the Dasa project and the Takardeit deposit resulted in increased RAR in the <USD 80/kgU and <USD 130/kgU cost categories. These increases were offset by a decrease of Imouraren deposit resources in the <USD 260/kgU category following an updated resource estimate. High-cost (<USD 260/kgU) resources were included for the first time for Pakistan (IR) and for Saudi Arabia (RAR, IR) where enhanced assessment work resulted in including the Jabal Sayid U-Th prospect and the Ghurayyah polymetallic deposit (U, Ta, Nb co-products). Additional IR were identified in Türkiye at the Avanos-Gülşehir deposit and the Malatya-Kuluncak area. The United States reported an 8% increase in RAR at <USD 260/kgU. Uzbekistan reported increased RAR at <USD 260/kgU (decreased at <USD 80/kgU and <USD 130/kgU) and dramatically decreased IR due primarily to the write-off of high-cost resources, and mining depletion, offset by some addition of resources from favourable exploration results. In Zambia, a new resource estimate for the Mutanga project resulted in increased RAR more than offset by decreased IR.

Three countries, Australia, Kazakhstan and Canada, collectively host around half of global identified conventional uranium resources. Australia dominates the world's uranium resources with 28% of the total identified recoverable resources at <USD 130/kgU and 24% of identified resources at <USD 260/kgU. Fully 68% of Australia's uranium resources (and 17% of global identified resources) are attributed to the world-class polymetallic Fe-oxide breccia complex, the Olympic Dam deposit, where uranium is mined as a co-product of copper. Kazakhstan remains second, hosting approximately 14% of worldwide identified resources at <USD 130/kgU and 11% at <USD 260/kgU. Canada's share remains similar as reported in the 2022 edition at about 10% in the <USD 130/kgU category and 11% in the <USD 260/kgU category. Fifteen countries represent approximately 95% of the total identified resources in the <USD 130/kgU cost category (see Figure 1.1) and more than 90% at <USD 260/kgU.

With respect to the lower cost categories, for this edition only four countries reported recoverable uranium resources in the lowest cost category (<USD 40/kgU), and of these Kazakhstan has by far the largest share (75%), followed by Brazil (13%), China (11%) and Spain (1%). In the <USD 80/kgU cost category, Kazakhstan holds a 39% share, followed by Canada (15%), South Africa (12%), China (9%), Brazil (5%), with ten other countries each holding shares of 1% to 2% in this cost category. Readers are cautioned concerning both these lower cost resource estimates (but particularly <USD 40/kgU), since Australia does not report resources in either of these cost categories, many countries do not report in the <USD 40/kgU category, the United States does not report IR, and some countries that have never (or have not recently) hosted uranium mining may be underestimating mining costs.

Starting in the 2016 edition, a summary has been prepared of worldwide in situ identified conventional resources (see Tables 1.2b, 1.3b and 1.4b). Table 1.2c is a summary comparison of in situ identified resources and recoverable identified resources by cost category. Overall, there is a 17% to 26% increase in the resource figures when they are reported as in situ. This corresponds to average recoveries ranging from approximately 74% to 83%. Total identified in situ resources increased marginally (0.4%) from 10 671 800 tU reported in the last edition to 10 714 400 tU for this edition.

Reporting in situ resources provides a view of the full available resource base in the ground, allows clear comparison of average recoveries, and by quantifying the non-recovered portion, gives an indication of how the resource base could be increased with improvements in mining and processing methods that would lead to better recovery. Nonetheless, recoverable resources still provide the better and more realistic estimate for forecasting future uranium supply.

Distribution of resources by production method

For this edition of the Red Book, countries reported identified resources by cost categories and by the expected production method: open-pit or underground mining, acid or alkaline in situ leaching (ISL, sometimes referred to as in situ recovery, or ISR), co-product/by-product, or unspecified.

In the cost category <USD 40/kgU, with only four countries reporting resources in this lowest cost category, there is a limited and concentrated subset of production methods represented, as is evident in Table 1.6 (RAR), mainly ISL acid, ISL alkaline, and co-product/by-product production methods. Low-cost resources amenable to production by ISL, mainly in Kazakhstan (entirely ISL acid) and to a lesser extent China (predominantly ISL acid and some non-reagent ISL introduced in recent years) dominate this lowest cost category, representing 83% of total RAR resources. Resources suited for co-product/by-product from phosphates in Brazil make up most of the remainder. Information for this lowest cost category is to be interpreted with caution as very few countries report resources in the <USD 40/kgU category, and some countries that have not recently hosted uranium mining may be underestimating mining costs.

Table 1.6. **Reasonably assured recoverable resources by production method**

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Open-pit mining	8 100	113 700	904 900	1 041 400
Underground mining	0	312 300	936 200	1 453 400
In situ leaching acid	279 300	473 500	572 700	636 000
In situ leaching alkaline	24 200	57 000	132 900	135 300
Co-product/by-product	53 000	219 400	1 276 500	1 425 700
Unspecified	0	4 800	45 700	86 900
Total	**364 700**	**1 180 700**	**3 868 800**	**4 778 700**

† Totals may not sum exactly, or exactly match totals reported in other tables of this report, due to rounding.

In the <USD 80/kgU category, resources amenable to production by ISL (Canada, China, Kazakhstan, Mongolia, Namibia, Russia, Ukraine and Uzbekistan) make the most significant contribution (40% ISL acid plus 5% ISL alkaline) with resources identified for underground mining methods (mainly from Canada and Ukraine, minor amounts from four other countries) being the second most represented at 26% of total resources. The by-product/co-product category (Brazil and South Africa) makes up nearly 20%, with open-pit mining (Argentina, Niger, Portugal, and Tanzania) rising in importance.

In the <USD 130/kgU category, resources in the by-product/co-product category make up 33% of the total, predominately a result of the Olympic Dam deposit in Australia, dramatically adding to the Brazil and South Africa resources. At this cost category, underground (mainly from Australia, Canada, China, Niger, Russia and Ukraine) and open-pit mining (mainly Australia, Brazil, Namibia, Niger and Tanzania) amenable resources each contribute close to 25% of the total, followed by ISL acid at 15%.

In the <USD 260/kgU category, the underground (predominantly Australia, India, Canada and Russia) and co-product/by-product (Australia, Brazil, Greenland, and South Africa) production methods contribute about 30% each, followed by open-pit mining (mainly Australia, Namibia and Niger) at 22%, and ISL acid at 13%. Australia holds by far the largest resource for co-product/by-product, Canada holds the largest resource total for underground mining, while Namibia makes the largest contributions in the open-pit production category. ISL makes an important contribution in all cost categories, with Kazakhstan being the dominant player for ISL acid and the United States for ISL alkaline.

The pattern of resource distribution by production method for IR (Table 1.7) is similar to that for RAR. In the lowest cost categories (<USD 40/kgU and <USD 80/kgU), resources amenable to ISL production dominate, principally in Kazakhstan. In the <USD 130/kgU category, ISL, dominated by Kazakhstan, China, and Mongolia, contribute the most resources, followed closely by underground mining (mainly Australia, Canada, China, Russia and Ukraine), co-product/by-product (Australia, Brazil and South Africa), and open-pit (mainly Botswana, Namibia and Niger). In the highest cost category (<USD 260/kgU), underground mining (mainly Canada and Russia, followed by Australia, China, Kazakhstan, South Africa and Ukraine) is the leading contributor, with co-product/by-product (mainly Australia, Brazil, Greenland and South Africa), open-pit (mainly Australia and Namibia, followed by Botswana and Niger) and ISL (mainly Kazakhstan, followed by Australia, China, Czechia and Mongolia) all making significant contributions. Since the United States does not report IR, the ISL alkaline category is under-represented in Table 1.7.

Table 1.7. **Inferred recoverable resources by production method**

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Open-pit mining	0	51 300	447 800	688 900
Underground mining	0	55 800	530 200	860 400
In situ leaching acid	237 500	428 900	509 700	616 700
In situ leaching alkaline	30 900	67 200	70 300	70 300
Co-product/by-product	33 800	95 400	461 200	657 300
Unspecified	0	1 800	37 700	262 200
Total	**302 200**	**700 400**	**2 056 900**	**3 155 700**

† Totals may not sum exactly, or exactly match totals reported in other tables of this report, due to rounding.

Distribution of resources by processing method

In 2023, countries also reported identified conventional resources by cost categories and by the expected processing method: conventional from open-pit or conventional from underground mining, ISL, in-place leaching, heap leaching from open-pit or heap leaching from underground, or unspecified. It should be noted that not all countries reported their resources according to processing method.

The overall distribution for the two lowest cost categories has changed since the last reporting period, owing primarily to the comprehensive review and reassessment of uranium resources conducted by Brazil that resulted in major changes to the distribution by methods, to recovery rates and reduced <USD 40/kgU resources by 85 000 tU and <USD 80/kgU resources by 103 000 tU. With only four countries reporting resources at the lowest cost category (<USD 40/kgU), Kazakhstan ISL acid amenable RAR completely dominate (Table 1.8). At <USD 80/kgU, conventional processing from underground mining becomes an equal contributor to ISL acid, largely driven by RAR from Canada. At the higher cost categories (<USD 130/kgU and <USD 260/kgU), the overall distribution is similar to that of the 2022 edition, with a majority of RAR identified as conventional processing from underground, owing principally to Australia's Olympic Dam deposit, followed by conventional processing from open pit and ISL. Heap leaching, primarily from open-pit mining, becomes increasingly important at the higher cost categories (<USD 130/kgU and <USD 260/kgU), particularly for Botswana, Namibia and Niger.

With respect to IR (Table 1.9), ISL dominates in the lowest cost category, is equivalent to conventional processing from underground at the <USD 80/kgU category, and in the two higher cost categories is surpassed by conventional from underground, with conventional from open-pit mining rising in importance. Heap leaching from open pit becomes increasingly important in the higher cost categories (<USD 130/kgU and <USD 260/kgU), particularly in Botswana, Jordan and Namibia. At the highest cost category more than 10% of IR is reported with an unspecified

processing method as the exploration of many deposits is insufficiently advanced for planning to define likely methods. Note that the United States does not report IR, leading to under-representation in the ISL alkaline category in Table 1.9.

Table 1.8. **Reasonably assured recoverable resources by processing method**

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional from OP	58 400	144 900	720 300	868 400
Conventional from UG	2 800	479 700	2 143 200	2 680 700
In situ leaching acid	279 300	473 500	572 700	636 000
In situ leaching alkaline	24 200	57 000	132 900	135 300
In-place leaching*	0	0	500	500
Heap leaching** from OP	0	19 100	234 800	273 000
Heap leaching** from UG	0	0	17 100	17 900
Unspecified	0	6 500	47 300	166 900
Total	**364 700**	**1 180 700**	**3 868 800**	**4 778 700**

† Totals may not sum exactly, or exactly match totals reported in other tables of this report, due to rounding.

* Also known as stope leaching or block leaching.

** A subset of open-pit and underground mining, since it is used in conjunction with them.

Table 1.9. **Inferred recoverable resources by processing method**

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional from OP	28 300	60 200	366 400	598 300
Conventional from UG	5 500	119 200	946 900	1 358 900
In situ leaching acid	237 500	428 900	509 700	616 700
In situ leaching alkaline	30 900	67 200	70 300	70 300
In-place leaching*	0	0	2 100	4 600
Heap leaching** from OP	0	19 400	109 300	156 400
Heap leaching** from UG	0	0	6 700	6 900
Unspecified	0	5 600	45 600	343 800
Total	**302 200**	**700 400**	**2 056 900**	**3 155 700**

† Totals may not sum exactly, or exactly match totals reported in other tables of this report, due to rounding.

* Also known as stope leaching or block leaching.

** A subset of open-pit and underground mining, since it is used in conjunction with them.

Distribution of resources by deposit type

In 2023, countries also reported identified resources by cost categories and by geological types of deposits using the deposit classification scheme introduced in the 2014 edition (Appendix 3).

Sandstone type RAR, mainly in Australia, China, Kazakhstan, Niger and the United States, tops all cost categories (Table 1.10). In the higher cost categories (<USD 130/kgU and <USD 260/kgU), polymetallic iron-oxide breccia complex deposits, namely Olympic Dam in Australia, become increasingly more important, along with Proterozoic unconformity-related resources (mainly in Canada), followed by metasomatite (mainly in Brazil, Russia and Ukraine), intrusive (mainly Greenland, Namibia and Russia) and paleo-quartz-pebble conglomerate resources (South Africa).

Similar patterns are apparent in the IR category (Table 1.11). Sandstone-hosted resources again dominate all cost categories and, at the lowest cost category (<USD 40/kgU), account for almost 90% of IR. In the higher cost categories (<USD 130/kgU and <USD 260/kgU), polymetallic iron-oxide breccia complex type deposits (Australia), metasomatite (mainly Kazakhstan, Russia and Ukraine), intrusive (mainly Greenland, Namibia, Russia and Saudi Arabia) and Proterozoic unconformity-type deposits (mainly Canada) rise in importance, but do not rival sandstone-based resources in abundance.

Proximity of resources to production centres

Estimates on the availability of resources for near-term production in eight countries are provided by reporting the percentage of identified resources (RAR and IR) recoverable at costs of <USD 80/kgU and <USD 130/kgU that are proximal to existing and committed production centres (Table 1.12). Resources proximal to existing and committed production centres in seven of the countries listed a total of 1 259 600 tU at <USD 80/kgU (about 88% of the total resources reported in this cost category). This is a 2.5% increase over the 2021 value of 1 228 843 tU. This change over the two-year reporting period is attributed to decreased proximal resources in this cost category for Brazil, and to a lesser extent Canada, offset by increases for Niger and South Africa. Resources proximal to existing and committed production centres in the eight countries listed a total of 3 185 800 tU at <USD 130/kgU (about 65% of the total resources reported in this cost category). This is 3.5% greater than the 3 078 504 tU reported for 2021 and is the result of increases of proximal resources in this cost category for Australia, Brazil and South Africa, offset by decreases for Canada, Namibia, Niger and Russia.

Table 1.10. **Reasonably assured recoverable resources by deposit type**

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Proterozoic unconformity	0	278 200	571 200	734 100
Sandstone	303 500	578 600	1 102 400	1 280 200
Polymetallic Fe-Oxide Breccia Complex	0	0	994 700	1 035 200
Paleo-quartz-pebble conglomerate[(a)]	2 800	169 100	231 500	241 500
Granite-related	8 100	26 800	60 900	85 200
Metamorphite	50 300	51 800	56 600	115 200
Intrusive	0	0	251 500	379 500
Volcanic-related	0	29 800	138 400	144 400
Metasomatite	0	44 600	258 300	365 200
Surficial deposits	0	1 900	149 300	168 400
Carbonate	0	0	0	151 300
Collapse breccia	0	0	0	0
Phosphate	0	0	34 600	42 300
Lignite - coal	0	0	16 400	16 400
Black shale	0	0	0	7 800
Unspecified	0	0	3 000	12 000
Total	**364 700**	**1 180 700**	**3 868 800**	**4 778 700**

† Totals may not sum exactly, or exactly match totals reported in other tables of this report, due to rounding.

(a) In South Africa, Paleo-quartz-pebble conglomerate resources include tailings resources.

Table 1.11. **Inferred recoverable resources by deposit type**

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes†)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Proterozoic unconformity	0	9 700	127 800	214 300
Sandstone	268 400	519 400	799 100	1 067 800
Polymetallic Fe-Oxide Breccia Complex	0	0	353 100	422 100
Paleo-quartz-pebble conglomerate[(a)]	5 500	67 200	79 900	108 900
Granite-related	0	17 900	42 400	60 800
Metamorphite	28 300	28 300	30 900	37 400
Intrusive	0	0	120 700	310 400
Volcanic-related	0	26 400	95 600	117 600
Metasomatite	0	30 300	315 200	457 700
Surficial deposits	0	1 100	59 800	166 400
Carbonate	0	0	19 800	19 800
Collapse breccia	0	0	0	0
Phosphate	0	0	7 100	45 900
Lignite - coal	0	0	1 900	72 700
Black shale	0	0	0	15 200
Unspecified	0	0	3 600	38 700
Total	**302 200**	**700 400**	**2 056 900**	**3 155 700**

† Totals may not sum exactly, or exactly match totals reported in other tables of this report, due to rounding.

(a) In South Africa, Paleo-quartz-pebble conglomerate resources include tailings resources.

Table 1.12. **Identified recoverable resources proximate to existing or committed production centres***

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes)

Country	Reasonably assured + inferred recoverable resources					
	at <USD 80/kgU			at <USD 130/kgU		
	Total	Proximate	% Proximate	Total (tU)	Proximate	% Proximate
Australia	NA	NA	NA	1 671 200	1 398 700	84%
Brazil[(a)]	86 800	0	0%	167 800	47 400	28%
Canada	287 900	287 900	100%	582 000	369 000	63%
Kazakhstan	730 800	679 600	93%	813 900	675 500	83%
Namibia	33 200	0	0%	497 900	227 500	46%
Niger[(b)]	31 700	31 700	100%	336 000	58 800	18%
Russia	32 400	32 400	100%	476 600	105 700	22%
South Africa	228 000	228 000	100%	320 900	303 200	94%
Total	**1 430 800**	**1 259 600**	**88%**	**4 866 300**	**3 185 800**	**65%**

* Identified resources only in countries that reported proximity to production centres; not world total.

(a) Resources from existing production centre Caetité - Lagoa Real - Engenho (9 927 tU) not included as these are classified as >USD 130/kgU and <USD 260/kgU.

(b) Assumes the Dasa Project is committed.

Undiscovered resources

Undiscovered resources (prognosticated and speculative; see Appendix 3) refer to resources that are expected to occur based on geological knowledge of previously discovered deposits and regional geological mapping. *Prognosticated resources* (PR) refer to those expected to occur in known uranium provinces, generally supported by some direct evidence. *Speculative resources* (SR) refer to those expected to occur in geological provinces that may host uranium deposits. Both PR and SR require significant amounts of exploration before their existence can be confirmed and grades and tonnages can be more accurately determined. All PR and SR are reported as in situ resources (see Table 1.13).

Worldwide, reporting of PR and SR is incomplete; a total of 38 countries reported undiscovered resources for this edition, compared to the 59 reporting identified resources (including 18 NEA/IAEA estimates). In most cases these estimates of undiscovered resources have not been updated for several years. Eighteen countries reported both PR and SR. Nine countries (Bulgaria, Egypt, Greece, Hungary, Indonesia, Paraguay, Portugal, the Slovak Republic, and Slovenia) reported only PR, whereas eleven countries (Brazil, China, Germany, Italy, Jordan, Madagascar, Mauritania, Nepal, Poland, Venezuela and Zimbabwe) reported only SR. These inconsistencies are likely due to a lack of standardised assessment and evaluation approaches and methodologies, as well as the absence of a unified reporting standard.

In addition to few recently updated assessments, some countries with significant resource potential, such as Australia and the United States, do not report undiscovered resources. A number of different quantitative mineral resource assessment approaches and integrated quantitative and mineral prospectivity mapping methods have been investigated and applied at local, regional and national scales, including in Australia (for surficial-type uranium deposits, using a variety of integrated methodologies), and the United States (for sandstone-hosted and surficial-type uranium deposits, using integrated mineral prospectivity mapping and 3-Part quantitative methods). For additional details on such methods and applications, see IAEA (2018a).

The US Geological Survey in the United States, for example, had re-estimated undiscovered resources using a combination of mineral prospectivity mapping and the "3-Part" form of quantitative mineral resource assessment (Singer et al., 2010). Two assessments were completed, estimating about 84 500 tU recoverable in the Texas Coastal Plain and 15 000 tU in situ in the Southern High Plains region (Mihalasky et al., 2015; Hall et al., 2017). However, this work is yet to be classified into either PR or SR categories and, as a result, is not reported in Table 1.13. In 2021 and 2022, the USGS did not complete any undiscovered resource estimates; however, progress was made toward completing some of the elements that are required for the USGS 3-part assessment. Specifically updated deposit models were completed for two prospective areas (the southern Appalachian and Colorado Plateau regions), and a grade and tonnage database were compiled for one region (the Colorado Plateau). More information is available in the United States country report. As of 2023, only about 10% of the undiscovered uranium resources in the United States have been recently reassessed but plans have been made to continue these assessments.

China, as well, reports significant resource potential, that has in recent editions not been included in Table 1.13. A systematic nationwide uranium resource prediction and evaluation estimated that PR amounted to 2 million tU, with no cost range assigned. As this estimate is understood to be based on evaluation of a systematic and nationwide resource prediction, it forms the basis in this edition for speculative resources included in Table 1.13, estimated by the Secretariat to be more than 1 million tU at an unassigned cost range.

There are major changes for two countries in this edition of Table 1.13, compared to 1 January 2021 (i.e. Red Book 2022). The first is an outcome of the comprehensive review and reassessment of uranium resources carried out by Brazil, which resulted in eliminating the previously reported 300 000 tU PR (at all cost categories) and reducing SR in the cost unassigned category from the previous 500 000 tU to 254 000 tU. The second, as discussed in the previous paragraph, is the inclusion of 1 000 000 tU speculative resources for China in the unassigned cost category.

Total PR in the highest cost category (<USD 260/kgU) amounted to 1 358 000 tU, an 18% decrease compared to 2021. Removing the impact of the changes in Brazil, there was a decrease of only 0.3%. In the lower cost categories (i.e., <USD 80/kgU and <USD 130/kgU), the PR totals decreased by 63% and 34% respectively (1.6% and 1.3% adjusting for the Brazil change), compared to the last reporting period. Unsupported long-term estimates for China and Mexico were dropped (in China's case replaced by the major addition to SR) and small decreases were reported for Egypt (<USD 130/kgU and <USD 260/kgU cost categories) and Uzbekistan (at all cost categories). Paraguay reported a small decrease at <USD 130/kgU and an increase at <USD 260/kgU. No changes have been reported for the remaining countries since the last reporting period.

Speculative resources in the <USD 130/kgU and <USD 260/kgU cost categories decreased by 0.7% and increased by 1.0% respectively, compared to 2021, due to increases reported by Jordan (<USD 260/kgU cost category only) and Russia, offset by removing reporting at the lowest cost category only (<USD 130/kgU) by Zimbabwe. The unassigned cost category increased overall by 42%, owing to the changes for Brazil and China, inclusion of SR for Nepal, and an increase reported by Uzbekistan. No other countries reported changes in speculative resources.

High-cost (<USD 260/kgU) PR and total SR amount to a combined total of 7 912 000 tU, an increase of 7% from the 7 366 000 tU reported in 2021.

Table 1.13. **Undiscovered (prognosticated and speculative) in situ resources**

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes)

Country	Prognosticated resources			Speculative resources			
	Cost ranges			Cost ranges			Total
	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	<USD 130/kgU	<USD 260/kgU	Unassigned	
Argentina	0	20 100	20 700	0	79 500	0	79 500
Brazil	0	0	0	0	0	254 400	254 400
Bulgaria	0	0	25 000	0	0	0	0
Canada[a]	50 000	150 000	150 000	700 000	700 000	0	700 000
Chile[a]	0	0	2 300	0	0	2 400	2 400
China[c]	NA	NA	NA	NA	NA	1 000 000	1 000 000
Colombia[b]	0	11 000	11 000	217 000	217 000	0	217 000
Czechia	0	0	222 900	0	0	17 000	17 000
Egypt	0	10 200	10 200	NA	NA	NA	NA
Germany[a]	0	0	0	0	0	74 000	74 000
Greece[b]	6 000	6 000	6 000	NA	NA	NA	NA
Hungary	0	0	14 800	0	0	0	0
India[d]	NA	NA	144 200	NA	NA	59 400	59 400
Indonesia	0	0	37 300	0	0	0	0
Iran, Islamic Republic of[b]	0	9 800	9 800	0	0	48 100	48 100
Italy[b]	0	0	0	10 000	10 000	0	10 000
Jordan[e]	0	0	0	0	70 000	NA	70 000
Kazakhstan	85 800	113 700	115 300	191 900	219 400	NA	219 400
Madagascar*	0	0	0	0	0	10 000	10 000

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Table 1.13. **Undiscovered (prognosticated and speculative) in situ resources** *(cont'd)*

(as of 1 January 2023, tonnes U, rounded to nearest 100 tonnes)

Country	Prognosticated resources			Speculative resources			
	Cost ranges			Cost ranges			Total
	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	<USD 130/kgU	<USD 260/kgU	Unassigned	
Mauritania*	0	0	0	NA	NA	19 000	19 000
Mexico(f)	NA	NA	NA	NA	NA	NA	NA
Mongolia(a)	13 300	13 300	13 300	1 319 000	1 319 000	NA	1 319 000
Namibia	0	0	57 000	0	0	150 700	150 700
Nepal(g)						12 300	12 300
Niger(a)	0	13 600	13 600	0	51 300	0	51 300
Paraguay	0	8 900	21 500	NA	NA	NA	0
Peru	6 600	19 800	19 800	45 400	45 400	0	45 400
Poland(a)	0	0	0	0	0	20 000	20 000
Portugal(a)	1 000	1 500	1 500	NA	NA	NA	NA
Romania(b)	0	3 000	3 000	3 000	3 000	NA	3 000
Russia	0	115 300	164 000	157 100	551 700	0	551 700
Slovak Republic	0	3 700	10 900	0	0	0	0
Slovenia(a)	0	1 100	1 100	0	0	0	0
South Africa(b)	0	74 000	159 000	243 000	411 000	280 000	691 000
Ukraine(a)	0	8 400	22 500	0	120 000	255 000	375 000
United States(h)	NA	NA	NA	NA	NA	NA	NA
Uzbekistan	20 000	20 000	20 000	NA	NA	45 000	45 000
Venezuela(b)	NA	NA	NA	0	0	163 000	163 000
Viet Nam(a)	NA	NA	81 200	NA	NA	321 600	321 600
Zimbabwe	0	0	0	0	25 000	0	25 000
Total	**182 700**	**603 400**	**1 357 900**	**2 886 400**	**3 822 300**	**2 731 900**	**6 554 200**

NA = Data not available.

* Secretariat estimate; no change since last edition.

(a) Reported in 2023 response, but values have not been updated within last 5 years.

(b) Not reported in 2023 response, data from Red Book 2022.

(c) China has conducted systematic domestic uranium resource prediction and evaluation with total speculative resources estimated by the Secretariat to be more than 1 million tU at an unassigned cost range.

(d) Cost data not provided, therefore resources are reported in the <USD 260/kgU category.

(e) Jordan also reports speculative unconventional resources of 98 000 tU at<USD 130/kgU category, associated with two phosphorite deposits.

(f) Mexico reports 80 localities with potential occurrences of radioactive minerals, half with geological potential for further exploration, however no estimate of undiscovered resources provided.

(g) Nepal reports estimated speculative resources of approximately 48 tU at Tinbhangale, 12 000 tU (and up to 100 000 tU) for the Lomanthang prospect, and 225 tU for the Bangabagar and Gorang prospects.

(h) US estimates of undiscovered resources were carried forward without alteration from 1994 to Red Book 2009. Since Red Book 2011 entries in these categories were discontinued until updated undiscovered resource estimates can be completed. To date no updated undiscovered resource estimates have been completed however in 2021-22 progress was made toward completing some of the elements required.

Other resources and materials

Conventional resources are defined as resources from which uranium is recoverable as a primary product, a co-product or an important by-product, while unconventional resources are resources from which uranium is only recoverable as a minor by-product, such as uranium associated with phosphate rocks, non-ferrous ores, carbonatite, black shale, and lignite (see Appendix 3 for definitions).

In essence, conventional resources are the types of resources that have historically been mined, whereas unconventional resources have been mined only occasionally, although there are exceptions. Moreover, the distinction between conventional and unconventional resources is not consistently defined: some countries consider unconventional resources to be a part of their conventional resource endowment: 1) if uranium grades are relatively high; 2) if uranium was the principal exploration target; or 3) if conventional resources are not available in the quantities needed to meet domestic requirements.

Historically, phosphate deposits (Barthel, 2005) are the only unconventional resources from which a significant amount of uranium has been produced. Processing of Moroccan phosphate rock in Belgium produced 690 tU between 1975 and 1999, and about 17 150 tU were recovered in the United States from Florida phosphate rocks between 1954 and 1962. As much as 40 000 tU were also recovered from processing marine organic deposits (essentially concentrations of ancient fish bones) in Kazakhstan. In the former German Democratic Republic, low grade (<0.006% U) Silurian black shales in the Ronneburg ore field were a source of significant quantities of uranium (nearly 100 000 tU) between 1950 and 1990 (IAEA, 2020). However, except for Belgian production from phosphates, production from such unconventional resources was undertaken principally to meet strategic demand when uranium prices were high and, in some cases, production costs were not considered important.

Most of the unconventional uranium resources reported to date are associated with uranium in black shales and phosphate rocks, but other potential sources exist (e.g. seawater, discussed below). Estimates of uranium resources associated with marine and organic phosphorite deposits point to the existence of almost 9 million tU in four countries alone: Jordan, Mexico, Morocco and the United States. Estimates of global uranium resources associated with phosphate rocks range considerably, from 6 million to 9 million tU (cited in IAEA reports, 1965-1993 Red Books, and Haneklaus, 2021), to as high as 22 million to 24 million tU (cited in Red Book 2005, and derived from the IAEA UDEPO database; see below). These estimates use various assumptions, methodologies, cut-off grades and other considerations, such as some addressing reserves and other resources. A more comprehensive discussion about the uncertainty of phosphate resources is presented in Gabriel et al. (2013) and Haneklaus (2021).

The variation in these estimates shows that these figures should be considered as part of a general mineral inventory rather than conforming to standard categories used in reporting resources. The development of more rigorous estimates of uranium in phosphate rocks will be required if uranium market prices justify the economic extraction of uranium during the exploitation of these deposits.

Unconventional resources are not usually classified to the same degree of certainty as conventional resources (i.e. they are not identified resources), although there are notable exceptions. The majority are not currently being mined but at least some have been mined in the past, as noted above, and could be mined in the future under the right circumstances. With the increased uranium price (i.e. spot, forward, and long-term pricing typically greater than USD 80/lb U_3O_8 throughout 2024) some unconventional resources that were once considered to be subeconomic may become economically feasible to exploit.

Unconventional resources and the UDEPO database

The IAEA maintains a database of global uranium deposits, the World Distribution of Uranium Deposits (UDEPO) (www.iaea.org/publications/12345/world-distribution-of-uranium-deposits-udepo). It is primarily a geological (mineral deposit) database, with little emphasis given to the economic aspects or implications of uranium ore bodies. It has several specific purposes, the primary one being to provide insights into uranium mineralisation. It is also used for the evaluation of regional-scale resource potential as well as related modelling and assessment methods.

UDEPO consists of uranium-bearing occurrences for which a resource estimate is (or was) available. They are classified into 15 main types and 50 subtypes according to the IAEA uranium deposit-type classification system (see IAEA, 2018b), several of which are considered to be largely subeconomic at the present time (these are dominated by low-grade unconventional deposit types, such as black shale deposits). For a given deposit, the maximum resource publicly reported is recorded. It is commonly an estimate calculated using the lowest cut-off grade, without any mining and processing constraints, and/or including all low-reliability mineralisation inferred. In rare cases, remaining resources or production estimates are given where they are the only known amounts available, but in general the resources given are the largest known initial resources. In addition, in some instances, a deposit in UDEPO may represent an ore body, or one of two or more mines exploiting a single larger ore body, or a mining district consisting of multiple ore bodies and mines that has not been disaggregated.

For the sake of completeness, UDEPO also contains many historic resources that do not comply with modern resource estimating procedures, or that utilise a variety of estimation techniques. Moreover, particularly in the case of unconventional resources, where formal resource estimates are rare, Secretariat estimates are given using minimal data. Secretariat estimates are also given for deposits that have not yet undergone formal ore delineation analyses, and may never be developed for economic reasons, such as low tonnages or low grades. These deposits, however, are important for predicting (modelling) the location and amount of undiscovered uranium resources at regional scales, and hence included in UDEPO.

It is important to note that the Red Book and UDEPO define "unconventional resources" somewhat differently. For the Red Book, unconventional resources are "resources from which uranium is only recoverable as a minor by-product, such as uranium associated with phosphate rocks, non-ferrous ores, porphyry copper, carbonatite, black shale and coal-lignite". For UDEPO, which is first and foremost a geological database, there is no economic connotation, thus unconventional resources are those of low to very low grade that are not or cannot be mined just for uranium. For example, with respect to deposit types, the Red Book considers resources associated with phosphate, lignite coal, black shale, polymetallic Fe-oxide breccia complex (with the exception of the Olympic Dam uranium by-product deposit in Australia), and a subtype of intrusive deposits (i.e. plutonic) to be unconventional. UDEPO considers resources associated with phosphate to be unconventional, and resources associated with lignite coal and black shale to be mostly unconventional, but with some notable exceptions to also be conventional (e.g. some "high grade" black shale deposits in Uzbekistan are considered conventional for UDEPO). Other discrepancies also exist. So, there is no simple one-to-one correspondence between unconventional resources reported in the Red Book and unconventional resources recorded in the UDEPO database.

Therefore, uranium resources recorded in UDEPO represent optimistic, maximum resource amounts that have been identified and entered into the database to date (there are certainly more deposits yet to be discovered). UDEPO should be used at an order-of-magnitude, aggregated, and global or continental scale. As such, deposit uranium resources and ore grades (where available) are provided only as ranges (e.g. 1-300 tU, 300-1 000 tU). Caution should be used when using UDEPO estimates or making comparisons with uranium resources reported in the Red Book. Further, on an individual basis, it is not recommended to use a deposit or small groups of deposits for economic representations or comparisons.

Given these caveats above, and using the UDEPO definition of "unconventional", the latest version of UDEPO (scheduled for release in late 2024), which has over 5 200 uranium deposits, reports about 61 million tU of unconventional resources in approximately 360 deposits (that have resource amounts recorded) located in 55 countries. Conversely, using the Red Book definition of "unconventional", UDEPO reports about 57 million tU in approximately 210 deposits (that have resource amounts recorded) in 53 countries. That represents a difference of 4 million tU, or 6.5%. As indicated above, these estimates of unconventional resources derived from UDEPO should be viewed with caution. A more reliable guide for unconventional resource totals of current economic interest can be found in recent editions of the Red Book.

This edition of the Red Book includes information for countries that: 1) have been preparing to mine or are mining unconventional uranium resources, and maintain well-defined deposits as part of their conventional mineral resource inventory; 2) have well-defined unconventional uranium resources, and have firm plans for mining; 3) have nuclear power aspirations but have not yet defined sufficient domestic conventional uranium resources, and are actively exploring unconventional resources; 4) have well-defined unconventional uranium resources that may be amenable to mining; and 5) have unconventional uranium resource targets in their early exploration programmes.

Countries preparing to mine or currently mining unconventional uranium resources, and maintaining well-defined deposits as part of their conventional mineral resource inventory:

- **Australia** – Considered an important by-product of copper and gold mining at Olympic Dam, substantial quantities of uranium have been produced for many years. The multi-metal Olympic Dam deposit is truly exceptional in size and uranium is routinely produced along with the primary targets of the mining operation, and is thus considered conventional by Australia.

- **India** – Carbonate deposits form the largest part of India's well-explored uranium resources, accounting for over 60% of recoverable RAR (more than 150 000 tU, cost range unassigned) and are considered conventional resources by India. Strata bound carbonates have provided feed for the Tummalapalle mill since 2017. India does not publish information on uranium production and details of the deposits being mined, so neither the grade of the deposits nor the total actual production from the mill are known. However, India reports the size of the mine and mill to be 3 000 tonnes per day (t/day) ore, with average recoveries of 60% (mining) and 70% (processing) for a nominal annual production capacity of 211 tU. An expansion to 4 500 t/day ore is planned.

- **Kazakhstan** – Although estimates are not made of Kazakhstan's unconventional uranium resources and other materials, the uranium contained in well-explored phosphate and lignite coal deposits is a small part of the total recoverable RAR and IR (<12% and <2% respectively) at the higher cost categories (<130 and <260 USD/kgU). The Balausa LLP is working on the Bala-Sauskandykskoye uranium-vanadium deposit by open pit methods, and about 0.7 tU has been mined and stockpiled as by-product to vanadium.

- **Russia** – Although only a small part of the country's resource endowment (<5% and <3% of RAR and IR respectively at the higher cost categories [<130 and <260 USD/kgU]), phosphates are considered conventional resources in Russia because uranium is the main commodity of interest.

- **South Africa** – A significant unconventional resource base in paleo-quartz-pebble conglomerates and derived tailings and coal-hosted deposits has been reported in recent Red Books, all of which could be sources of by-product uranium. Uranium is hosted primarily by coal (with minor amounts in the mudstones) in the Springbok Flats. In the 2016 edition of the Red Book, 70 775 tU in lignite and coal deposits were reported as inferred in situ conventional resources. This is a good example of a reclassification of resources from unconventional to conventional. This reclassification is subjective since there are some parts of the definition of these resource classes that are open to different interpretations. In addition, uranium production and resources from tailings are reported as conventional and in association with the paleo-quartz-pebble conglomerate deposit type.

  As reported in the 2011 edition of the Red Book, a field of manganiferous phosphate nodules was identified off the west and south-west coast of South Africa on the continental shelf. The nodules contain low grades of uranium and are currently considered uneconomic with respect to both phosphate and uranium extraction. Renewed interest in phosphate-hosted uranium deposits, however, may generate future investigation. These unconventional resources have been previously estimated to contain up to 180 000 tU.

- **Uzbekistan** – Several black shale-type uranium deposits were identified during the 1960s in the Auminzatau Mountains district. Although resources of individual deposits are relatively small and low grade (0.02 to 0.13% U; averaging 0.05% U), uranium resources in well-explored black shales amount to approximately 14% and 42% of total RAR and IR respectively at the highest cost (<260 USD/kgU) category. Following a substantial write-down of high-cost black shale resources as reported in this edition, black shale deposits in Uzbekistan are estimated to contain close to 12 000 tU of identified recoverable uranium resources.

  In August 2009, GoscomGeology (Uzbekistan's State Geology and Mineral Resources Committee) and the China Guangdong Nuclear Uranium Corp. (CGN-URC) set up a 50%-50% uranium exploration joint venture to focus on uranium extraction from black shale deposits in the Boztau area of the Central Kyzylkum Desert in the Navoi region, where approximately 5 500 tU resources have been reported. From 2011 to 2013, CGN-URC was to develop technology for producing uranium and vanadium from these deposits, but no activities have been reported since that time. Given complicated processing technology and high projected costs, development of Uzbekistan's black shale deposits has been indefinitely delayed.

Countries with well-defined unconventional uranium resources and firm plans for mining:

- **Brazil** – The Santa Quitéria phosphate/uranium project, an INB-Brazilian fertiliser producer partnership agreement, remains under development (note that, while according to Red Book standards Santa Quitéria is categorised as an unconventional resource, Brazil categorises it as a conventional resource because uranium is considered an important by-product, not a minor by-product; see the Brazil country report and appendix 3). The deposit is estimated to contain over 50 000 tU recoverable RAR available at an incremental cost of <USD 40/kgU, approximately 45% of the country's well-explored uranium endowment. Santa Quitéria's phosphates are also higher in uranium grade (0.08% U) than most phosphate deposits. At full production, the Santa Quitéria Project could produce close to 1 950 tU/yr.

  The licensing of the Santa Quitéria phosphate/uranium project is split into a non-nuclear part, involving milling and phosphate production, and a nuclear part, involving uranium concentrate production. In 2012, the project operators applied for a construction licence that was denied in 2018. INB and its partner subsequently developed a new model for the project and a revised licence application was filed in 2020. The preliminary environmental licensing decision is expected at the end of 2024 and the operation is now scheduled to begin in 2027.

- **Denmark (Greenland)** – The Ilimaussaq igneous complex of South Greenland hosts the REE-U-Zn-F Kvanefjeld deposit. It is a high-tonnage, low-grade uranium-enriched layered intrusive deposit, with concentrations of around 300 ppm U (0.03% U). Uranium was planned to be mined (see below) as a by-product from a proposed open-pit mine, accounting for about 5% of total revenue from the mining. Kvanefjeld is the only uranium deposit or occurrence in Greenland with reasonably assured uranium resources. The supply cost for uranium was expected to be very low, as most of the costs were to be borne by the production of REE, the primary mining target (Kvanefjeld is one of the largest REE deposits in the world). A uranium-specific supply cost of approximately USD 13/kgU (USD 5/lb U_3O_8) has been reported, which is incremental to the cost of the REE production.

  Kvanefjeld is estimated to contain over 50 000 tU recoverable RAR with more than 60 000 tU recoverable IR additionally related to the Kvanefjeld deposit and two other nearby zones. Recoverable uranium resources were calculated using the established and pilot plant tested recovery factor of approximately 50%.

  Development of the project has taken many years, in part related to issues associated with uranium mining in a jurisdiction that has never produced uranium, complicated by a previous ban on uranium mining, and the need for Greenland and Denmark to agree to all legislative and regulatory requirements for uranium mining and export. This was further complicated by the April 2021 election in Greenland that led to a change in government that passed a new law prohibiting exploration and exploitation of uranium as of December 2021. Passage of this new law led the project developer, Energy Transition Minerals Ltd (formerly

Greenland Minerals Ltd), to request arbitration proceedings with the governments of Greenland and Denmark concerning the impact of new legislation on its exploration licence for the Kvanefjeld REE zinc and uranium project under development in southern Greenland. On 20 July 2023, Energy Transition Minerals announced it had filed a statement of claim with an arbitral tribunal, on the matter of this dispute (Energy Transition Minerals, 2023).

- **Finland** – A 2022 resource update from project operator Terrafame Oy estimated in situ unconventional resources of approximately 19 200 tU RAR and about 7 000 tU IR for the Talvivaara black schist-hosted Ni-Zn-Cu-Co deposit. The Talvivaara deposit is hosted by metamorphosed black shales in the Kainuu Schist Belt. It is a low-grade, large-tonnage deposit averaging 0.26% Ni, 0.53% Zn, 0.14% Cu, 0.02% Co and 0.0018% U. Given the very low uranium grade, and that uranium is a minor by-product, the Talvivaara resources have so far not been included with the conventional uranium resources reported by Finland.

  Between 2010 and 2015, Talvivaara Sotkamo Oy prepared for uranium recovery as a by-product from the Talvivaara deposit in Sotkamo, eastern Finland. In 2012, the Finnish government granted a uranium extraction licence to Talvivaara Sotkamo Oy. However, in 2013 the Supreme Administrative Court returned the licence to the Finnish government for reassessment due to several changes in the operations after the licensing decision, including a corporate reorganisation. Talvivaara Sotkamo Oy then filed for bankruptcy in 2014. The state-owned company Terrafame Oy acquired the operations and assets of Talvivaara Sotkamo Oy from its bankruptcy estate in 2015, and as of 1 January 2023, was carrying on the mining operations in Sotkamo.

  In 2017, Terrafame Oy applied to the Finnish government for a licence to recover uranium as a by-product at Terrafame's mine in Sotkamo, in accordance with the nuclear energy legislation. In February 2020, the Finnish government granted a uranium extraction licence to Terrafame, a decision that was subsequently appealed. In June 2021, the Supreme Administrative Court ruled the licence to be legally valid. The mine site in Sotkamo had an almost fully completed uranium solvent extraction plant from the time of Terrafame's predecessor, Talvivaara Sotkamo Oy. In December 2022, Terrafame commenced preparations (total investment of around EUR 20 million) for the extraction of uranium, with startup of the uranium recovery plant expected in 2024, and full capacity of about 200 tU per year expected by 2026, after the ramp-up phase.

  Following inspections at the uranium recovery plant and a review of written materials submitted by Terrafame, Finland's Radiation and Nuclear Safety Authority (STUK) issued a decision on 17 June 2024 stating that the safety requirements set for the use of the facility will be met if the documented procedures are followed. That decision cleared the way for Terrafame to commission the facility (WNA, 2024a).

Countries with nuclear power aspirations that have not yet defined sufficient conventional uranium resources, and are actively exploring unconventional resources:

- **Jordan** – In 1982, a feasibility study for uranium extraction from phosphoric acid was completed by a German engineering company on behalf of the Jordan Fertiliser Industry Company, leading to the subsequent purchase by the Jordan Phosphate Mines Company. One of the extraction processes evaluated was originally found to be economically feasible, but as uranium prices dropped in the 1990s, the process became uneconomic, and construction of an extraction plant was deferred.

  After SNC-Lavalin performed a technological and economic feasibility study for the recovery of uranium from the phosphoric acid produced at the Aqaba Fertilizer Complex, the economics of the project improved and JUMCO has been conducting research to develop optimised extraction parameters, with promising results. Jordan's phosphate deposits are estimated to contain some 100 000 tU in situ but, due to limited exploration, are not yet considered classified resources.

- **Malawi** – In the Kanyika Niobium Project held by Globe Metals, uranium is an important by-product in the complex niobium and tantalum ore in a pegmatite quartz vein, hosted in Proterozoic felsic schists. Niobium and tantalum products would be produced with uranium as by-product. As of December 2012, total in situ resources amount to 68.3 Mt of ore at an average grade of 0.28% Nb_2O_5, 0.0135% Ta_2O_5 and 0.0067% U (4 550 tU), contributing 2 200 tU RAR and 500 tU IR to Malawi reported recoverable uranium resources at the highest cost (<260 USD/kgU) category.

  Globe Metals & Mining submitted an environmental impact assessment (EIA) for the Kanyika Niobium Project for public review in May 2012. In January 2019, Globe Metals announced that it had finalised the feasibility study, including revision of the mineral resource estimates, mining, metallurgical studies, processing, engineering design and infrastructural support. As of January 2023, Globe Metals and Mining had been issued with a Mining Licence and the Mine Development Agreement (MDA) was signed thereafter.

- **Saudi Arabia** – An exploration programme was initiated in 2017 to develop domestic mineral resources in line with Saudi Arabia's Vision 2030 goal to have a mining sector that contributes to the national economy and to develop domestic uranium resources to fuel its planned nuclear power programme. From 2017 to 2019, the first phase of uranium (U) and thorium (Th) exploration was conducted. Geological, geochemical, and geophysical surveys, as well as trenches, were completed and nine subareas were tested by an extensive drill programme. In 2022, another exploration programme was implemented to follow up on the results of the 2017-2019 work. The first phase was carried out with modern exploration techniques and brought the database up to modern levels. The second phase continued testing many subareas. As a result of this exploration, three uranium deposits and prospects have been reported as in situ unconventional resources.

  The Ghurayyah deposit is a granite intrusion with polymetallic mineralisation, including uranium, thorium, niobium, tantalum, zirconium, hafnium, tin, and REEs, with U considered a co-product of the Ta and Nb. The mineral resource estimate includes 49 000 tU inferred resources. A second intrusive plutonic deposit, the Jabal Sayid U-Th prospect, is also enriched in rare earth elements (REE) and transition metals such as Nb, Ta and Zr. The JORC (2012) mineral resource estimate includes 8 000 tU indicated and 4 400 tU inferred resources.

  The phosphorite deposits within the sediments of the Sirhan-Turayf shelf in northern Saudi Arabia form part of the large North African Middle East Tethyan phosphate province, which stretches from Morocco to Iraq. The Thaniyat phosphorite member at the base of Jalamid Formation of late Cretaceous (Campanian) to Paleocene age, was deposited in a shallow marine shelf to intertidal zone. The uraniferous phosphorite layer extends continuously within a target area of about 70 km^2 and has an average thickness of 1.8 m, with an average density of 2.0 g/cm^3. The Thaniyat Turayf prospect inferred in situ resources are estimated at 14 500 tU.

  The unconventional resources for the Ghurayyah deposit and Jabal Sayid prospect are included in the resource tables in this edition of the Red Book, reflecting the extensive exploration programme, resource estimates made to modern standards and uranium expected to be a co-product. Conversely, Thaniyat Turayf prospect resources are not included as uranium is expected to be a by-product and is not currently considered economic. As a result, recoverable resources of 6 000 tU RAR and 40 000 tU IR are included for Saudi Arabia.

Countries with well-defined unconventional uranium resources that may be amenable to mining:

- **Central African Republic** – While the Bakouma uranium deposit is associated with phosphates and the country does not report unconventional resources, it is classified as a conventional deposit because of relatively high uranium grades (0.15-0.30% U). In its 2022 Annual Report, Orano (the current owner of the project) reports in situ IR of 36 475 tU at an average grade of 0.20% U (resource evaluation completed in 2020), resulting in approximately 29 000 tU recoverable IR at the highest cost (<260 USD/kgU) category.

Start-up of the Bakouma pilot project was initially planned for 2010, with open-pit mining planned initially for 1 200 tU/yr and 2 000 tU/yr at full capacity. The uranium mining project was, however, suspended at the end of 2011 for one to two years due to low uranium prices and the need for further research on the metallurgy. In June 2012, gunmen attacked the Bakouma project site, and since then all activities have been suspended.

- **Chile** – Identified unconventional recoverable RAR amount to 1 169 tU (<USD 260/kgU), including 415 tU in phosphates, while undiscovered unconventional resources are estimated to total 5 458 tU.

  The production of copper oxide minerals has quadrupled in Chile over the last decade and the copper industry, particularly large-scale mining, has strategic (sub-economic) uranium potential in the large volumes of copper oxide leaching solutions that could be recovered. These resources are assigned an in situ potential of 1 000 tU. However, no background studies have been performed to confirm these estimates.

  Over the last decade, private firms have explored 12 "exotic copper" deposits in Chile, essentially paleochannels filled with gravel, mineralised with copper silicates, oxides and sulphates primarily from the natural leaching of porphyry copper deposits. These mineralised bodies contain variable uranium contents ranging between 7 to 116 ppm (0.007 to 0.016% U). The leaching solutions in the plants that treat these copper oxide minerals contain up to 10 ppm U that is technically recoverable using ion-exchange resins at a likely production cost of over USD 80/kgU. A pilot-level trial, conducted between 1976 and 1979, obtained about 0.5 tU from copper-rich solutions containing 10 to 15 ppm U (0.001 to 0.0015% U).

  There has been no experience in recovering uranium from phosphorites in Chile. The only deposit currently being worked is Bahía Inglesa in Atacama region, which produces a solid phosphate concentrate used directly as fertiliser. In 2001, Compañía Minera de Fosfatos Naturales Ltda. (Bifox Ltda.) began producing phosphoric acid from this deposit, opening the possibility of recovering uranium from the acid.

Countries with unconventional uranium resource targets in their early exploration programmes:

- **Ecuador** – Early-stage exploration activities included the examination by the Universidad Técnica Particular de Loja (UTPL) of the Puyango sedimentary deposit (V, Zn, U, Cu, Pb), where tabular-shaped uranium mineralisation is hosted by the Early Cretaceous Puyango Unit, which consists of black limestone, bituminous limestone and calcareous sandstone. This deposit may be a potential source of U, where this metal may be recovered as minor co- or by-product to other metals. As of 2023, the Geophysics and Geochemistry sectors of the Department of Geosciences of the UTPL estimated speculative resources of the Puyango deposit to contain 4 300 tU.

- **Egypt** – Egyptian phosphate deposits represent one of the more promising unconventional uranium resources, with estimates suggesting that they amount to about 700 million tonnes, with uranium content ranging between 50 ppm and 200 ppm (0.005-0.02% U). However, no reliable estimate of the uranium resources has been made since 2008, when it was reported in the 2009 Red Book that Egyptian phosphate deposits may contain up to 42 000 tU.

  Black sands are considered the second most important unconventional source of uranium in Egypt and are estimated to contain about 6 million tonnes of radiogenic and rare earth minerals. In one area, the monazite (one of the black sand minerals) contains up to 0.5% U and 6% Th, as well as rare earth elements (REE).

  From 1999 to 2003, Egypt worked on the development of a semi-pilot plant for the extraction of uranium from phosphoric acid, but unexpected technical problems delayed uranium production. The project was suspended due to challenges related to the low uranium content of the phosphoric acid and difficulties in the extraction cycle. The semi-pilot plant has since been converted to produce phosphoric acid for agricultural, food and other domestic purposes, and the country has returned to the development of conventional sources of uranium.

- **Indonesia** – The uranium resource potential in the Bangka and Belitung areas includes placer deposits of monazite within a tin deposit. Monazite, a uranium/thorium phosphate mineral, was deposited in the alluvium and has mostly accumulated as a tailings by-product material of tin mining. The total resource from deposits in Bangka and Belitung islands amounts to 25 236 tU. In Singkep, the uranium potential is in lateritic soil, with a resource of 1 100 tU. In Semelangan (West Kalimantan), uranium is present in bauxite lateritic deposits, with resources of 624 tU. In Katingan (Central Kalimantan), monazite is present as a by-product material of zircon mining, with resources of 485 tU. Total unconventional monazite resources are therefore estimated to amount to 27 445 tU, with about 100 000 tU contained in Indonesian phosphate deposits. However, no effort has yet been made to develop uranium extraction technologies from these unconventional deposits.

- **Mexico** – The San Juan de la Costa phosphorite deposit is estimated to contain significant uranium resources, but no systematic evaluation of the contained uranium or the optimal processing method to extract the uranium has been conducted.

- **Nepal** – Based on early exploration efforts, the most important phosphate occurrence in Nepal is the Baitadi Carbonate Formation in the Lesser Himalaya of Far East Nepal. The phosphate-rich horizon of middle Proterozoic age is confined to the stromatolitic, Massive Cherty Dolomite Member which extends laterally for more than 25 km and has a thickness varying from a few metres to 18 m. The P_2O_5 content varies from 10 to 32 wt%. Neither the average phosphate nor uranium content of the occurrence has been determined, prohibiting the evaluation of the economic potential of the Baitadi Formation.

  Coal occurrences in Nepal are found in four stratigraphic horizons: Quaternary lignite of the Kathmandu valley, Siwalik coal of the Sub Himalayas/Churia Range, Eocene coal of the Western and mid-Western Nepal, and Gondwana coal. Although the uranium content of these horizons is unknown, the lignite horizon in the Kathmandu valley may have significant uranium contents as indicated by the presence of uranium showings in the gneissic muscovite-tourmaline granites and pegmatites north of Kathmandu city. Only the Quaternary lignite of the Kathmandu valley and the Eocene coal has been mined for domestic needs and as these resources are quite limited, even if they were relatively rich in U, its recovery would not be of economic interest.

  Black shales also occur in various parts of Nepal, but they are generally metamorphosed and deformed, and their uranium content is not known. The probability of having significant uranium resources in this type of lithology is limited given the present state of knowledge.

- **Peru** – Unconventional resources in Peru account for a minimum of 41 600 tU in situ, which include phosphates (16 000 tU), granites with high uranium content (20 000 tU) and hydrothermal deposits (5 600 tU).

  In 2010, the Vale company (formerly Vale do Rio Doce) of Brazil started exploitation of the Bayóvar phosphate deposit through its local subsidiary, Miski Mayo SRL. Before the start of the operation the company planned for the possibility of uranium recovery during phosphate production, but these plans have not yet been implemented.

- **Sri Lanka** – Sri Lanka reported in the Red Book 2020 that a current focus of its early work on national fissile material development was to identify radioactive mineralisation in the country with an emphasis on the extraction of uranium from unconventional sources. Through IAEA technical co-operation projects, a substantial amount of technical assistance was provided to Sri Lanka for the discovery of economic uranium and thorium mineralisation, but no resource determinations have been reported.

  Varying concentrations of heavy mineral sands (ilmenite, rutile, garnet, zircon, monazite) occur in the beach sands of the country. However, only certain locations have concentrations that are deemed sufficient for potential economic exploitation. From 2016 to 2019, four new areas of anomalous radioactivity were identified in the coastal stretch from Talaimannar to Galle. Fieldwork from Talaimannar to Kudiramalai was completed in 2017 and continued to Puttalam to the end of 2019. Follow-up work is anticipated. Monazite-rich beach sand placer deposits are known to occur along the coastal stretch covering the

Aluthgama-Beruwala-Induruwa southwest sector and the Kudiramalai northwest sector of the island. Notable amounts of thorianite-rich sands are reported in beach sands in the Beruwala-Induruwa areas. Monazite and thorianite sands are reported to occur in lesser concentrations within the Pulmuddai, Thirukkovil and Galle mineral sand occurrences. Urano-thorianite deposits also occur in river placers (southwest). Monazite concentrations of 0.3-1% are known to occur in approximately 75 million tonnes of inland REE deposits (northwest). Monazite-bearing beach mineral samples collected from the east coast Pulmoddai Deposit were processed to separate monazite and analyse for trace elements by AEB laboratories. The analysis revealed values up to 23% Ce in monazite. Geophysical surveys for near offshore minerals in southwest Sri Lanka identified an estimated volume of sediments of 170 million tonnes in 11 potential basins to a depth of 2 metres. Monazite concentrations of up to 1.1% were estimated based on gamma-ray spectrometry analysis.

- **Viet Nam** – Uranium exploration activities associated with rare earth element ores (Dong Pao bastnaesites, Namxe bastnaesite, YenPhu xenotime and beach sand monazite, etc.) are being conducted, but resource determinations stemming from these efforts have yet to be reported. Research focused on the recovery of thorium and uranium from rare earth concentrates has been undertaken, and a continuous counter-current extraction process for the simultaneous recovery of thorium and uranium from the Yen Phu rare earth concentrate leach solutions was developed by the Institute for Technology of Radioactive and Rare Elements. Results show that the extraction method is suitable for the recovery of thorium and uranium from rare earth concentrate with thorium and uranium purities of greater than 99%.

In summary, unconventional uranium deposits remain an important part of the global uranium endowment, and in some countries, mining is already underway or planned. However, for many of the unconventional deposits discussed above, sufficient exploration has not yet been conducted to develop high confidence resource estimates, although costs may be somewhat more economically favourable for commercial production in today's market (i.e. when in January 2024 the uranium spot price rose to USD 106/lb U_3O_8, and since March through August of 2024 has averaged between USD 80 to 90/lb U_3O_8). Moreover, licensing for mining some of these deposits has proven challenging, particularly in jurisdictions that have not recently or have never mined uranium, since licensing involves both radiological (nuclear) and non-radiological components. Development of mines that extract uranium as a co- or by-product also depends on the primary mining target(s), markets, and the fortunes of the companies conducting the mining, which may have little experience with uranium. However, if uranium demand and prices continue to rise to near historic highs, or if demand for REE, lithium and other co-occurring targets of interest rises sufficiently, unconventional uranium resources could once again contribute more significant quantities of uranium to the global market.

Seawater

The world's oceans have long been regarded as a possible source of uranium because of the large amount of contained uranium (over 4 billion tU). However, because seawater contains such low concentrations of uranium (3-4 parts per billion), developing a cost-effective method of extraction remains a challenge.

Research on uranium recovery from seawater was carried out initially from the 1950s to the 1980s in Germany, Italy, the United Kingdom and the United States. From 1981 to 1988, the Agency for Natural Resources and Energy, the Ministry of International Trade and Industry, and the Metal Mining Agency of Japan teamed up to operate an experimental marine uranium adsorption plant based on TiO_2 adsorbents.

A renewal of interest in the last 15 years led to a special issue of the Journal of Industrial and Engineering Chemical Research devoted to the recovery of uranium from seawater (ACS, 2016). One of the leading methods considered for extracting uranium from seawater at that time involved infusing fibres made of polyethylene, a common plastic, with amidoxime, a chemical group pioneered by Japanese researchers in the 1980s that attracts uranium dioxide and binds it to the fibre (Kuo et al., 2016; Abney et al., 2017). Researchers at the Pacific Northwest National

Laboratory and LCW Supercritical Technologies subsequently produced five grams of yellowcake using this method (PNNL, 2018). This and other developments are estimated to have reduced the cost of uranium extraction from seawater by a factor of three to four based on laboratory experience (CNA, 2016; PNNL, 2016).

Researchers at Stanford University subsequently developed an electrochemical method to capture uranium from seawater, demonstrating a nine-fold increase in uranium capacity, a four-fold faster rate of uranium accumulation, and favourable reusability compared to the best adsorbent materials developed for the same purpose (Abate, 2017; Liu et al., 2017). The application of carbon nanotube technology to extract uranium from seawater was also investigated, owing to the high surface area of the material for adsorption and its rapid ion transport capability (Ahmad et al., 2020; Zhao et al., 2019). However, finding a simple method to prepare the new carbon structure proved challenging.

To overcome bio-fouling on wet sorbent surfaces, a guanidine and amidoxime polypropylene non-woven fabric was developed that showed improved selectivity and anti-fouling performance, thereby accelerating the rate of uranium sorption (Zhang et al., 2018). Poly phenylacetylene conductive chains incorporated into the porous adsorbent channels as a pathway for ion transportation by electrically driven motility achieved a record uptake capacity of uranium in a 90-day test using natural seawater (Wang et al., 2020), although low uranium seawater concentrations and interfering ions reduced overall efficiency. “Pre-enriching” uranium content in seawater was experimentally achieved through development of a glycerine cross-linked graphene oxide-based membrane that effectively captured co-existing ions (K^+, Na^+, Ca^{2+} and Mg^{2+}) while rejecting approximately 100% of the uranium (Chu et al., 2022).

A reusable bioinspired film with extremely small pores that adsorbs uranyl ions rapidly through hierarchical (increasingly smaller) porous channels increased adsorption capacity up to 20 times (Zhang, 2021). Importantly, the film can be cleaned with HCl for reuse (Sparkes, 2021). Calcium carbonate mesospheres synthesised by nanoemulsion to produce interconnected mesospheres of high surface area showed high rates of uranium adsorption that was easily recovered after adsorption by dissolution of the mesospheres in acid (Dongsheng et al., 2022). Inspired by the high uranium content in natural marine carapaces, tests using the crystalline calcium carbonate in ground crab carapace achieved high uranium extraction capacities (Feng et. al., 2022). These and other techniques have been recently investigated in what has become an active area of research, particularly in China. In 2019, China National Nuclear Corporation led the establishment of the Chinese Technology Innovation Alliance of Uranium Extraction From Seawater with 13 universities and research institutes, followed in 2021 by the establishment of the Council of Chinese Technology Innovation Alliance of Uranium Extraction From Seawater.

While the above studies resulted in an improvement in both the capture and recovery of uranium from seawater, it is important to note that these are by and large laboratory tests only. Development of an industrial scale method of extracting uranium from seawater, even with the bench scale improvements recently demonstrated, will need to overcome several challenges, including the vast amounts of seawater that would need to be processed, ecological concerns potentially arising from such a process, and production costs that remain significantly above market prices. With the lack of large-scale marine open-water tests, problems with bio-fouling, and such low concentrations of uranium (3-4 parts per billion), the cost of recovery remains high at this time and is a challenge for commercial extraction of uranium from seawater.

Uranium exploration

Non-domestic

Only four countries (China, France, Japan and Russia) have reported non-domestic exploration and development expenditures since 2008 (Table 1.14). Whereas China did not report in the last edition, it has again reported in this edition, resulting in a data gap only for 2020. Non-domestic expenditures are a subset of domestic (i.e. within country) expenditures as the totals reported on a country-by-country basis are a total of expenditures from both domestic and foreign sources within each country. The recent trend in non-domestic exploration and development expenditures is depicted in Figure 1.4. During this reporting period, non-domestic expenditures declined from USD 56.8 million in 2019 to USD 45.7 million in 2020 (albeit excluding expenditures by China), increased to USD 81.2 million in 2021 and declined to USD 66.8 million in 2022. They are expected to increase to USD 78.8 million in 2023 (preliminary data). On an individual country basis, non-domestic exploration and development expenditures reported by France and Japan have each been relatively consistent for some time, in the case of France at around the USD 30 million range since at least 2016, and for Japan at USD 2 to 3 million since 2017. Expenditures by China trended down dramatically from 2016 (Husab mine development) to 2019 and annual expenditures appear to be in the USD 20 to 25 million range since. Expenditures by Russia, on the other hand, increased considerably from very low levels in 2017 and 2018 to USD 25 million in 2021 as exploration and mine development activities continued in Namibia, Kazakhstan and Tanzania, raising non-domestic expenditures by Russia to levels not seen since 2012.

Several countries do not report non-domestic expenditures or have not reported these expenditures recently, and thus the data are incomplete. Private companies in Australia and Canada are known to make non-domestic investments and are likely leading investors in foreign uranium exploration and development activities, but no information has been reported by these governments for the past several years.

Table 1.14. **Non-domestic uranium exploration and development expenditures***

(as of 1 January 2023, USD thousands in year of expenditures, for countries listed)

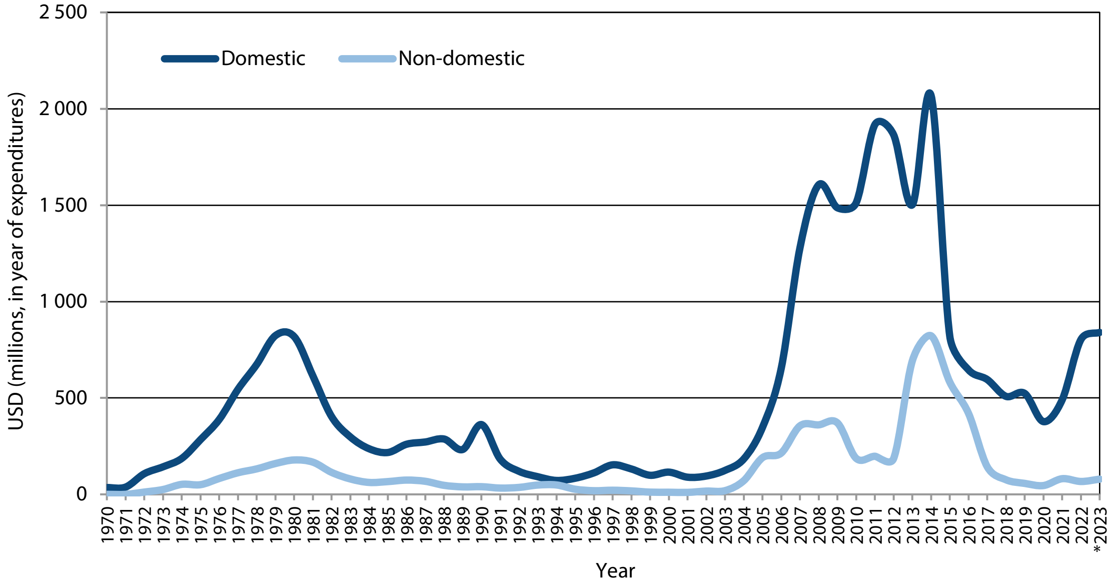
Country	Pre-2016	2016	2017	2018	2019	2020	2021	2022	2023 preliminary
Australia	NA	NA	NA	NA	NA	NA	NA	NA	NA
Belgium	4 500	0	0	0	0	0	0	0	0
Canada	355 644	NA	NA	NA	NA	NA	NA	NA	NA
China	2 732 790	378 010	108 110	41 480	23 580	NA	20 740	20 150	26 960
France	1 577 146	30 736	30 765	30 240	26 400	31 355	32 220	25 290	26 287
Germany	403 158	0	0	0	0	0	0	0	0
Japan	452 810	5 089	2 245	2 239	3 228	3 238	2 962	2 408	2 947
Korea	NA	NA	NA	NA	NA	NA	NA	NA	NA
Russia	NA	6 100	1 800	1 700	3 610	11 100	25 300	19 000	22 600
Spain	20 400	0	0	0	0	0	0	0	0
Switzerland	29 679	0	0	0	0	0	0	0	0
United Kingdom	61 263	0	0	0	0	0	0	0	0
United States	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total	**5 637 390**	**419 935**	**142 920**	**75 659**	**56 818**	**45 693**	**81 221**	**66 847**	**78 794**

* Domestic exploration and development expenditures represent the total expenditure from domestic and foreign sources within each country. Expenditures abroad are thus a subset of domestic expenditures. Unless otherwise noted, all expenditures made by majority government-owned companies and their subsidiaries are considered expenditures by government.

NA = Data not available.

Figure 1.4. **Trends in uranium exploration and development expenditures**

(USD millions in year of expenditures)



Note that expenditures for some significant producing countries were not available at the time of data collection and writing for this edition. Data prior to the early 1970s is incomplete or aggregated across multiple prior years, and thus cannot be properly represented in this chart.

* Preliminary data.

Domestic

Twenty-seven countries reported domestic exploration and mine development expenditures for this edition (Table 1.15). The totals reported are on a country-by-country basis and represent the total expenditures from both domestic and foreign sources within each country. The recent trend in domestic exploration and development expenditures is depicted in Figure 1.4. The overall picture is substantially changed from the previous recent editions, as steadily declining expenditures from USD 876 million in 2015 to USD 377 million in 2020 reversed dramatically and increased to USD 803 million in 2022, a 113% increase from the 2020 low. Expenditures were expected to increase further to USD 840 million in 2023 and may likely be higher as some countries did not provide preliminary expenditure data, most notably the United States, where activity has been strong. Decreased expenditures from 2015 to 2020 were related to persistently low uranium prices that slowed exploration and mine development projects, and conversely, increased expenditures since 2020 were related to rapidly rising uranium prices.

Of the twenty-seven countries reporting exploration and mine development expenditures for 2021, 2022 and estimated expenditures for 2023 (seven of these countries reporting only for 2021 and 2022), the total expenditures over this three-year period amounts to over USD 2.1 billion. Canada (USD 722 million, or 34% of the total) led the way, followed by China (USD 528 million or 25%), Russia (USD 220 million) and India (USD 204 million) each at about 10%, Namibia (USD 186 million, 9%), and Uzbekistan (USD 63 million, 3%). These six countries together accounted for 90% of the total exploration and development expenditures over this period. The next six countries in order of expenditure, Australia (USD 57 million), United States (USD 42 million, excluding 2023), Saudi Arabia (USD 38 million), Kazakhstan (USD 19 million, excluding 2023), Niger (USD 16 million, excluding 2023) and Argentina (USD 16 million) together accounted for another 8% of the total. Expenditures in Canada have consistently been at the top, demonstrating that the Athabasca Basin in Saskatchewan, Canada remains the prime destination for uranium exploration.

Table 1.15. **Domestic (industry and government) uranium exploration and development expenditures***

(as of 1 January 2023, USD thousands in year of expenditures, for countries listed)

Country	Pre-2016	2016	2017	2018	2019	2020	2021	2022	2023 preliminary
Algeria	NA	0	0	0	0	0	0	0	0
Argentina	125 777	4 142	5 092	2 376	1 496	1 089	4 971	7 815	2 971
Australia	1 701 120	17 295	15 115	9 044	7 138	4 592	9 304	15 059	16 700
Bangladesh	453	NA	NA	6	6	7	5	5	7
Belgium	2 487	0	0	0	0	0	NA	NA	NA
Bolivia	9 343	NA	NA	NA	NA	0	0	0	0
Botswana**	12 629	NA	NA	NA	NA	NA	NA	NA	NA
Brazil	189 956	1 348	574	0	0	0	0	0	1 253
Cameroon	1 282	NA	NA	NA	NA	NA	NA	NA	NA
Canada	7 688 313	319 785	253 435	198 496	210 687	112 409	164 639	256 031	300 986
Central African Rep.	21 800	NA	NA	NA	NA	0	0	0	0
Chile	9 618	NA	NA	NA	NA	0	0	0	0
China	1 089 000	128 000	125 000	120 000	154 000	124 000	124 000	202 000	202 000
Colombia	25 946	NA	NA	NA	NA	NA	NA	NA	NA
Costa Rica	364	NA	NA	NA	NA	NA	NA	NA	NA
Cuba	972	NA	NA	NA	NA	NA	NA	NA	NA
Czechia[(a)]	317 160	514	17	9	197	8	56	21	46
Denmark/Greenland	6 405	NA	NA	NA	NA	NA	NA	NA	NA
Ecuador	1 945	NA	NA	NA	NA	NA	NA	NA	NA
Egypt	117 271	28	28	84	90	186	192	160	97
Ethiopia	22	NA	NA	NA	NA	NA	NA	NA	NA
Finland	126 227	0	0	0	0	0	0	0	0
France	907 240	0	0	0	0	0	0	0	0
Gabon	102 443	NA	NA	NA	NA	NA	NA	NA	NA
Germany[(b)]	2 002 789	0	0	0	0	0	0	0	0
Ghana	90	NA	NA	NA	NA	0	0	0	0
Greece	17 547	NA	NA	NA	NA	NA	NA	NA	NA
Guatemala	610	NA	NA	NA	NA	NA	NA	NA	NA
Hungary	4 051	NA	NA	NA	NA	NA	NA	NA	NA
India	741 489	52 156	63 732	60 852	66 165	47 805	62 205	66 815	74 912
Indonesia	18 602	233	121	81	246	42	25	169	53
Iran, Islamic Rep. of	324 135	17 320	39 221	13 567	8	NA	NA	NA	NA
Ireland	6 200	NA	NA	NA	NA	NA	NA	NA	NA
Italy	75 060	0	0	0	0	NA	NA	NA	NA
Jamaica	30	NA	NA	NA	NA	NA	NA	NA	NA
Japan	16 697	0	0	0	0	0	0	0	0
Jordan	42 376	2 886	3 531	4 831	3 531	2 458	3 602	2 881	3 136
Kazakhstan	624 725	23 935	36 620	37 252	18 779	13 367	9 767	9 489	NA
Korea	17 866	NA	NA	NA	NA	NA	NA	NA	NA
Lesotho	21	NA	NA	NA	NA	NA	NA	NA	NA
Madagascar	5 239	13	24	NA	23	0	30	32	NA
Malawi	0	NA	NA	NA	NA	NA	NA	NA	NA
Malaysia	10 478	NA	NA	NA	NA	NA	NA	NA	NA
Mali	58 983	387	390	354	298	30	1 157	1 220	NA
Mexico[(c)]	35 512	1 237	886	1 204	871	660	810	630	1 000
Mongolia	200 789	6 600	7 172	4 857	158	71	74	4 229	NA

Continued on next page.

Table 1.15. **Domestic (industry and government) uranium exploration and development expenditures*** *(cont'd)*

(as of 1 January 2023, USD thousands in year of expenditures, for countries listed)

Country	Pre-2016	2016	2017	2018	2019	2020	2021	2022	2023 preliminary
Morocco	2 752	NA	NA	NA	NA	NA	NA	NA	NA
Namibia	1 395 578	8 253	3 310	3 718	5 960	11 068	25 329	86 079	74 607
Niger[(d)]	1 048 927	4 504	322	6 937	2 912	2 527	12 743	3 527	NA
Nigeria	6 950	NA	NA	NA	NA	NA	NA	NA	NA
Norway	3 180	0	0	0	0	NA	NA	NA	NA
Paraguay	27 050	0	NA	NA	250	250	250	0	0
Peru	4 776	NA	NA	NA	NA	NA	NA	NA	NA
Philippines	3 492	NA	NA	NA	NA	NA	NA	NA	NA
Poland	229	NA	NA	NA	NA	0	0	0	0
Portugal	17 637	NA	NA	NA	NA	0	0	0	0
Romania	10 060	NA	NA	NA	NA	NA	NA	NA	NA
Russia	1 034 503	18 907	9 980	8 336	8 782	13 809	25 569	89 662	104 519
Rwanda	1 505	NA	NA	NA	NA	NA	NA	NA	NA
Saudi Arabia[(e)]	0	0	9 000	16 000	9 000	3 000	9 889	9 889	18 355
Slovak Republic	408	NA	NA	0	0	NA	NA	NA	NA
Slovenia[(f)]	1 581	0	0	0	0	0	0	0	0
Somalia	10 000	NA	NA	NA	NA	NA	NA	NA	NA
South Africa[(g)]	304 336	NA	NA	NA	NA	NA	NA	NA	NA
Spain	217 296	1 160	1 180	908	893	284	447	252	355
Sri Lanka	43	NA	NA	NA	NA	NA	NA	NA	NA
Sudan	200	NA	NA	NA	NA	NA	NA	NA	NA
Sweden	47 900	NA	NA	NA	NA	NA	NA	NA	NA
Switzerland	3 359	0	0	0	0	0	NA	NA	NA
Syria	1 151	NA	NA	NA	NA	NA	NA	NA	NA
Tanzania	0	NA	NA	NA	NA	NA	NA	NA	NA
Thailand	11 299	NA	NA	NA	NA	0	0	0	0
Türkiye	42 158	223	768	2 987	14 245	7 288	4 200	3 315	NA
Ukraine	59 534	484	1 111	800	2 235	1 762	3 458	157	NA
United Kingdom	3 815	0	0	0	0	0	NA	NA	NA
United States[(h)]	3 689 113	34 700	16 600	15 000	15 000	18 700	15 300	26 200	NA
Uruguay	231	NA	NA	NA	NA	NA	NA	NA	NA
USSR	3 692 350	0	0	0	0	0	0	0	0
Uzbekistan	269 715	NA	NA	NA	NA	11 320	11 410	13 730	38 220
Viet Nam	19 858	1 794	1 540	NA	NA	NA	NA	NA	NA
Zambia[(i)]	9 732	NA	710	607	502	536	974	3 751	690
Zimbabwe	6 902	NA	NA	NA	NA	0	0	0	0
Total[(k)]	**28 608 682**	**645 904**	**595 479**	**508 305**	**523 472**	**377 268**	**490 405**	**803 118**	**839 906**

* Total exploration and development expenditures from both domestic and foreign sources in each country for the year. ** Secretariat estimate. NA = Data not available. (a) Includes USD 312 560 expended in Czechoslovakia (pre-1996). (b) Includes USD 1 905 920, spent in GDR between 1946 and 1990. (c) Government exploration expenditures only. (d) Partial exploration spending. Pan African and Global Atomic exploration spending only in 2018 and 2019, Global Atomic exploration spending only in 2020. Global Atomic and GoviEx exploration spending in 2021, GoviEx only exploration spending in 2022. (e) Secretariat estimate of annual distribution. from total spending reported in Country Report of USD 37 000 000 for 2017-2020, USD 19 778 580 for 2021-2022. (f) Includes expenditures in other parts of the former Yugoslavia. (g) Includes expenditures for both uranium and gold in the Witwatersrand Basin until 2012. (h) Red Book 2007 to 2022 included United States reclamation and restoration expenditures for the years 2004 to 2017, and reported as NA for the years 2018 to 2020. This is adjusted in this edition of the Red Book to remove all reclamation and restoration expenditures and to include estimates of exploration and development expenditures for the years 2018 to 2020. The revised values are derived from US country report data and Secretariat estimates of reclamation expenditures for the years 2004, 2005, 2018, 2019, and 2020. In total, the restatement reduces reported cumulative US uranium exploration and development expenditures by USD 597 million. (i) Non-government industry expenditures between 2011 and 2013, 2017 and 2018. (k) Red Book edition 2024 updated totals from 2004 onwards with corrected expenditures for United States (2004-2020).

The great majority of these countries reported increasing expenditures over the three-year period, or in some cases relatively consistent expenditures. There are, however, a few notable exceptions. Kazakhstan's 2021 and 2022 annual expenditures of USD 9 to 10 million continued the steady decrease since 2016 with no sign of rebound as yet. For Niger, 2021 expenditures increased dramatically to by far the highest level since 2016 and then dropped back to trend in 2022. The country's political change in July 2023 can be expected to have had a significant impact on exploration and development expenditures. In the case of Türkiye, 2021 expenditures decreased compared to 2020, but 2022 then rebounded to approximately 10% above 2020 expenditures, as reported in Turkish lira (TRY); however, due to the extreme devaluation of the TRY versus USD from 2021 to 2022, on a converted (to USD) basis the expenditures appear to have decreased. Ukraine reported a doubling of expenditures for 2021 compared to the previous year; however, in 2022 expenditures then decreased twenty-fold compared to 2021, to less than 9% of 2020 levels. Preliminary 2023 data were not available for any of these four countries.

Global exploration and mine development expenditures were expected to increase in 2023 to USD 840 million, a 5% increase compared to 2022, although the increase is likely greater since 2023 expenditures were not reported for key countries such as Kazakhstan, Mongolia, Niger, Türkiye, Ukraine, and the United States. Increases in expenditure from 2022 to 2023 are, however, expected in important uranium producing countries such as Australia, Canada, India, Russia and Uzbekistan. For the 2021 to 2023 period, of the countries that separately reported exploration and development expenditures, Canada, China, and Kazakhstan reported greater exploration than mine development expenditures (except for Kazakhstan in 2022), whereas Namibia, Russia and Ukraine reported greater mine development than exploration expenditures (except for Namibia in 2021).

Building on the table first introduced in the previous (2022) edition of the Red Book, Table 1.16 summarises recent global drilling activities (although not comprehensive nor complete). In total, twenty-two countries with reported drilling activities are included in this edition, although thirteen reported only partially (i.e. some years or entities involved in exploration and/or mine development activities were not reported) and data for one country was included from the previous edition of the Red Book to round out data for 2020. Data for three additional countries (Brazil, Uzbekistan and Zambia) are included for the first time and in the case of four countries (Canada, China, Mexico and Russia) 2020 data have been updated/corrected from what was reported in the previous (2022) edition. For the countries reporting data, total drilling increased by 6% from 2020 (2 704 330 m) to 2023 (2 853 428 m), despite eight of the twenty-two countries not reporting expected drilling for 2023. For the countries reporting exploration and development drilling meterage separately, development drilling accounted for 30% of total drilling in 2020, 50% in 2021, 62% in 2022 and 11% in 2023, although this includes only 16, 14, 15, and 9 countries for 2020, 2021, 2022, and 2023, respectively. Note that United States data for 2020 and 2021 are withheld, owing to confidentiality of company data concerns when aggregate data represent a single company. Despite these gaps, it is clear that global drilling efforts picked up significantly from 2020 and 2021 to 2022 (3 955 169 m drilled, 46% increase), and the apparent decline back down in 2023 is likely an artefact of reporting, as eight of the countries did not report expected results for 2023. The trend is now one of increasing drilling, although still well down from 2012, when 17 countries drilled 5 368 268 m, as reported in the 2016 edition of the Red Book.

In terms of exploration drilling metreage from 2020 to 2023, ten countries reported increasing trends, four countries had relatively steady drilling, five countries reported a decreasing trend, and three countries had highly variable year to year metres drilled. Canada, China, India, Namibia and Uzbekistan were the major countries among the ten that reported an increasing trend. Of the countries that reported relatively steady drilling for each year, Egypt and Saudi Arabia were notable examples although Egypt had the much smaller programme. Kazakhstan, Niger, Paraguay, Türkiye and Ukraine reported decreasing drilling distances while Russia reported a variable drilling distance. Excluding 2023 (as numerous countries did not report this data), the exploration drilling for the combined years of 2020 to 2022 totalled more than 7 276 000 m. Just over 98% of this drilling was reported from the top ten countries – China (2 280 000 m, 31%), Uzbekistan (1 859 032 m, 26%), India (900 333 m, 12%), Kazakhstan (826 523 m, 11%), Canada (464 974 m, 6%), Türkiye (349 731 m, 5%), Namibia (192 138 m, 3%), Russia (140 252 m, 2%), Saudi Arabia (77 374 m, 1%) and the United States (46 000 m, 1%, excludes 2020 and 2021 as data withheld).

Only six countries reported any development drilling and of these only Canada, Egypt and Namibia for all four years (2020-2023), as Kazakhstan and Ukraine did not report 2023 expected data, and the United States neither reported 2023 expected data nor 2020-2021 data (withheld for company confidentiality reasons). Four of these countries (Canada, Egypt, Kazakhstan and the United States) reported increasing trends, Namibia reported variable drilling distances between the years (although 2023 drilling was significantly higher than in 2020) and Ukraine reported decreasing development drilling. Excluding 2023 (as only three countries reported 2023 expected results), the development drilling for the combined years of 2020 to 2022 totalled more than 2 094 000 m. Almost 99% of this drilling was reported from the top four countries – Kazakhstan (1 746 739 m, 83%), Canada (147 557 m, 7%), the United States (117 000 m, 6%, excludes 2020 and 2021 as data withheld), and Namibia (57 263 m, 3%).

Trenching data reported is minimal, with only Argentina, Egypt and Madagascar reporting full data across four years from 2020 to 2023. Additionally, Iran reported data were not available for all years and Saudi Arabia reported numbers of trenches (0 for 2020, 11 for 2021-22, 7 for 2023) but not metres. Argentina reported 0 metres trenching for each of 2020, 2021, 2022 and 700 m (200 trenches) for 2023. Egypt reported 330 m (14 trenches) in 2020, 400 m (10 trenches) in 2021, and 520 m (14 trenches) in each of 2022 and 2023. Madagascar reported 16 m (6 trenches) in 2021, and 66 m (5 trenches) in 2022.

Table 1.16. **Exploration and development drilling data for select countries**

(as of 1 January 2023, for 2020-2023, metres)

Country	2020			2021			2022			2023 (expected)		
	Exploration	Develop.	Total	Exploration	Develop.	Total	Exploration	Develop.	Total	Exploration	Develop.	Total
Argentina	385	0	385	1 493	0	1 493	6 880	0	6 880	3 171	0	3 171
Brazil*	0	0	0	0	0	0	0	0	0	6 000	0	6 000
Canada**	109 232	39 821	149 053	155 615	43 506	199 121	200 127	64 230	264 357	281 583	34 855	316 438
China**	620 000	NA	620 000	620 000	NA	620 000	1 040 000	NA	1 040 000	1 040 000	NA	1 040 000
Egypt	1 550	200	1 750	800	400	1 200	950	650	1 600	950	650	1 600
India	195 308	0	195 308	309 242	NA	309 242	395 783	NA	395 783	290 750	NA	290 750
Indonesia	0	0	0	0	NA	0	600	NA	600	0	NA	0
Kazakhstan	433 462	358 957	792 419	205 015	488 285	693 300	188 046	899 497	1 087 543	NA	NA	NA
Mauritania[a,c]	NA	NA	NA	5 000	NA	5 000	5 000	NA	5 000	NA	NA	NA
Mexico**	1 257	0	1 257	1 943	0	1 943	0	0	0	NA	NA	NA
Mongolia	0	0	0	0	0	0	40 662	0	40 662	NA	NA	NA
Namibia***	47 423	5 319	52 742	67 453	32 861	100 314	77 262	19 083	96 345	75 085	12 950	88 035
Niger[b]	NA	NA	NA	30 906	NA	30 906	6 500	NA	6 500	NA	NA	NA
Paraguay[c]	330	0	330	330	0	330	0	0	0	0	0	0
Russia**	112 008	NA	112 008	5 000	NA	5 000	23 244	NA	23 244	23 275	NA	23 275
Saudi Arabia[c]	0	0	0	38 687	0	38 687	38 687	0	38 687	30 409	0	30 409
Spain	0	0	0	0	0	0	0	0	0	0	0	0
Türkiye	193 329	0	193 329	98 662	0	98 662	57 740	0	57 740	NA	NA	NA
Ukraine	0	12 740	12 740	1 485	9 710	11 195	0	2 065	2 065	NA	NA	NA
United States[d]	NA	NA	NA	NA	NA	NA	46 000	117 000	163 000	NA	NA	NA
Uzbekistan*	573 009	NA	573 009	588 544	NA	588 544	697 479	NA	697 479	1 046 750	NA	1 046 750
Zambia*	0	0	0	5 980	0	5 980	27 684	0	27 684	7 000	0	7 000
Totals	2 287 293	417 037	2 704 330	2 136 155	574 762	2 710 917	2 852 644	1 102 525	3 955 169	2 804 973	48 455	2 853 428

* Country added to drilling data table for this Red Book 2024 edition. Data not previously provided. ** 2020 information updated and changed from what was reported in Red Book 2022. *** 2020 information from Red Book 2022. (a) Aura Energy's Tirus project drilling only. (b) 2021 drilling data - Global Atomic Corporation's (GAC) Dasa project and GoviEx's Madaouela project only; 2022 drilling data - GAC's Dasa project and ENRG Elements' Takardeit project only. (c) Total drilling reported for multiple years divided into equal yearly totals. (d) 2020 and 2021 data withheld, for confidentiality of company data concerns.

Current activities and recent developments

North America

The North American region continued to dominate reported uranium exploration and mine development activities, accounting for 35% to 37% of total global expenditures in each of the years from 2020 and 2023, levels very similar to the region's long-term position accounting for 40% of total pre-2016 global expenditures. Note that whereas in the previous (2022) edition, percentages were impacted (and explained) by notable data gaps for China and the United States, those are no longer the case as China has since reported the missing years' data and a Secretariat review of the past and current data from the United States resulted in a revision to Table 1.15 (refer to footnote [h]) that, among other changes, now includes estimates for all years other than 2023. This dominance of the region continues as Canada, continues to lead the world in uranium exploration and development expenditures.

After almost a decade of depressed uranium prices and declining exploration and development expenditures, 2020 marked the low point and, like the global trend, expenditures reached their trough in Canada in 2020, with strong growth in each subsequent year. Total Canadian uranium exploration and development expenditures in 2021 amounted to USD 165 million (34% of global expenditures), a 46% increase from 2020. Similarly, expenditures were USD 256 million in 2022 and USD 301 million (preliminary estimate) in 2023, annual increases of 56% and 18% respectively, and representing 32% to 36% of global expenditures.

Canada's high grade uranium deposits associated with the Proterozoic unconformity in the Athabasca Basin of Saskatchewan remain the prime target for uranium exploration, and the location of all but 15 of the 120 uranium exploration projects in the country in 2022. Relatively recently discovered large high grade uranium deposits include Phoenix/Gryphon (Denison Mines Corp.), Arrow (NextGen Energy Ltd.), Triple R (Fission Uranium Corp.), Fox Lake (Cameco Corp.) and Hurricane (IsoEnergy Ltd.). In the western Athabasca Basin, NexGen's Arrow deposit is the world's second-largest high-grade uranium deposit (130 000 tU) and a project to develop an underground mine and a mill is currently undergoing environmental assessment (EA). Fission's nearby Triple R deposit (52 000 tU) is undergoing a recently started EA process for the development of an underground mine. In the eastern Athabasca Basin, Denison's Phoenix deposit (26 900 tU) is undergoing an EA for a proposal to develop an ISL mining operation, the first proposed use of this method for unconformity-type uranium deposits. Denison's nearby Gryphon deposit (24 000 tU) has the potential to be mined by conventional underground methods. In 2020, Denison conducted a preliminary economic assessment (PEA) for also mining the Heldeth Túé deposit using ISL methods. Denison's Phoenix project and NexGen's Arrow project are each well advanced through the Federal and Provincial EA approval process since submitting their initial draft environmental impact statements in 2022.

In the United States, after a decade of dramatically decreasing expenditures that saw most of the uranium mines and projects indefinitely paused, the total (i.e. production, reclamation, drilling, land, and exploration) uranium industry expenditures reached an almost two-decade low of USD 72.5 million in 2021 before increasing to USD 84.7 million in 2022. Exploration and development drilling activity data were released again in 2022 by the US Energy Information Administration (EIA), after four years of being withheld due to extremely low levels of drilling activity. Of the 2022 total expenditures, the categories of drilling, land, and exploration amounted to USD 26.2 million, as is included in Table 1.15. Industry exploration and development activity in the United States started to increase due to sustained higher uranium prices and uranium purchases by the federal government, which were publicly announced in late 2022 as part of a newly funded federal programme to purchase US-produced uranium to be held in a national reserve. Activity resumed on several of the uranium mines and projects with notable examples as follows. In Texas, enCore Energy Corp. worked through 2021 and 2022 updating the infrastructure of the Rosita ISR processing plant, installing and sampling monitoring wells, and permitting for production that subsequently commenced in 2023 (WNA, 2023a). In October 2022, Strata Energy (Peninsula Energy Ltd.) received a license amendment for its Lance ISR project in Wyoming to convert to low pH lixiviants, becoming the first low pH ISR (i.e. ISL acid) project in the United States, as previously all ISL in the United States has been with alkaline lixiviants.

In Mexico, beginning in 2009, the Mexican Geological Survey (SGM) has been conducting a programme to validate and re-evaluate modern international standards, after earlier resource declarations for 53 previously discovered uranium deposits. From 2009 to 2018, a total of 17 361 metres were drilled in 154 holes, focussed on uranium resources located in the Peña Blanca (Chihuahua State), Los Amoles (Sonora State) and La Coma (Nuevo León State) areas. Within the period 2019-2020, a total of 3 200 metres were drilled in 56 holes with core recovery. From 2020 to 2022, regional exploration campaigns were carried out in Sonora, Chihuahua and Durango states. Resources data reported in this edition of the Red Book reflect resource estimates derived from the SGM studies, and only less than 4% of the total reported identified resources remain based on historic estimates. Since 2009 the government has invested more than USD 11 million in this re-evaluation effort, including the most recently reported expenditures of USD 660 000, USD 810 000 and USD 630 000 for 2020, 2021 and 2022 respectively, while the preliminary estimate for 2023 is for a further USD 1 million.

Central and South America

Uranium exploration and mine development expenditures in the Central and South American region accounted for 1% of reported global expenditures from 2020 to 2023, with expenditures, primarily from Argentina, ranging between a low of USD 1.3 million in 2020 and a high of USD 7.8 million in 2022.

In Argentina, continued investment in uranium exploration aligns with the 2006 government policy of reactivating the national nuclear energy programme. Exploration is carried out by the government through the National Atomic Energy Commission (CNEA) and, since the 2000s, by private uranium exploration companies. Reported exploration expenditures by government in 2020 were USD 0.4 million, increasing to USD 1.0 million in 2021, USD 0.9 million in 2022, with USD 0.8 million expected in 2023. Expenditures by private exploration companies amounted to USD 0.7 million, USD 3.9 million and USD 6.9 million in 2020, 2021 and 2022 respectively, but are expected to decrease to USD 2.2 million in 2023. Whereas there is no requirement for private industry to report exploration expenditures, the companies active in the country have all provided exploration expenditure data; therefore, the amounts reported are believed to reflect substantially all expenditures in the sector.

In recent years, exploration activities carried out by the government have slowed down and from 2017 to 2021 no drilling has been carried out. Activities increased in 2022, which included a programme of 1 197 metre drilling (6 holes) in the Neuquén Basin (Río Negro Province). In 2023, 1 exploration hole of 171 m was drilled in this basin. In 2022 CNEA signed a co-operation agreement with FOMICRUZ S.E., aimed at uranium exploration in the Santa Cruz Province and in 2023 an exploration programme started in the Meseta Sirven area (Santa Cruz Province), excavating 63 exploration trenches (approximately 220 m) in the first part of the year with a total of 200 trenches (700 m) planned for the year. In 2022-2023, the CNEA formulated a new investment project on exploration of Neogene and Quaternary uranium deposits in the Puna and Pampean Ranges (Jujuy, Salta and Catamarca Provinces), with activities planned for 2024.

Of those uranium deposits managed by the CNEA, the most relevant in the assessment/exploration stage is Cerro Solo deposit (9 230 tU) in Chubut Province. Laboratory-scale sample testing to define hydrometallurgical extraction of uranium and molybdenum has been completed, but further testing was postponed. From 2012 to 2023, one of the main activities at the Cerro Solo deposit was related to environmental monitoring and baseline surveying. In this regard, hydrological, palaeontological, socio-economic, air quality, flora and fauna, pedological and archaeological studies have been completed, while a radiometric/radiological baseline is underway and natural acidic drainage survey is planned to be carried out in 2023-2024.

Blue Sky Uranium Corp., Consolidated Uranium Inc. and Sophia Energy S.A. reported exploration activities during the 2019-2023 period. In 2019, Blue Sky Uranium Corp. announced the first PEA for the Ivana deposit (Amarillo Grande project), and an updated inferred in situ resource estimate (8 730 tU at 0.031% U and 2 920 tV at 0.011% V). Exploration from 2020 to 2022 focused on expanding mineralisation proximal to the Ivana deposit, and on advancing the Ivana deposit. Mapping, sampling, radiometric and geophysical surveys were conducted to define new proximal targets and 4 214 m of drilling (83 holes) carried out on these targets. The Ivana deposit was advanced with more drilling (3 346 m in 350 RC holes) and metallurgical testing. The 2023 plan includes a continued new target drilling programme (3 000 m), completing metallurgical test-work, updated mineral resources, and an updated PEA.

In 2021, Consolidated Uranium Inc. purchased the Laguna Salada project (Chubut province) from U3O8 Corp. In 2022, Consolidated undertook mapping and surface sampling on the project. The company has no exploration plans for 2023 and the project will be put back into care and maintenance. In 2023 Consolidated also acquired the Huemul Project, an early-stage exploration project located in the southern part of Mendoza Province.

In recent years, Sophia Energy S.A. continued exploration of its mining properties at the Laguna Sirven deposit (Santa Cruz province), including a radiometric airborne survey of the entire project. In 2019, Sophia Energy S.A. received approval from the provincial government to perform a two-year advanced exploration programme focused on resource assessment, but exploration activities placed on hold in early 2020 due to COVID-19 have not yet resumed. A trenching exploration and resource assessment programme has been formulated to start in 2023-2024.

Exploration drilling by private companies totalled 385 m (8 holes) in 2020, 1 493 m (38 holes) in 2021, 5 683 m (387 holes) in 2022, with 3 000 m (80 holes) expected for 2023.

In Brazil, no exploration and mine development expenditures were reported from 2018 to 2022. In late 2020, a reassessment of resources in several deposits in the Lagoa Real uranium province was started. For 2023 a 6 000 m drilling programme (USD 1.2 million estimate) was scheduled to upgrade the resource category of one of these deposits. Efforts have been devoted to making the transition from open pit to underground mining of the Cachoeira deposit, developing open-pit mining of the Engenho deposit and expanding the Lagoa Real production centre.

Chile did not report exploration and development expenditures for this edition. Given the lack of updates on projects in northern Chile’s iron-oxide copper-gold belt, with potential for copper, gold, silver and uranium, activity has likely continued at a reduced pace since 2016.

In Ecuador, between 2019 and 2021, the Geological and Energy Research Institute (IIGE) of Ecuador, assisted by the IAEA through the Undersecretariat of Nuclear Control, Investigations and Application´s liaison, updated and reviewed historical information on uranium exploration in the country. In 2022, through the IAEA interregional project INT2022, the IIGE benefited from training that increased technical capacities to carry out research on uranium resources in the country. In 2020, the Private Technical University of Loja (UTPL) carried out a geochemical survey in the Puyango area, finding anomalies of V, U and Zn related to black limestones, bituminous limestones and calcareous shales of marine origin. In 2023 a study led by UTPL presented partial results from the La Sota area, suggesting that U is linked to P in a geochemical P-U-HREE-Ni association. Other than this background research, there has been no reported private or state uranium exploration in recent years.

Since U3O8 Corp. left Guyana in 2012, there has been no significant exploration, but the Guyana Geology and Mines Commission (GGMC) continues to conduct annual geochemical projects to map the country’s mineral potential. In recent years, GGMC data from Permission for Geological and Geographical Survey (PGGS) Areas for both light and heavy rare earth elements has shown that uranium concentrations are higher than other elements, ranging from more than 2.7 to 296 ppm (0.0003% U to 0.03% U). Since 2020 no project work was done; however, GGMC is expecting to continue carrying out geochemical survey projects in Guyana’s interior.

The government of Paraguay did not respond to the Red Book questionnaire for this edition, although exploration was carried out by Uranium Energy Corporation (UEC) from 2019 to 2021 in the Coronel Oviedo area. Several radon emmanometry surveys and exploration drilling of approximately 1 000 m were carried out, with total expenditures estimated at USD 750 000. No activities have been reported in the 2022 to 2023 period.

For Peru, no exploration and development expenditures were reported in this edition, and the industry is not required to report expenditures to the government. In 2021, American Lithium Corp. acquired Plateau Energy Metals and its projects in the Macusani district and announced drilling plans (12 000 m; 70 holes) for the Macusani project to expand existing uranium resources and identify new deposits. The permitting process has been initiated, including development of an environmental impact assessment and community access agreements. Drilling is expected to start once an exploration permit is granted.

European Union

Uranium-related exploration and mine development activities in the European Union accounted for 0.1% and less of total reported global expenditures from 2020 through 2023, as the main activities continued to be focused on remediation of closed uranium mines. Potential mine projects in Denmark (Greenland) and Hungary have been blocked by unsupportive jurisdictions as discussed in the following sections for each country, while Spain has denied a project due to safety matters. As a result, current activity is in arbitration proceedings and legal appeals, not exploration and development. The encouraging news for the uranium industry was in Finland with the Talvivarra deposit uranium byproduct production finally cleared to move forward, and in Sweden where the government is now working to abolish the 2018 ban imposed on uranium exploration and mining.

In Czechia, recent exploration activities have been focused on the conservation and processing of previously collected exploration data from Czech uranium deposits. Advanced processing of the exploration data and building of an exploration database will continue in the coming years. In 2021 and 2022, activities included analysis and evaluation of rock samples, geological documentation, developing a feasibility study and final reports, as well as archiving data. No drilling data have been reported in Czechia since 2016. Expenditures for 2021, 2022 and expected for 2023 were approximately USD 56 000, 23 000, and 47 000, respectively.

Denmark (Greenland) reported no expenditure figures for the 2020 to 2023 period, and no drilling data. Since 2007, Energy Transition Minerals Ltd (ETML), formerly Greenland Minerals Ltd, had conducted exploration activities for REE-U-Zn mineralisation in the Kvanefjeld area in southern Greenland, including 57 710 m of core drilling. A mining/exploitation licence application was submitted in July 2019, including updated environmental and social impact assessments and a navigational safety investigation study. The project includes recovery of uranium (425 tU/y) and zinc by-products in addition to the main REE products. However, an April 2021 election in Greenland led to a change in government that passed a new law prohibiting exploration and exploitation of uranium as of December 2021. Passage of this new law led ETML to request arbitration proceedings with the governments of Greenland and Denmark concerning the impact of new legislation on its exploration licence for the Kvanefjeld REE, zinc and uranium project under development in southern Greenland. On 20 July 2023, ETML announced it had filed a statement of claim with an arbitral tribunal, on the matter of this dispute (Energy Transition Minerals, 2023).

In Finland, no exploration or development expenditures or drilling data exclusively for uranium have been reported since 2014. In December 2022, after receiving confirmation of the validity of its license to recover uranium as a by-product at the Talvivaara deposit mine in Sotkamo, Terrafame Oy commenced preparations (total investment of around EUR 20 million) for the extraction of uranium, with startup of the uranium recovery plant expected in 2024, and full capacity of about 200 tU per year expected by 2026, after the ramp-up phase. On 17 June 2024, final regulatory approval of the constructed plant was received, clearing the way for Terrafame to commission the facility (WNA, 2024a).

In France, although no domestic uranium exploration and mine development activities have been carried out since 1999, majority government-owned Orano S.A. (formerly Areva S.A.) and its subsidiaries remain active abroad. As of 2022, Orano has been working outside France, focusing on the discovery of exploitable resources in Canada, Gabon, Kazakhstan, Mongolia, Namibia, Niger and Uzbekistan. In Canada, Kazakhstan and Niger, Orano is also involved in uranium mining operations. Total non-domestic exploration expenditures remained relatively steady from 2020 to 2021 at about USD 32 million per year and declined by 19% to around USD 26 million per year for 2022 and 2023.

There have been no exploration activities in reunified Germany since the end of 1990, and no non-domestic exploration by German mining companies since 1997.

The government of Hungary did not report any exploration or mine development expenditures for this edition. A non-governmental mine development project of the Mecsek deposit and surroundings, started in 2007, is still in the environmental licensing phase. To date, the environmental impact studies (EIS) submitted failed to obtain the necessary licence to develop a mine, even at reduced production rates. The company has again submitted a modified EIS; however, besides the environmental approvals, the only way to establish a mining property is through public concession tendering, provided the government will launch the tendering procedure.

For Poland, no exploration and development expenditure data were reported. There are no up-to-date uranium deposits documented, although there are some prospective indications of uranium and some small prospects amenable for the discovery of uranium.

In Portugal there has been no exploration or exploitation of uranium since 2001, although there are unexploited uranium deposits located in the southern part of the country. No future production centres are planned, and rehabilitation and remediation are the only activities being undertaken.

In the Slovak Republic, exploration in Kuriskova associated with the Košice uranium deposit, initiated in 2011 by Ludovika Energy Ltd (a subsidiary of European Uranium Resources), came to an end in 2015 when exploration licences were not renewed by the government. Several protests and lawsuits over the allocation of exploration areas followed, as well as political discussions to ban uranium mining and exploration in the country, and no new uranium exploration licences have been issued in the Slovak Republic since.

In Slovenia, expenditures on uranium exploration ended in 1990, and there are no recent or ongoing uranium exploration activities in the country. In 1992, the final closure and subsequent decommissioning of the Žirovski Vrh mine and mill complex began with the production facility being dismantled. All remediation work was finished on the mine waste pile site, and in 2015, long-term environmental surveillance began. A hydrometallurgical tailings and associated waste rock disposal site has been undergoing environmental remediation, with additional recent work (including in 2019 and 2021) and studies being carried out to reduce groundwater level and improve stability of the site before the facility can transition to long-term surveillance and maintenance.

In Spain, annual exploration and mine development expenditures reported by industry amounted to between USD 240 000 and USD 370 000 for the 2020 to 2023 period. There was no exploration drilling activity. After actively exploring for uranium for several years, Berkeley Minera España S.L.U. advanced the Salamanca project (four potential open-pit uranium mines and an associated milling facility) to the licensing approval stage. Berkeley received various required permits and licenses; however, the Spanish government's Nuclear Safety Council (CSN) denied Berkeley the final permits to allow for Salamanca's construction in 2018. From 2019 to 2021, the company continued with attempts to receive the final remaining permits to advance the project to the development stage. However, in July 2021, the CSN issued a negative report on the construction licence for the processing plant. The report is mandatory, and when negative or regarding the conditions imposed, it is also binding. Consequently, the Ministry for the Ecologic Transition and the Demographic Challenge (MITERD) denied Berkeley's request to build the uranium processing plant at the company's Salamanca project in western Spain. Currently, this decision by the MITERD is appealed in the Spanish National Court.

On 16 May 2018, the Parliament of Sweden passed an amendment to the Environmental Code banning uranium exploration and mining in the country. Prior to this, most exploration activity was related to the potential of alum (black) shale, where uranium could be recovered as a by-product along with other co-products such as molybdenum, vanadium, nickel, zinc and petroleum products. The Australian company, Aura Energy Ltd, having worked for several years developing the Häggån Project for uranium and vanadium mining, lodged a claim against the Swedish government in November 2019 for compensation of financial losses resulting from the 2018 ban on uranium exploration and mining. On 23 February 2024, Sweden's Climate and Environment Minister announced the launch of an investigation to abolish the country's ban on uranium mining, to determine what rule changes are needed to enable and clarify the conditions for uranium extraction (WNA, 2024b). The result of the investigation, with the purpose to remove the ban, was to be reported by 15 May 2024, at which point the government will determine next steps.

Europe (non-EU)

Uranium exploration and mine development expenditures in non-EU countries in Europe accounted for 6% to 7% of total reported global expenditures in 2020 to 2021, jumping to 12% in 2022 to 2023, with the latter years heavily dominated by activities in Russia as expenditures dropped in Ukraine and Türkiye.

In Russia, early-stage prospecting exploration aimed at new deposit discovery and preliminary evaluation is financed by the federal budget of Russia through the Federal Agency for Mineral Resources (Rosnedra), whereas exploration and development of identified deposits is carried out by the subsidiary uranium mining enterprises of JSC Atomredmetzoloto (ARMZ), which is a part of the Russian State Atomic Energy Corporation (Rosatom).

In 2021 to 2022, early-stage work focused on identifying large deposits and occurrences suitable for development by ISL and conventional mining methods was carried out mainly in the Siberian Federal District (Irkutsk Region) and in the Far Eastern Federal District (Republic of Buryatia, Trans-Baikal Region, Amur Region and Jewish Autonomous Region). In 2021, work carried out at various locations included a mining test, preparation of a technical report on resources, a comprehensive airborne geophysical survey and greenfield exploration. In 2022, geological and geophysical surveys were carried out and 17 holes were drilled at several sites of the Tuyukan area.

With respect to advanced stage work, in 2021 the Priargunsky production centre continued limited exploration focused on identifying uranium resources on the flanks of the deposits by drilling boreholes from underground mine workings. Activities in 2022 were concentrated at the Dobrovolnoye and Dalmatovskoe deposits (Dalur mine) with the main drilling operations focused on the Ust-Uksyanskaya section and exploration of the Dalmatovskoe deposit. The Dalur mine exploration programme is scheduled to continue to 2025.

Mine development work at JSC Dalur (Kurgan Region) continued with preparation for pilot uranium mining at the Dobrovolnoye deposit in 2021-2022, with completion of pilot plant facilities construction planned for 2023. In 2021-2022, JSC Khiagda (Republic of Buryatia) continued development at the Kolichikan deposit (6 530 tU RAR) and the Dybryn deposit (6 634 tU RAR). Dybryn is planned for commercial mining in 2023. Also, during 2021-2022, the Priargunsky production centre continued construction of the surface complex and infrastructure elements of new mine No. 6 (design capacity of 2 300 tU/yr) that will support the development of the Argunskoye and Zherlovoye deposits. The development of Elkon uranium region deposits was suspended due to unfavourable market conditions.

Total domestic exploration and mine development expenditures increased from about USD 14 million in 2020 to USD 26 million in 2021 and USD 90 million in 2022, with USD 104 million expected for 2023. Of these totals, mine development expenditures accounted for 17%, 88%, 97%, and 96% respectively for the 2020 to 2023 period.

Russia, through Uranium One (owned by Rosatom), also carried out exploration for uranium at joint ventures in Kazakhstan, exploration at the Wings deposit in Namibia, and works in Tanzania to prepare for the development of the Mkuju River uranium project. In Kazakhstan, six uranium mines jointly owned by Uranium One are in commercial operation. In 2021, exploration in the expanded geological allotment of the Zarechnoye deposit was completed and additional resources were identified to extend the mine's life. During 2021 to 2023, exploration was carried out at the Kharasan mine to convert resources into more reliable categories. In Tanzania, Mantra Resources completed major exploration of the Mkuju River deposit in 2016. In 2020, a decision was made to build a pilot processing plant and to proceed with pilot open-pit mining during 2023-2025. In 2022, the company received all approvals for construction works. At the beginning of 2023, the construction of the main production facilities was completed, and the equipment of the processing complex was installed. In Namibia, Uranium One Group, through its subsidiary Headspring Investments Pty., completed an intensive drilling exploration programme in 2021 that increased JORC compliant resources of the sandstone-type uranium deposit, Wings, to 18 536 tU RAR (measured and indicated) and 22 977 tU of inferred resources. Additional exploration potential was estimated to be 30 000 tU. A pre-feasibility study completed in 2021 confirmed positive economics for the ISL mining method. The Wings deposit is a first deposit in Namibia which is potentially amenable for development by ISL. In 2022-2023 the company planned to start with an onsite ISL pilot test and a pilot test site was prepared for commissioning, with the test planned to start after regulatory approval is received.

In Türkiye, government exploration expenditures decreased from USD 7.3 million in 2020, to USD 4.2 million and USD 3.3 million for 2021 and 2022, respectively, with a 2023 estimate not available. Exploration drilling amounted to just over 193 300 m (576 holes) as previously reported for 2020, 98 600 m (290 holes) in 2021 and 57 700 m (140 holes) in 2022. For 2020 to 2022, granite, acidic igneous and sedimentary rocks around the Thrace Basin (Edirne, Kırklareli and Tekirdağ provinces), Çanakkale, Nevşehir, Yozgat, Giresun, Manisa, Malatya and Aydın provinces were explored for radioactive raw materials. Drilling was conducted at sites licensed by the General Directorate of Mineral Research and Exploration (MTA) inside the Thrace Basin, Nevşehir, Yozgat, Çanakkale, Giresun, Malatya and Aydın provinces.

In early 2019, Westwater Resources Inc. reported that the Turkish government had cancelled all exploration and operating licences held by Adur in June 2018 (Adur was Westwater's Turkish subsidiary, Adur Madencilik Limited Sirketi). Adur and its predecessors had been developing the Temrezli and Şefaatli projects, carrying out drilling, testing and studies to move the projects towards production. In December 2018, Westwater filed a Request for Arbitration before the International Centre for the Settlement of Investment Disputes. On 3 March 2023, the arbitral tribunal issued its final award in the proceeding and in December 2023, Westwater accepted a payment of USD 3.1 million from the Republic of Türkiye as complete and full settlement of the matters at issue (Westwater Resources, 2023, 2024).

In Ukraine, exploration and development expenditures totalled USD 1.7 million in 2020, USD 3.4 million in 2021 and USD 150 000 in 2022 with no estimate for 2023. Mine development expenditures accounted for 96%, 92%, and 100% respectively for these years. A total of over 13 260 m of drilling (677 holes) was carried out for the 2021 to 2022 period (data not available for 2023), all by the government, with the majority (87% in 2021, 100% in 2022) for development. State Enterprise Kirovgeology undertook analytical work on existing geological data to identify areas prospective for uranium exploration within the country.

Africa

Uranium exploration and mine development expenditures in Africa accounted for about 4% of total reported global expenditures in 2020, rising to 8% in 2021 and 12% in 2022, with 9% estimated for 2023 although preliminary expenditure information was not available for some countries. Approximately 70% of the region's USD 95 million expenditures in 2022 are attributed to mine development in Namibia. In response to the recovery in uranium price, Africa experienced a dramatic increase in the level of uranium exploration and mine development, particularly as work accelerated on several projects to bring them to the point of Final Investment Decision. Political events in Niger in 2023 and subsequent impacts on the country's uranium industry in 2023 and 2024 are of concern and have greatly elevated the risk profile of the country's uranium production and potential new projects.

In Algeria, in 2017 and 2018 the Agency of the Geological Service of Algeria, in collaboration with the United States Geological Survey, carried out preliminary prospecting work for undiscovered mineral resources, including uranium, related to granites, calcretes, alkaline rocks and carbonatites in the Eglab Region. No uranium prospecting or mine development work was carried out between 2019 and 2021, largely due to the COVID-19 pandemic.

Algeria moved to regulate activities related to the research, production and peaceful use of nuclear energy with the adoption of Law No. 19-05 on 17 July 2019, leading to the creation of the National Authority for Nuclear Safety and Security (NNSSA) on 20 April 2021. The NNSSA is the competent regulatory authority charged with drafting legislation, regulations, and guidance documents relating to nuclear activities, and ensuring their application, issuing authorisations and licenses, controlling installations, and co-operating with international and regional organisations. The Atomic Energy Commission (COMENA) for its part will continue to provide aid and assistance to the NNSSA.

In Botswana, no exploration and mine development expenditures were reported. In 2018, Australia-based A-Cap Energy Limited suspended exploration activities at the Letlhakane Uranium Project due to an unfavourable uranium price outlook. In September 2021, the government amended the mining licence at A-Cap's request to delay the specified construction period start to 30 September 2024. In mid-2022, A-Cap Energy commenced a comprehensive programme aimed at restarting exploration and advancing Letlhakane, including a planned 1 500 m drill programme, to collect up to 2 t of ore for additional beneficiation tests. Later in 2023, it was announced that the Australian company Lotus Resources Limited will acquire the Letlhakane project, and the acquisition was implemented on 7 November 2023.

There has been no exploration and mining development for uranium in the Central African Republic since the attack at the Bakouma project site in 2012 that led to the suspension of all activities. In 2020, Orano updated the Bakouma resource estimate to inferred in situ resources of 36 475 tU at an average grade of 0.20% U in the <USD 260 cost category (reported in Orano 2022 annual report), a downgrade from the previous estimate. While the Bakouma uranium deposit is associated with phosphates, which are typically reported as unconventional resources, it is classified as a conventional deposit because of the relatively high (0.15-0.30% U) uranium grade.

For the first time since 1983, Cameroon provided a report for this edition of the Red Book. In the last strong uranium market period, there was active uranium exploration by several companies; however, the uranium price decline after 2011 greatly affected uranium exploration in Cameroon, exploration licenses for the more advanced Kitongo and Lolodorf deposits have expired, and there are currently no ongoing uranium exploration activities.

The last time the Democratic Republic of Congo (DRC) reported exploration activities for the Red Book was in 1988 (at that time the DRC was known as Zaire). From 2018 to 2024, the IAEA provided support for the identification and evaluation of uranium and other radioactive resources in the Katanga province in the DRC through the Technical Co-operation programme entitled, "Strengthening National Capacities for the Assessment of Uranium Resources and Other Radioactive Minerals and for the Regulation of Associated Mining Activities".

Egypt reported government exploration and mine development expenditures of USD 186 000 in 2020 and USD 192 000 in 2021, with a decrease to USD 160 000 and USD 97 000 in 2022 and 2023 respectively, as the Egyptian Nuclear Materials Authority (NMA) continued to focus efforts on the exploration of four prospects in the Eastern Desert and South Sinai. Activities involved exploratory trenching and shallow drilling programmes, supported by geophysical and geochemical surveys. Notably, work at the Abu Rusheid project supported upgrading previously prognosticated resources to inferred resources, thereby increasing Egypt's identified conventional uranium resources (<USD 260/kgU) to 16 100 tU (in situ), an increase of 13 600 tU. For the 2020 to 2023 period, a total of 1 770 m (52 trenches) of exploratory trenching and 4 250 m (267 holes) of drilling were completed. Mine development expenditures for the period comprised 33% of total expenditures as pilot production facilities planned for 2025 at Abu Rusheid and El Sella. This is in addition to established facilities at Gattar and Abu Zenima which continue to investigate uranium recovery through heap and vat leaching, and beginning in 2019, by ion exchange. No exploration of new areas has been carried out since the beginning of 2020 as the decision was made to reduce uranium-related activities and new exploration expenditures.

Egypt has had ongoing support for over two decades in developing uranium exploration and production capacities through several IAEA Technical Co-operation projects. The most recent include "Enhancing Regional Capabilities for a Sustainable Uranium Mining Industry" and "Supporting a Feasibility Study for Uranium and Rare-Earth Element Recovery from Unconventional Resources", both of which began in 2018; "Supporting Uranium, Thorium and Rare Metal Evaluation, Production and Purification from Conventional Resources" and "Supporting Uranium Recovery from Solid Radioactive Waste Produced in the Radioisotope Production Facility", both of which began in 2020 and continue through 2024; and "Enhancing Regional Capabilities for Sustainable Uranium Exploration and Mining (AFRA)" and "Supporting Feasibility Study for Uranium, Thorium and Rare Metals Recovery from Conventional Resources", both of which began in 2022 and continue through 2024.

For the first time since 1983, Ghana provided a report for this edition of the Red Book. An African Regional Cooperative Agreement for a Research project commenced in January 2022 with the objective of determining uranium and thorium concentrations in Takoradi Carboniferous black shales, with sample results showing average Th and U contents of 21 ppm and 8 ppm, respectively.

For the first time, Kenya provided a report for this edition of the Red Book. The Government of Kenya has established a multi-agency team led by the State Department of Mining to undertake exploration of mineral resources including uranium and thorium. Since 2021, the Government of Kenya has funded a country-wide geophysical survey in search of uranium deposits. Since the early 1950s, and as of 2023, approximately KES 2 billion (approximately USD 15 million) have been spent on various mineral exploration surveys, the latest of which is an ongoing 1:20 000 scale country-wide airborne radiometric survey started in 2021 that is currently in the ground-truthing validation phase.

Uranium exploration was revived in Madagascar in 2015. Since then, the Office of National Mines and Strategic Industries (OMNIS), with the help of the IAEA, examined the general geology of the Morondava Basin and uranium mineralisation previously discovered in the Karoo formations in the Makay mountain range, with field work carried out each year through 2019 before being interrupted in 2020 by the COVID-19 pandemic. For 2021 and 2022, OMNIS continued detailed uranium exploration activities in the Makay and Vinanikitony areas including geophysical and radiometric surveys, geological studies and mapping, 82 m of trenching (11 trenches) and collection of rock pit samples for analysis. In 2023, OMNIS will continue detailed uranium exploration in the Ambakaka river, Vinanikitony area and another site. Exploration expenditures were approximately USD 30 000 for each of 2021 and 2022.

For Malawi, no exploration and mine development expenses were reported. Lotus Resources Limited through its subsidiary Lotus Africa Limited (LAL) acquired the Kayelekera Project in March 2020 and the Livingstonia prospect in 2021. Lotus owns 85% of LAL, with the remaining 15% held by the Government of Malawi. Early in 2022 Lotus released an updated mineral resource estimate for Kayelekera (17 810 tU in situ identified resources), followed by a Restart Definitive Feasibility Study, in August 2022. The company's regional exploration in 2022 defined an inferred Mineral Resource Estimate of 6.9 MT at 320 ppm U_3O_8 (0.027% U) at Livingstonia, and intersected uranium at another target. In 2023, the government assented to the 2023 Mines and Minerals Act, replacing the 2019 Act.

In Mali, reported industry exploration and mine development expenditures dropped from approximately USD 300 000 for 2018 to 2019 to USD 30 000 in 2020 as a rebellion in the north-eastern part of the country limited activities to the western regions. Expenditures then rebounded dramatically to around USD 1.2 million for each of 2021 and 2022, with the 2023 estimate not available. In 2020 and 2021, Canada's GoviEx Exploration completed Induced Polarisation (IP) and resistivity surveys on the Faléa project area that defined a large IP anomaly which extends southward for over 2 km from the Faléa deposit and has not yet been drill-tested. In the same period, GoviEx conducted a 142-hole (6 354 m) air-core drilling programme to test gold potential associated with soil anomalies on the Madini license area (part of the Faléa project). Assay results highlight some remarkable intercepts, which warrant follow-up. In early 2022, GoviEx conducted a 12-hole (6 002 m) diamond drilling programme on the Faléa licence (10 holes) and the Bala licence (2 holes). Uranium results confirmed mineralisation in the Upper North and North Deep deposits, and a strong correlation was observed between copper and uranium mineralisation within the sedimentary sequence.

In Mauritania, no exploration and development expenditures were reported, although industry activity to advance mine development continues, notably by Australia's Aura Energy at the Tiris (Reguibat) project. The Tiris Project is 100% owned by Tiris Ressources SARL, which is 85% owned by Aura Energy Ltd and 15% by the Mauritanian Government's Agence Nationale de Recherches Géologiques et du Patrimoine Minier (ANARPAM).

In 2019, Aura released the results of a Definitive Feasibility Study (DFS). The project is comprised of a shallow open-pit mine, a processing plant, and supporting infrastructure. Uranium mineralisation lies largely within 3 to 5 m of the surface in a relatively soft, free-digging material containing patchy calcrete. Based on test work to date, the mineralisation is not expected to require blasting before mining or crushing before beneficiation. Vanadium by-product could be recovered as vanadium pentoxide (V_2O_5). In 2021-2022, Aura completed an enhanced DFS of the project. Compared to the 2019 study, projected annual production increased from 310 tU to 770 tU. In 2023, Aura released a new JORC code compliant resource estimation for the Tiris project, including the Tiris East deposit group and the Tiris West deposits. Based on an 85 ppm U cut-off (0.0085% U), total in situ resources for the Tiris project are estimated at 11 423 tU measured and indicated (RAR), and 11 270 tU inferred resources.

Support in the uranium production cycle has been provided through an IAEA Technical Co-operation project, “Establishing an Effective Monitoring Mechanism for Environmental Protection related to Uranium and Mining Activities”. The project began in 2014 and continued through 2017. The specific objective of the project was to put in place a framework for environmental management and build capacity for environmental and radiological site characterisation, leading to baseline generation of potential uranium mining sites in Mauritania and building capacity for monitoring of radionuclides in the environment. Mauritania is currently a participant in the Technical Co-operation regional Africa project, “Enhancing Regional Capabilities for Sustainable Uranium Exploration and Mining”, which started in 2018 and continues through 2024.

In addition, the United States Geological Survey, in co-operation with the Ministry of Petroleum, Energy, and Mines of the Islamic Republic of Mauritania, conducted a preliminary mineral resource assessment for 12 commodities (including uranium), and in 2015 published the assessment as Open-File Report 2013–1280, “Second projet de renforcement institutionnel du secteur minier de la République Islamique de Mauritanie (PRISM-II) phase V”. With respect to uranium mineral resources, the assessment report indicated that Mauritania has 80 known occurrences and, at the time, was a focus of active uranium exploration by several companies. Seventeen occurrences have published resource estimates and can be considered as mineral deposits. Fourteen of these are calcrete-type deposits with total resources of 138 million tonnes at an average grade of 331 ppm U_3O_8. The three bedrock-hosted deposits are granite-hosted vein/shear zone type deposits with total resources of 46 million tonnes at a grade of 248 ppm U_3O_8 (0.02% U). Further, areas for undiscovered uranium deposit types were also delineated.

In Namibia, exploration and development activities between 2020 and 2023 were undertaken both at existing mine sites and at developing properties, with intensive activity through the period.

Exploration drilling resumed on the Rössing mining license area in 2022 with about 12 500 m of diamond drilling and a further 7 500 m planned for 2023. At the Husab mine, Swakop Uranium conducted infill drilling and focussed exploration on their adjacent exclusive prospecting leases, including drilling at the Holland’s Dome prospect during 2021, 2022 and planned for 2023, as well as geophysical surveys, geological mapping and modelling, drilling, and resource evaluation testing of other prospects. The Australian company Paladin Energy Limited completed a restart PFS of Langer Heinrich in June 2020, followed by a value study in October 2021. Restart activities, including extensive refurbishment coupled with process upgrades, have been underway since July 2022. While Trekkopje remains under care and maintenance, Orano has conducted research to improve future uranium recovery.

Australia-based Bannerman Energy continued evaluation and permitting work on its Etango Project, where two-thirds of the identified resources (82 400 tU in situ) are located within 200 m of the surface. Environmental approvals are in place for a mine that could produce 2 770 tU/y. However, following metallurgical test work at its demonstration plant, Bannerman decided to initially develop the mine at a reduced scale with an annual production of 1 350 tU/y. The Etango Mining Licence application was granted in December 2023 and the company has commenced early development works in anticipation of a Final Investment Decision (FID) during 2024.

Reptile Mineral Resources (RMR) (a subsidiary of the Australian company Deep Yellow Limited) completed a PFS and commenced a DFS for the Tumas Project (51 100 tU in situ identified resources) in February 2021. In support of the DFS, an infill drilling programme (nearly 1 500 holes totalling approximately 25 000 m) was carried out in 2021 at the Tumas 3 and Tumas 1 East deposits to convert sufficient inferred resources to indicated and measured resources categories, as well as geotechnical drilling and water production test holes. Environmental approvals for the project and a 20-year Mining Licence were granted in September 2023. The Tumas DFS results (1 400 tU/yr operation) were released in February 2023 and a DFS re-costing study in December 2023. The company anticipates an FID later in 2024. RMR also resumed exploration drilling at the Omahola Project (48 000 tU in situ identified resources) in 2021 with 340 holes drilled during 2021 and 2022.

From 2015 to 2019 the Australia-based Elevate Uranium Limited suspended all drilling activities due to depressed market conditions and focused on metallurgical testing for the Marencia Project of its U-pgrade™ beneficiation process to increase the grade of mined ore prior to leaching. Between mid-2019 and 2022, Elevate made four uranium discoveries in Namibia – Koppies, Hirabeb, and Namib IV in the Namib area, and Capri in the Central Erongo area. On resuming exploration drilling, the focus has mainly been resource drilling at Koppies. In November 2023, the company reported Koppies inferred resources increased to 18 462 tU (in situ), with 95% of the resources within approximately 15 metres of surface and 50% of the resources within 6 metres of surface.

Zhonghe Resources' (majority owned by China National Nuclear Corporation [CNNC]), Happy Valley Project had for most of the past decade focussed on resource evaluation, feasibility study and economic reassessment. However, in 2021-2022, a series of geological and geophysical surveys were carried out as well as a diamond drilling programme which started in August 2022. In 2023, Forsys started a programme to update and improve on its 2015 DFS for the Norasa Uranium Project, which includes drilling, geotechnical optimisation of pit parameters, evaluation of alternative metallurgical processes including heap leaching, and other review items, with an updated DFS anticipated in 2024.

In south-eastern Namibia, Headspring Investments Pty. (a subsidiary of Russian owned Uranium One), discovered and has been developing a new sandstone-type uranium deposit (Wings) that is potentially amenable for extraction by ISL, the first potential ISL mine in Namibia. An intensive 2019 to 2021 drilling programme (nearly 85 000 m, 504 core drill holes) formed the basis for JORC compliant identified in situ resources of 41 500 tU. In 2021 a PFS for Project Wings was completed confirming positive economics for the ISL mining method and plans were prepared for an ISL pilot test. In 2022 the pilot plant and well field construction were completed, with a start in production subject to the granting of permission by Namibian regulators.

After averaging only USD 5 million annually from 2016 to 2019, uranium exploration and mine development expenditures in Namibia increased dramatically to USD 11 million, USD 25 million, and USD 86 million in 2020, 2021, and 2022, respectively, with USD 75 million expected for 2023. Of these totals, mine development expenditures accounted for 1%, 5%, 79%, and 82% respectively for the 2020 to 2023 period. A total of 342 436 m (9 900 holes) were drilled in Namibia from 2020 to 2023, with 78% of the drilling for uranium exploration.

In Niger, uranium exploration and development expenditures were not reported for all operations in this edition. Reported expenditures were available only for Global Atomic Corporation (GAC) in 2020, 2021 and GoviEx Uranium Inc. in 2021, 2022, and amounted to USD 2.5 million in 2020, USD 12.7 million in 2021 and USD 3.5 million in 2022 (no estimates available for 2023).

In 2020, GAC completed a PEA of the Dasa project, submitted an EIS and applied for a mining permit. In December 2020, the government approved the mining permit and granted GAC three-year permit extensions for each of its six exploration properties in Niger. In September 2021, GAC started a 15 000 m drilling programme that was subsequently extended by a further 1 000 m in 2022. A feasibility study focused solely on Phase 1 (underground mine, 12 years production of 17 460 tU), was completed in November 2021 and formed the basis for GAC's decision to proceed with the Dasa project. A new uranium resources estimate (61 800 tU in situ identified resources including 42 000 tU RAR and 19 800 tU IR), focused solely on an underground mine model, was released in May 2023 and in January 2023, GAC released an update of the FS based on this new estimate.

In 2020, GoviEx undertook to update the PFS for the Madaouela project, comprising an integrated development plan for five deposits (Marianne, Marilyn, Miriam, MSNE and Maryvonne), with results announced in February 2021. In 2021, the company carried out a

15 900 m diamond drilling programme over the Miriam and Marianne deposits to obtain information (i.e. molybdenum assay, uranium grade confirmation, geotechnical drilling, sterilisation drilling at planned process plant location) required for FS and advanced planning. In July 2022, GoviEx released the results of a new NI 43-101 compliant uranium and molybdenum mineral resources estimate (44 800 tU in situ identified resources including 37 300 tU RAR and 7 500 tU IR) for the Madaouela project. In November 2022 GoviEx released an FS for the Miriam open pit project, process plant and associated infrastructure, and updated previous PFS on the two underground mines. A conventional drill, blast, truck and shovel operation is planned for the Miriam open pit. The M&M and MSNE-Maryvonne deposits are planned to be mined sequentially, as two independent underground room and pillar operations, following completion of the Miriam open pit operation. A 20-year project life is forecast, producing an estimated total of 19 100 tU, averaging 950 tU/y.

In 2021 to 2022, Orano continued exploration and development activities in the Somaïr mine perimeters and Arlit concession and increased resources and reserves, such that Somaïr has more than ten years of production viability. On 31 March 2021, the Akouta mine operated by Cominak ceased production after more than 40 years of operation and 75 000 tU extracted. Remediation of the site began immediately after production ceased and is expected to last about ten years, followed by a period of environmental monitoring of at least five years. In 2022, as part of optimisation studies for the Imouraren open-pit mining project, a mineral resource update was carried out with the use of a deterministic ore envelope model that led to a decrease in mineral resources and economic reserves recognised by Orano. However, this was accompanied by an increase in the average grade and improvement in classification of the resources. Work is underway to determine the technical and environmental feasibility of mining Imouraren using the ISL method with the aim to minimise the environmental impact and improve the economics of mining the deposit.

The Takardeit project was acquired by the Australian company, ENRG Elements in 2021. In 2022, ENRG completed an exploration programme including 5 340 m of rotary mud drilling and 160 m of diamond core drilling. In March 2023, ENRG released the results of a new JORC compliant mineral resource estimate (8 300 tU in situ inferred resources) for the project.

On 26 July 2023, a coup d'état occurred in Niger, the country's democratically elected president was detained, and a military junta established (ACLED, 2023). These political events and the subsequent world political responses have led to disruptions and considerable uncertainties within Niger's uranium industry. In September 2023 Somaïr halted yellowcake production at the Arlit mine and brought forward plant maintenance initially planned for early 2024, meanwhile continuing only mining operations, as the events had resulted in disruption of supplies of chemical products. In June 2024 Orano announced that Nigerien authorities had withdrawn the operating permit for the Imouraren uranium mine (WNA, 2024c; Orano, 2024). In July 2024 GoviEx announced that the government had withdrawn its mining rights to the Madaouela project (WNA, 2024d; GoviEx, 2024).

Senegal reported uranium exploration activity for the first time since 2016. Haranga Resources Ltd. acquired the Saraya project and launched confirmatory drilling in 2022 to test the validity of historical results. In March 2023 Haranga reported results of the 3 000 m (22 holes) drill programme, which validated historical drill data, identified extensions to known uranium mineralisation, and validated the exploration target for the project area of 1 500 tU to 13 500 tU.

For South Africa, no exploration and mine development expenditures were reported in this edition. In 2022, Sibanye-Stillwater initiated a PFS to determine the optimal uranium extraction strategy for Cooke tailings. On 31 August 2023, Sunshine Mineral Reserves (Pty) Ltd released SAMREC compliant inferred resources of 34 320 tU and 2.63M ounces of gold for Beisa North and South.

For Tanzania, exploration and development expenditures were not reported in this edition. Mantra Resources (owned by ARMZ of Russia and operated through Uranium One) continued work at the Nyota sandstone-type deposit (Mkuju River Project) with JORC compliant in situ identified resources of 58 500 tU (47 900 tU RAR and 10 600 tU IR). After earlier confirming the amenability of the portion of the resources below the water table for extraction by ISL, Mantra Resources shifted its focus, and in 2020 decided to build a pilot processing plant to proceed with a small-scale open pit mining and processing (5 tU/y) pilot operation planned for 2023 to 2025. In 2022 Mantra Resources received all necessary approvals for construction works, and in 2023 construction was completed and the equipment of the pilot processing complex installed. The start of operations is subject to final approval by regulators.

In mid-2021 Australian company Gladiator Resources Limited acquired Zeus Resources Ltd. and Tanzanian tenements known as the Likuyu North, Mtonya, Minjingu, Mkuju, Liwale, Foxy and Eland uranium projects. In 2021 Gladiator began exploration at the Minjingu Project and drilled holes to evaluate historical intercepts. In 2022 Gladiator reviewed historical data of the Likuyu North deposit and issued a JORC compliant resource estimate (1 770 tU in situ identified resources). In January 2023, the Australian company AuKing Mining Limited acquired uranium projects in Tanzania (Mkuju, Manyoni, Itigi, Magaga) and started an exploration programme at Manyoni Project to verify historical resources.

Uganda does not report data to the Red Book but may in future since the IAEA has continued to support Uganda's efforts to identify and evaluate uranium resources through the Technical Co-operation programmes "Strengthening the National Capacity for Uranium Exploration and Evaluation" from 2014 to 2017, "Enhancing Regional Capabilities for a Sustainable Uranium Mining Industry" from 2018 to 2021, and "Supporting Uranium Exploration and Evaluation", starting in 2022 and scheduled to continue through 2025. The government continues to evaluate national uranium resources utilising their Geological Survey and Mines Department as part of long-term planning as the country considers adding nuclear energy to its future energy mix.

In Zambia, GoviEx Uranium Inc.'s Mutanga Project consists of five main uranium deposits (Mutanga, Dibbwi, Dibbwi East, Njame, and Gwabi) on three fully permitted contiguous mining licences, and additionally three exploration licences. In 2021 and 2022, GoviEx conducted an extensive infill drilling programme (33 600 m in 262 holes) of the Dibbwi East deposit, targeting conversion of inferred resources to indicated category. Additionally, over four tonnes of ore was sent for metallurgical test work to support the feasibility study process, design and costing. In 2023 GoviEx planned to conduct 7 000 metres of rotary mud drilling to target areas of open mineralisation at Dibbwi East, expand its feasibility study to include detailed engineering and design and complete the Environmental and Social Impact Assessment. In Aug 2023 GoviEx announced updated NI 43-101 compliant in situ identified resources (dated effective 31 March 2023) of 17 100 tU (12 900 tU RAR and 4 200 tU IR). Total Zambia exploration expenditures increased from USD 536 000 in 2020, to USD 974 000 in 2021 and USD 3 571 000 in 2022 with USD 690 000 expected for 2023.

For the first time since 1998, Zimbabwe provided a report for this edition of the Red Book. There were no recent exploration activities for uranium in Zimbabwe. However, the cost category of existing resources was updated.

Middle East, Central and Southern Asia

Uranium exploration and mine development expenditures in the Middle East, Central and Southern Asia region amounted to about 20% of total reported global expenditures for 2020 and 2021, 13% for 2022 and an expected 16% for 2023, levels significantly greater than the region's long-term position accounting for 7% of total pre-2016 global expenditures. More than 60% of the region's expenditures were in India; however, Kazakhstan, Saudi Arabia and Uzbekistan each also reported significant expenditures for the period, averaging more than USD 10 million per year.

In Bangladesh, from 2018 to 2022, the Bangladesh Atomic Energy Commission (BAEC), through the Institute of Nuclear Minerals of the Atomic Energy Research Establishment, conducted preliminary uranium and thorium exploration along the transboundary rivers of north-eastern Bangladesh, and over the exposed Tertiary sediments of the Juri and Fultola region, Moulovibazar district, where previously uranium mineralised zones were reported. Reported expenditures totalled USD 24 000 from 2020 to 2023.

In India, after remaining relatively steady at more than USD 60 million from 2017 to 2019, government exploration expenditures dipped to USD 48 million in 2020 but returned to the more than USD 60 million level in 2021 and 2022, with USD 75 million expected for 2023. In 2022, India's exploration expenditures represented more than 8% of the total global reported uranium exploration and mine development expenditures. A total 900 333 m of government exploration drilling was completed in India from 2020 to 2023, with 290 750 m expected for 2023.

As in recent years, exploration activities remain concentrated on various Precambrian and Palaeozoic through Cenozoic basins, shear zones, fold belts and metamorphic complexes. Extensive exploration, including ground and heliborne geophysical, ground geological, radiometric and geochemical surveys, and drilling are planned in other geological domains of the country that have the potential to host uranium. These efforts have resulted in a 15% increase in RAR from 2021 to 2023 due to appreciable resource additions in the contiguous area of the stratabound deposits in the southern part of the Cuddapah Basin and the extension of areas of known deposits in the Singhbhum Shear Zone, Bhima Basin and North Delhi Fold Belt.

Iran did not respond to the Red Book 2024 questionnaire and no exploration and development expenditures were reported, although government exploration and mine development is ongoing. Following the development of a comprehensive plan, reconnaissance and detailed exploration activities have been ongoing within favourable areas across the country, with a focus on granite-related, metasomatite, volcanogenic, intrusive, and sedimentary deposit types. The development continues of mines No. 1 (open-pit) and No. 2 (underground) at the Saghand mining and industrial complex. At mine No. 2 main and ventilation shafts have been sunk, adits are being drilled, and some stopes are being developed at different levels for ore production. Feasibility studies of other uranium ore deposits such as Narigan and Khoshoumi are planned.

In Jordan, government uranium exploration and development expenditures continue at similar levels to recent years, ranging between USD 2.5 million and USD 3.6 million for 2020 to 2022, with USD 3.1 million expected for 2023. For this period no trenching or drilling was reported and 100% of the expenditures were categorised as development expenditures. Having earlier defined JORC compliant, total identified resources (35 000 tU in situ) for the Central Jordan Uranium Project (CJUP) deposit, the Jordan Uranium Mining Company (JUMCO) has more recently focussed on determining the hydrometallurgical process and establishing a pilot plant. Design and engineering of the uranium extraction process has progressed during the period 2017 to 2022, and a pilot-plant constructed and commissioned in 2021. As of 1 January 2023, hundreds of tonnes of uranium ore were processed by heap leaching technology to produce several kilogrammes of uranium concentrate. Supporting this work, a state-of-the-art analytical laboratory was established in 2020 at the CJUP site and equipped in co-operation with the IAEA, an added value beyond the project and more broadly, to other national mining projects. JUMCO is performing a PFS for CJUP to have better cost estimation that considers different options and scenarios. The PFS will then be the baseline for a bankable feasibility study.

Uranium production cycle activities in Jordan have been supported by several IAEA Technical Co-operation projects, most recently the "Enhancing Capabilities in Extracting Uranium from Local Ores on a Pilot Scale Level" project in 2018 and 2019; "Supporting Capacity Building in Member States for Uranium Production and Safety of Naturally Occurring Radioactive Material Residue Management" and "Developing a Detailed Engineering and Complete Feasibility Study for Uranium Extraction from Local Ores" projects started in 2020 and ended in 2023; and the "Enhancing the National Capabilities in Exploiting Uranium Ores in a Safe and Environment Friendly Manner" project started in 2022 and continuing through 2024.

In Kazakhstan, exploration and development expenditures continued the downward trend of recent years, declining to USD 13.4 million in 2020, USD 9.8 million in 2021, and USD 9.5 million in 2022, with no estimate provided for 2023. These expenditures are the lowest since Kazakhstan started ramping up its exploration and development activities in 2007 and 2008. During the most recent reporting period (2020 to 2022), 37% of the total expenditures were devoted to mine development activities, the remainder to exploration. Drilling over this same period amounted to 2 573 300 m (5 476 holes), with development drilling (1 746 700 m) accounting for 68% of the total metres drilled.

In 2020, JSC NAC Kazatomprom completed a geological prospecting study for sandstone roll front type mineralisation within prospective areas of the Shu-Sarysu uranium province, and continued exploration of promising areas in 2021 and 2022. From 2019 to 2022, exploration was undertaken at the Moinkum, Inkai and Budenovskoye deposits in the Shu-Sarysu Uranium Province and at the Northern Kharasan and Zarechnoye deposits in the Syrdaria Uranium Province. JV Katko LLP completed pilot production in the southern part of the site No. 2 (Tortkuduk) of the Moinkum deposit and in 2022 received permission for its commercial development. JV Inkai LLP completed exploration of site No. 1 of the Inkai deposit, and Kazatomprom completed exploration at site No. 3 of the Inkai deposit and continued exploration of site No. 2. Budenovskoe LLP completed exploration at the sites No. 6 & 7 of the Budenovskoye deposit and started an ISL pilot test in 2023. JV Kharasan continued exploration of the Northern Kharasan deposit. Exploration at the Zhalpak deposit was completed in 2020 and commercial uranium mining began in 2022.

Exploration resulted in resource additions for 2021 to 2022 at sites No. 6 and No. 7 of the Budenovskoye deposit and site No. 1 of the Inkai deposit, which effectively offset resource depletion from total Kazakhstan mining production (43 113 tU) over those same years.

Nepal submitted a country report for this edition of the Red Book, the first time it has done so, following on the IAEA Secretariat generated country report included in the last edition, based on information gathered through Nepal expert missions. No exploration and development expenditures were reported. Nepal is currently building capacity to explore for uranium deposits and to analyse samples for U and Th. The IAEA continues to support Nepal through national and inter-regional technical co-operation projects on uranium exploration and production (2012-2023). These projects support national capacity building for the exploration and mining of uranium and thorium resources, with a focus on training, equipment procurement and technology transfer. Priority exploration targets include the Tinbhangale and Upper Mustang Lomanthang sandstone-type uranium occurrences, with hard rock hosts like the Banku quartzite and nepheline syenite also considered important. Nepal has no identified uranium resources but has reported estimated speculative resources for a few prospects, as included in Table 1.13.

Pakistan did not report exploration and development expenditures. Uranium exploration activities conducted by the Pakistan Atomic Energy Commission (PAEC) are underway in continental sediments, granitic rocks of Indian and Eurasian plates, surficial deposits (calcretes) in deserts and placers in Northern Pakistan.

The Kingdom of Saudi Arabia, for only the second time, provided information for this Red Book edition. Government exploration expenditures for 2021 to 2022 were almost USD 20 million, with more than USD 18 million expected for 2023. Government drilling totalled 77 400 m (290 holes) for 2021 to 2022 with 30 400 m (176 holes) expected for 2023.

The focus this period was on follow-up to the intensive, USD 37 million, uranium and thorium exploration programme previously carried out from 2017 to 2019 that had evaluated nine designated areas (including 36 subareas) across Saudi Arabia. Resource estimates were carried out for three subareas, the Ghurayyah, Jabal Sayid and Thaniyat Turayf. In 2022, another exploration programme was implemented to follow up on the results. The first phase was carried out with modern exploration techniques and brought the database up to modern levels. The second phase continued testing many subareas both within the Arabian Shield and in the cover rocks (eastern part of the Arabian Shield).

The uranium resources identified are classified as unconventional resources, including 61 500 tU in situ uranium resources associated with Nb, Zr, REE, Ta + Th, in peralkaline granite and pegmatite (intrusive plutonic deposit type) in the Ghurayyah and Jabal Sayid subareas, and 14 500 tU in situ uranium resources associated with phosphate horizons (phosphorite type) at the Thaniyat Turayf prospect. The unconventional in situ uranium resources for the Ghurayyah deposit (49 000 tU IR) and Jabal Sayid prospect (JORC compliant 8 100 tU RAR and 4 400 tU IR) are however included in Chapter 1 resources tables in this edition of the Red Book, reflecting the recent extensive exploration programme, resource estimates made to modern standards, and uranium expected to be a co-product.

The Saudi Nuclear and Radiological Regulatory Commission (NRRC), a legal public organisation with financial and administrative autonomy, aims to regulate activities, practices, and facilities involving the peaceful use of nuclear energy and ionising radiation as Saudi Arabia prepares to bring nuclear power into its energy mix by the mid-2030s, introducing demand for uranium to fuel the reactors.

Uranium production cycle activities in Saudi Arabia have been supported by IAEA Technical Co-operation activities, most recently in 2019 with an Integrated Nuclear Infrastructure Review Mission and workshops on “Developing a Policy and Strategy on Nuclear Fuel Cycle” and “Uranium Production Feasibility Studies: Processing, Economic, Social and Environmental Aspects”, all of which focused on the front-end and back-end of the nuclear fuel cycle, as well as project management.

In Uzbekistan, since 1994, the Navoiy Mining and Metallurgy Combinat (NMMC) funded all uranium exploration activities. In January 2022, NMMC was split into three independent entities, with mining (including exploration and development) and processing of natural uranium and rare earth metals organised under Navoiyuran, the sole state uranium mining company in the country. About a year earlier, in December 2019, France and Uzbekistan established the French-Uzbek uranium joint venture, Nurlikum Mining LLC, which is 51% owned by Orano and 49% by Uzbekistan’s State Committee on Geological and Mineral Resources (GoscomGeology). Nurlikum Mining LLC will conduct uranium exploration and mining operations throughout Uzbekistan, focusing on sandstone-type uranium mineralisation in the Djengeldi region of Kyzylkum province. Navoiyuran government exploration is focused on ISL amenable resource expansion at known operating deposits and on resource identification at new prospective areas.

In July 2022, Uzbekistan’s President signed a resolution to double the country’s uranium production from 3 500 tU in 2021 to 7 100 tU in 2030 and increase uranium resources to 100 000 tU by 2030. Uzbekistan’s ability to reach this target will depend on rapid expansion of its resource base, driving significantly increased exploration activity. Navoiyuran exploration expenditures more than tripled during the past four years, from USD 11.3 million in 2020 to USD 38.2 million in 2023. Navoiyuran drilled in a range of 1 539 to 1 734 holes annually during 2020-2022 and plans to increase drilling to 2 551 holes (more than 1 million metres of drilling) in 2023. This activity resulted in the addition of 3 967 tU resources in 2021 and 5 827 tU in 2022, about 95% in the RAR category.

Information on Nurlikum Mining exploration and development expenditures is not available; however, first field exploration commenced in 2020 and by the end of 2022 Nurlikum had carried out more than 50 000 meters of drilling. In June 2023, the company commissioned and started up the pilot plant at the Dzhengeldi deposit to confirm the feasibility of ISL mining. Nurlikum reported indicated resources of 4 070 tU and inferred resources of 2 813 tU.

South-eastern Asia

Uranium exploration and mine development expenditures of less than USD 300 000 for the South-eastern Asia region amounted to <0.1% of total reported global expenditures for the 2020 to 2023 period. Ongoing modest uranium exploration expenditures continue in Indonesia, with Viet Nam reporting some exploration and investigations into uranium processing although associated expenditures have not been reported since 2017.

In Indonesia, exploration expenditures ranged from USD 42 000 in 2020, USD 25 000 in 2021, USD 169 000 in 2022 to USD 53 000 in 2023. Exploration in 2021 was conducted in the Mamuju (geological-radiometric-geomagnetic mapping), Bangka Island (grid-based radon gas survey over the paleo-placer target, including petrographic and geochemistry analysis), and Melawi regions (radiometric and radon gas mapping). In 2022, uranium exploration activities were conducted in co-operation with the Energy and Mineral Resources Ministry to delineate potential rare earth element mining areas in the Melawi (sampling of laterite soils, review of uranium metallogeny in the Kalan basin by sampling all primary uranium sectors, laboratory analysis [XRF and Micro XRF]) and Mamuju regions (semi-detailed 12-hole [approximately 600 m] core drilling campaign, laboratory analysis by ICP-MS and micro XRF scanning for confirmation of mineralisation).

Thailand had no uranium exploration activity. However, from 2017 to 2018, the Royal Thai Department of Mineral Resources (DMR) conducted reconnaissance/regional survey activities for REE deposits in various parts of Thailand that identified uranium and thorium associated with some weathered granitic profiles in the vicinities of Mae Hong Son, Chiang Mai and Tak Provinces.

In Viet Nam, uranium mineralisation is associated with rare earth element deposits (Lao Cai province), phosphate deposits (Cao Bang province), and sandstone and coal deposits (Quang Nam province). Government uranium exploration expenditures amounted to USD 1.8 million and 1.5 million in 2016 and 2017, respectively, but no expenditures have been reported since.

Activities to estimate the uranium potential of 12 orebodies in the Palua-Parong area were undertaken from 2016 to 2019. In support of these efforts, research on ore leaching treatment methods, laboratory and pilot-scale tests, as well as investigations on the management of mining wastes and tailings, have been carried out by the Institute for Technology of Radioactive and Rare Elements (ITRRE). The results show that the heap leach method is suitable for the low-grade Parong ore, with uranium recovery greater than 75% achieved.

Current ITRRE activities are focused on the recovery of thorium and uranium from rare earth concentrates, and a continuous counter-current extraction process for the simultaneous recovery of thorium and uranium from the Yen Phu rare earth concentrate leach solutions was developed. Separation of thorium and uranium from xenotime leach solutions was achieved by solvent extraction using primary and tertiary amines. Results show that the extraction method is suitable for the recovery of thorium and uranium from rare earth concentrate with thorium and uranium purities of greater than 99%. Uranium exploration and research on uranium extraction from uranium ores are continuing but no production centre has been planned to date.

East Asia

Uranium exploration and mine development expenditures in the East Asia region amounted to 33% of total global expenditures in 2020 and approximately 25% for each of 2021, 2022 and expected for 2023, levels much greater than the region's long-term position accounting for 5% of total pre-2016 global expenditures. Whereas some expenditures are reported for Mongolia the region's high share of global expenditures is fully attributable to intensive uranium exploration and mine development efforts by China since about 2007. From 2020 to 2023, China uranium exploration and development expenditures were second only to Canada.

China reported total domestic exploration and mine development expenditures of USD 124 million for each of 2020 and 2021, increasing to USD 202 million for 2022 and 2023. Government exploration expenditures comprised 80% to 85% of the total, followed by industry exploration expenditures and industry development expenditures.

Domestic uranium exploration focused principally on sandstone-type uranium deposits in northern China with positive outcomes, resulting in resource expansion in the Ordos, Yili, Songliao and Erlian Basins. New uranium occurrences were discovered in the Songliao, Junggar, Ordos and Erlian Basins. Exploration work in southern China mainly focused on exploring the deeper parts and periphery of volcanic-related and granite-related uranium deposits, in the Xiangshan uranium ore field in Jiangxi Province, the Xiazhuang and Zhuguang uranium ore fields in Guangdong Province, and the Miaoershan uranium ore field in Guangxi Autonomous Region.

In total, 1 660 000 m drilling was completed between 2021 and 2022 (about 620 000 m in 2021 and 1 040 000 m in 2022), resulting in an increase of uranium resources in northern China basins, such as the Yili, Ordos, Erlian, and Songliao Basins, and a moderate increase of uranium resources in the deeper parts and on the periphery of the Xiangshan, Miaoershan, southern Zhuguang, and Xiazhuang uranium ore fields in southern China. Overall, the exploration efforts resulted in an increase to in situ identified uranium resources of 19%, or 66 200 tU (35 800 tU RAR and 30 400 tU IR) compared to the previous (2022) edition.

Total non-domestic exploration and development expenditures were reported at USD 20.7 million in 2021, USD 20.1 million in 2022 and USD 27.0 million expected for 2023. China National Nuclear Corporation (CNNC) and China General Nuclear Power Corporation (CGN) are involved in several non-domestic uranium mining projects, mainly in Namibia, Kazakhstan and Niger. In 2014, CNNC bought a 25% equity stake from Paladin Energy in its Langer Heinrich uranium mine, which has been in care and maintenance since September 2018. In August 2022, Paladin's board of directors approved a decision to restart operation in 2024 and reach production in 2025 at Langer Heinrich. In 2019, CNNC acquired a 68.62% equity stake of the Rössing uranium mine in Namibia. Uranium production continued through 2021 and 2022 at Rössing, and at CGN's Husab uranium mine also in Namibia. The CNNC Azelik uranium project in Niger remains in care and maintenance since the end of 2014. The CGN-Kazatomprom held Semizbay and Irkol mines in Kazakhstan continued production. In July 2021, CGN acquired a 49% stake of the JV Ortalyk, which owns and operates the operating Central Mynkuduk mine and the Zhalpak mine, which is under construction.

Over the past several years, the IAEA has supported China through the Technical Co-operation programme. Some of the most recent projects include the project "Developing Exploration Techniques for Deep Blind Deposits in Typical Hydrothermal Uranium Ore Fields", which was conducted from 2014 to 2016; "Studying Identification Technology and Technical Economic Evaluation of Typical Sandstone-hosted Concealed Uranium Deposits", which began in 2018; "Implementing Exploration Techniques for Paleochannel Sandstone-Hosted Uranium Deposits and Fluid-Rock Interaction in In-Situ Leaching Processes", carried out from 2020 to 2021; "Evaluating the Technical and Economic Viability of Uranium Resources in Different Exploration Stages", which started in 2022 and ended in 2023; and the current project, "Developing Enhanced Exploration Techniques for Hard Rock Type Uranium Resources and Promoting Green and Efficient Uranium Recovery Technology by External Field Reinforcement", which started in 2024 and is ongoing.

Japan reported annual non-domestic government exploration development expenditures in the range of USD 2.4 million to USD 3.2 million for 2020 to 2023. The Japan Organization for Metals and Energy Security (JOGMEC) continues exploration activities in Uzbekistan and Namibia. Japanese private companies hold shares in companies developing uranium mines and in those operating mines in Australia, Canada, and Kazakhstan

In Mongolia, there was no drilling activity in 2021 to 2022 and annual industry exploration expenditures declined to less than USD 75 000. In 2022 expenditures rebounded to USD 4.2 million with 40 700 m of industry exploration drilling. No development expenditures were reported. Estimates of expenditures or drilling were not available for 2023.

Four companies are engaged in uranium exploration, mainly working in the south Mongolian sedimentary basins, focusing on the identification of sandstone-type uranium mineralisation amenable to ISL mining. Badrakh Energy conducted exploration and development activities during 2019-2020 at the Zuuvch Ovoo and Dulaan Uul uranium deposits in southeast Mongolia. As a result, uranium resources of the Zuuvch Ovoo deposit were increased to 93 300 tU in situ and a technical report was submitted to the Mongolian Professional Committee of Resources in February 2020. After receipt of all required authorisations from government authorities, including validation of an environmental impact assessment and environmental management plan, a pilot ISL test was started in 2021 and operated until December 2022, providing key technical and economic parameters for future ISL commercial production. The pilot test results confirmed the economic and environmental feasibility of the project. A feasibility study is being finalised and is being discussed with the Mineral Resources Professional Council of Mongolia.

Gurvansaikhan LLC holds licences for the Kharaat, Khairkhan, Ulziit and Gurvansaikhan uranium deposits in south Mongolia. Major exploration activities were conducted during 1998-2012 and resources of 23 000 tU accepted by the Mongolian Professional Committee of Resources. The company restarted activities in 2022 and conducted an additional 40 700 m of exploration drilling; it is working on a technical report updating resources according to JORC standards.

An IAEA Technical Co-operation project, Regional Asia Pacific, was initiated in 2016 and continued through 2019. The project, "Conducting the Comprehensive Management and Recovery of Radioactive and Associated Mineral Resources", is aimed at supporting member states in the Asia-Pacific region in developing sustainable mining of deposits with associated radioactive minerals. Uranium production is one potential aspect of economic development in the region where balancing consumption and production is of interest. Most recently in 2022, an Integrated Uranium Production Cycle Review Mission for the Mongolian Nuclear Energy Commission was conducted.

Pacific

Uranium exploration and mine development expenditures in the Pacific region (i.e. Australia) accounted for about 2% of total global expenditures reported for this edition of the Red Book from 2020 through 2023.

In Australia, domestic exploration expenditures by industry declined to USD 4.6 million in 2020, the lowest level since 2003, and subsequently increased to USD 9.3 million and USD 15.0 million in 2021 and 2022 respectively, with USD 16.7 million expected for 2023. During this period, uranium exploration was most active around known resources in Western Australia and South Australia.

In Western Australia, in 2017, the State Government announced a ban on future uranium mining leases but noted that it would not prevent development of four projects that had previously received State Ministerial approval. These projects are, however, subject to legally binding State Ministerial approval conditions and were required to have been substantially commenced within five years from the date of the approval. The Mulga Rock Project is wholly owned by Deep Yellow Ltd, following a merger between Vimy Resources Ltd (the previous owner) and Deep Yellow in August 2022. In September 2021, the Western Australian Department of Mines, Industry Regulation and Safety approved the Mulga Rock mining proposal and associated mine closure plan. The project involves shallow open-pit mining of 4 polymetallic deposits, with a production rate of 1 350 tU/yr for 15 years.

The Yeelirrie deposit, wholly owned by Cameco Australia Pty Ltd, is one of the world's largest surficial uranium deposits. The Yeelirrie Uranium Project, which has proposed production of nearly 3 300 tU/yr over 19 years utilising open-pit mining and alkaline leach technology, received environmental approval from the Commonwealth Government in April 2019. However, the environmental approval that was granted by the Western Australian Government in January 2017 has since expired. The unconformity-related Kintyre uranium deposit, also wholly owned by Cameco Australia Pty Ltd, is well suited for open-pit mining. It is estimated that average production from the Kintyre project would be around 2 290 tU/yr with an estimated mine life of 15 years. Cameco Australia secured Commonwealth and state environmental approval for the Kintyre project in 2015, which has since expired.

The Wiluna Uranium Project is a surficial calcrete-hosted regional resource comprised of six deposits and wholly owned by Toro Energy Ltd. Mining is planned as shallow strip excavation to a maximum depth of 15 m, with estimated average production around 500 tU/yr and 0.7 Mlbs/yr of vanadium pentoxide (V_2O_5) for an estimated mine life of 17 years. The Wiluna Project received Commonwealth and state environmental approval in 2017, with the state environmental approval now expired. In 2023, Toro Energy continued evaluation activities in respect of optimisation of the project, and reported (Toro Energy, 2023) that it intends to apply for an extension to the "substantial commencement" condition that would allow for the future development of the Wiluna Uranium Project.

In South Australia, the sandstone-type Honeymoon deposit (23 300 tU identified recoverable resources), operated by Boss Energy Ltd, has reopened after going into care and maintenance in 2013. ISL mining operations recommenced in early 2024 and production is expected to reach about 1100 tU/yr within 3 years. Alligator Energy Ltd is planning an ISR field recovery trial in 2023/2024 at the Blackbush deposit, one of two uranium deposits comprising the Samphire Project. Outcomes of the trial and further exploration will determine if an application for mining will be sought by the company.

Through 2021 and 2022, Australian-listed mineral companies were involved in uranium exploration activities in other countries. However, non-domestic expenditures are not reported by Australia.

Uranium production

In 2022, 17 countries produced uranium, with the global total amounting to 49 490 tU. Kazakhstan remained by far the world's largest producer, at 43% of global production, even as production continued at scaled back levels. Kazakhstan's production alone in 2022 amounted to more than the combined production from Canada, Namibia, Australia, and Uzbekistan, respectively the second, third, fourth and fifth largest producers of uranium that year. Just six countries accounted for 90% of the world's uranium production in 2022, and the top nine countries accounted for 99%. Russia, Niger, China, and India were respectively the sixth, seventh, eighth and ninth largest producers in 2022. Of the 17 countries that produced uranium in 2022, six produced less than 100 tU for the year, and two of these – Czechia and Hungary, only from mine remediation activities.

Table 1.17 summarises major changes in uranium production and Table 1.18 shows production in all producing countries from 2020 to 2023. Figure 1.5 shows 2022 production shares, and Figure 1.6 illustrates the evolution of production shares over the past decade.

Table 1.17. **Production in select countries and reasons for major changes**

(as of 1 January 2023, tonnes U)

Country	Production 2020	Production 2022	Difference	Reason for changes in production
Australia	6 195	4 555	-1 640	Ranger ceased production in January 2021 (~1 350 tU of difference). Decreased Olympic Dam uranium production (~250 tU).
Brazil	0	43	43	Resumption of production from Caetité production centre (current design capacity of 220 tU/year) through the heap leaching process from Engenho Mine ore.
Canada	3 878	7 380	3 502	Cigar Lake back to full production after COVID-19 pandemic. McArthur River/Key Lake (shut down since 2018) resumed production in Nov 2022.
Kazakhstan	19 477	21 279	1 802	Restoration of uranium production due to favourable market conditions. Increases at Inkai (~500 tU) and Ortalyk (~340 tU).
Namibia	5 412	5 612	200	Continued increase of Husab annual production, although 2022 was negatively impacted by 39 production days lost on account of water shortages.
Niger	2 991	2 020	-971	Production in 2022 is now only from the Arlit mine as the Akouta mine ceased production on 31 March 2021.
Russia	2 846	2 508	-338	Decreased Priargunsky underground mining production (~250 tU). Slight decrease at Khiagda ISL mine (~100 tU) as commercial mining started at new deposits.
Ukraine	711	120	-591	After decreasing to the 700-800 tU range over 2015-2020, production recently decreased further due to resource depletion at higher cost underground mines.

Table 1.18. **Historical uranium production**

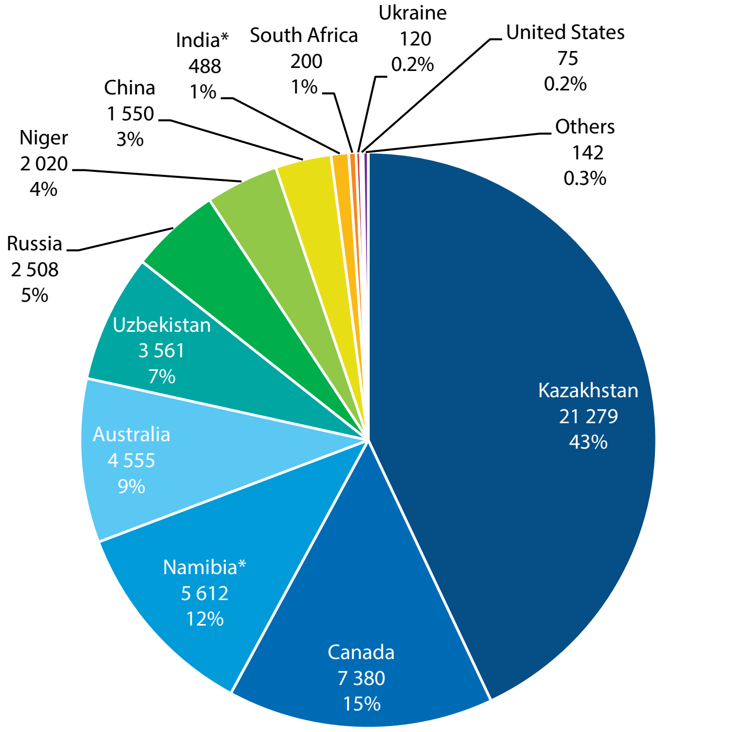
(as of 1 January 2023, tonnes U)

Country	Pre-2020	2020	2021	2022	Total end 2022	2023
Argentina	2 582	0	0	0	2 582	0
Australia	225 641	6 195	3 798	4 555	240 189	4 658
Belgium	686	0	0	0	686	0
Brazil[(a)]	4 257	0	29	43	4 329	171
Bulgaria	16 347	0	0	0	16 347	0
Canada[(b)]	538 869	3 878	4 747	7 380	554 874	10 986
China	47 899	1 600*	1 540	1 550	52 589	1 600
Congo, Dem. Rep. of	25 600	0	0	0	25 600	0
Czechia[(c)]	112 195	34[(e)]	34[(e)]	26[(e)]	112 289	25[(e)]
Finland	30	0	0	0	30	0
France	80 978	0	0	0	80 978	0
Gabon	25 403	0	0	0	25 403	0
Germany[(d)]	219 789	7[(e)]	0	0	219 796	0
Hungary	21 086	3[(e)]	2[(e)]	2[(e)]	21 093	3[(e)]
India*	13 413	540*	450	488	14 891	485
Iran, Islamic Rep of	138	21*	21*	21*	201	21*
Japan	84	0	0	0	84	0
Kazakhstan	361 106	19 477	21 834	21 279	423 696	21 112
Madagascar*	785	0	0	0	785	0
Malawi	4 217	0	0	0	4 217	0
Mexico	49	0	0	0	49	0
Mongolia	535	0	0	0	535	0
Namibia*	142 221	5 412	5 754	5 612	158 999	6 985
Niger	149 121	2 991	2 248	2 020	156 380	1 130
Pakistan[(f)]	1 649	35	47	50	1 781	50*
Poland	650	0	0	0	650	0
Portugal	3 720	0	0	0	3 720	0
Romania	18 974	0	0	0	18 974	0
Russia	173 636	2 846	2 635	2 508	181 625	2 600
Slovak Republic	211	0	0	0	211	0
Slovenia	387	0	0	0	387	0
South Africa[(g)]	161 393	250*	192*	200*	162 035	200*
Spain[(h)]	5 028	0	0	0	5 028	0
Sweden[(h)]	200	0	0	0	200	0
Ukraine	133 729	711	496	120	135 056	300
United States[(i)]	376 990	76*	8	75	377 149	19*
USSR[(k)]	102 886	0	0	0	102 886	0
Uzbekistan	143 966	3 512	3 526	3 561	154 565	4 000
Zambia	86	0	0	0	86	0
Total	**3 116 536**	**47 588**	**47 361**	**49 490**	**3 260 975**	**54 345**
Total OECD-only	**1 586 593**	**10 193**	**8 589**	**12 038**	**1 617 413**	**15 691**

* Secretariat estimate. (a) Pre-2020 total production updated by Brazilian authorities after a review of historical records. (b) Includes 61 tU recovered from recycling refinery wastes from 2014 to 2017. (c) Includes 102 241 tU produced in the former Czechoslovakia and CSFR from 1946 through 1992. (d) Production includes 213 380 tU produced in the former GDR from 1946 through 1989. (e) Production from mine rehabilitation efforts only. (f) Pre-2020 total and 2020 updated consistent with 2017 to 2022 annual production from Pakistan authorities. (g) Pre-2020 total and 2020 production updated consistent with WNA adjusted production figures for 2019 and 2020. (h) For pre-2010, other sources cite 6 156 tU for Spain, 91 tU for Sweden. (i) Secretariat estimate of 2020 production based on industry information, as US data withheld to avoid disclosure of individual company data. (k) Includes production in former Soviet Socialist Republics of Estonia, Kyrgyzstan, Tajikistan, Uzbekistan.

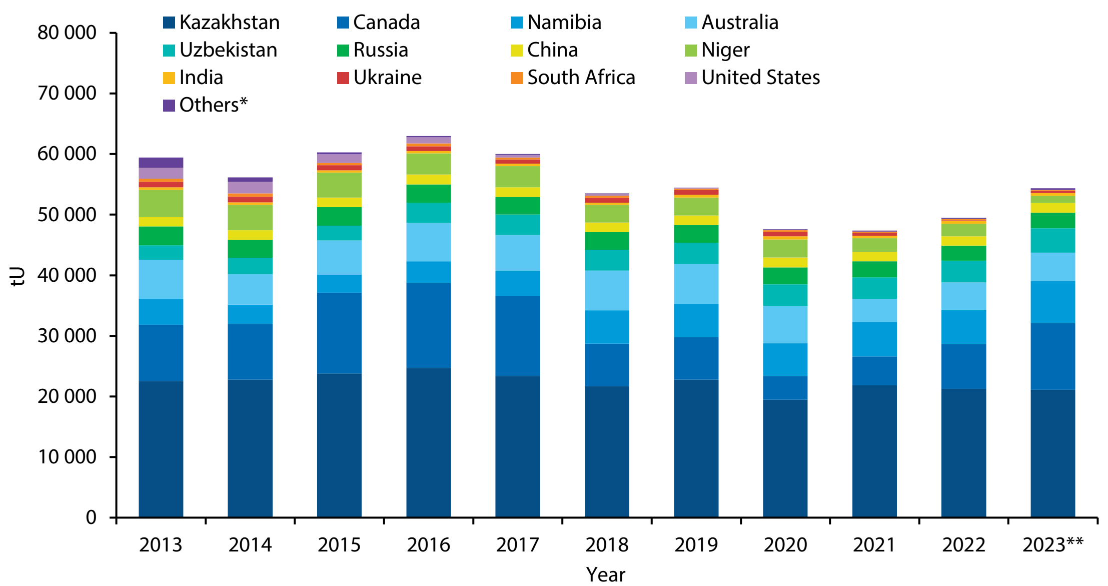
Figure 1.5. **World uranium production 2022: total 49 490 tU**

(as of 1 January 2023; in tU and percent of total production)



* NEA/IAEA estimate.

Figure 1.6. **Last decade of world uranium production**



* "Others" includes the remaining producers (see Table 1.18 and previous Red Book editions).

** NEA/IAEA estimate.

Overall, world uranium production reached its low point in 2020 and 2021 at 47 588 tU and 47 361 tU, respectively, before then increasing 4.5% to 49 490 tU in 2022 and increasing a further 9.8% to 54 345 tU in 2023. Production for 2023 was still just 86% of 2016 peak production of almost 63 000 tU, reached before the impact of broad-based production cuts brought about the five-year period of declining production from 2016 to 2021. Within OECD countries, the 2016 to 2021 decline was even more dramatic, as production decreased from 21 521 tU in 2016 to around 13 750 tU for each of 2018 and 2019, primarily due to production cuts in Canada and the United States in response to the persistently low uranium price market conditions. It then dropped to 10 120 tU in 2020 and further to 8 477 tU in 2021 as COVID-19 production suspensions were implemented and as operations at the Ranger mine in Australia wound down before closing in early 2021. At the 2021 low, this remarkable peak to trough decrease amounted to a 60% reduction from the 2016 OECD production levels. With COVID-19 production suspensions lifted and production resumed at the previously idled McArthur River mine, 2022 and 2023 OECD production recovered strongly, reaching 15 691 tU in 2023, albeit still nearly 6 000 tU less than 2016 production.

With uranium prices having solidly recovered as evidenced by year-end spot prices of USD 47.75/lb U_3O_8 (USD 124/kg U) for 2022 and USD 91.00/lb U_3O_8 (USD 236/kg U) for 2023, producers are now unwinding production cuts of the past years and advancing plans to restart production from idled mines. In February 2024, Cameco provided guidance that its plan is to produce 6 925 tU at each of McArthur River/Key Lake and Cigar Lake in 2024, and that it plans to undertake an evaluation of the work and investment necessary to expand production at McArthur River/Key Lake up to its annual licensed capacity of 9 600 tU (Cameco, 2024). In August 2022, Kazatomprom announced plans to increase Kazakhstan uranium production in 2024 to 10% below subsoil use agreements (WNA, 2022), and in September 2023 announced plans to increase production further in 2025 to 100% of the levels specified in subsoil use agreements (WNA, 2023b). However, due to sulphuric acid shortages the company subsequently reduced guidance for 2024 (WNA, 2024e), a reminder of the numerous risks to increasing, and even maintaining, production rates. Several idled uranium production centres are also now in the process of implementing restart plans or ramping up production.

Present status of uranium production

North America

North American production of 7 455 tU amounted to 15% of world production in 2022, an increase of 3 500 tU (89%) compared to the unusually low 2020 production due to COVID-19 work restrictions in Canada. Improving uranium market conditions are leading to restarts of idled operations in the region that will result in increased production in future years; however, this did not yet have a material impact on 2022 production.

Canada lost its standing as the world's largest uranium producer in 2009 due to production increases in Kazakhstan, though it remains the dominant North American producer and is typically the world's second largest producer. As reported in the previous edition, Canada dropped from second to fourth-largest producer in the world in 2020, as COVID-19 pandemic closures, compounded with operations having been idled for market reasons, resulted in production of 3 878 tU, the lowest level since 1975. As it turns out, 2020 was the low point, and in 2022 Canada was once again the second largest uranium producer, with production accounting for almost 15% of the world total.

Current Canadian uranium production is well below the full licensed production capacity of the uranium mills. Production in 2022 was 7 380 tU, 55% above 2021 production of 4 747 tU, as operations at the Cigar Lake mine returned to full production after being affected by the COVID-19 pandemic, and the McArthur River mine and Key Lake mill, which had been shut down since 2018, resumed production in November 2022. Canadian uranium output is expected to increase as operations at McArthur River and Key Lake ramp up to full production.

The McArthur River mine (Cameco Corporation 70%, Orano Canada Ltd 30%) has identified recoverable resources of 153 000 tU with an average grade of 5.4% U. The Key Lake mill (Cameco 83%, Orano 17%), which along with McArthur River, had been idled since January 2018, resumed production in November 2022, with 442 tU produced from McArthur River ore by year-end.

The Cigar Lake mine (Cameco 54.547%, Orano 40.453%, Tokyo Electric Power Company 5%), with identified resources of 107 200 tU at an average grade of 11.5% U, is the world's third-largest high-grade uranium deposit. Cigar Lake was the world's largest producing uranium mine in 2021 and 2022 as operations returned to full production after being closed for several months in 2020 and 2021 due to the COVID-19 pandemic.

The McClean Lake production centre (Orano 77.5%, Denison Mines Corp. 22.5%) processes the ore from Cigar Lake. Production from Cigar Lake ore was 6 938 tU in 2022, an increase of 48% from 2021 production of 4 679 tU. The McClean Lake mill produced an additional 68 tU in 2021 from McClean Lake ore that was mined using Surface Access Borehole Resource Extraction (SABRE) technology.

The Rabbit Lake production centre (Cameco 100%) was idled in mid-2016 due to low uranium prices, and the facility placed in care and maintenance. Remaining identified resources at the facility's Eagle Point mine amount to 27 000 tU at an average grade of 0.63% U.

Uranium mines in the United States produced 75 tU in 2022 from five facilities: four ISR plants in Nebraska and Wyoming (Crow Butte Operation, Ross CPP, Nichols Ranch, and Smith Ranch-Highland Operation) and the White Mesa Mill in Utah. US production less was less than 100 tU for a fourth consecutive year in 2022, as total production for the four-year period from 2019 to 2022 amounted to only 226 tU. At these low levels, production is understood to be from: in-circuit uranium inventories extracted from Pond Return campaigns, and Alternate Feed Materials processed at the White Mesa Mill, uranium recovered from wellfield reclamation activities at idled ISR operations, and residual from previously developed well fields as they are wound down, as no new well fields were developed during this period.

At the end of 2022, two US uranium in situ recovery (ISR) plants were reported in operating status with a combined capacity of 7.5 million pounds of uranium oxide (U_3O_8) (2 900 tU) per year (the Lost Creek Project and the Smith Ranch-Highland Operation in Wyoming), however both plants had curtailed wellfield development, Smith Ranch-Highland since mid-2016 and Lost Creek more recently. Nine ISR plants were on standby at the end of 2022, and nine new ISR plants were planned across four states: New Mexico, South Dakota, Texas, and Wyoming, many with some degree of permitting or development. Most of these were indefinitely paused, awaiting more favourable market conditions.

Currently, most of the uranium oxide (U_3O_8) commodity and technology used in the uranium enrichment process in the United States comes from foreign sources. US-sourced material accounted for 5% of total deliveries in 2022. In 2021 the government established the Strategic Uranium Reserve and in July 2022 increased its funding to USD 4.3 billion to purchase enriched uranium (i.e. uranium and enrichment services) directly from domestic producers and decrease imports. As part of this programme, the US Department of Energy's National Nuclear Security Administration (NNSA) is overseeing the direct purchase of an estimated 385 tU of domestically produced uranium oxide (U_3O_8), in up to four separate awards. The first awards were approved in December 2022 and the US uranium mining companies are optimistic that this programme, along with increased uranium market prices, will revitalise the US uranium industry.

As a result, numerous US uranium producers and developers have recently been accelerating the restart of idled mines and development of new properties, many of which were in some degree of permitting and development. Notably, enCore Energy Corp. updated the infrastructure of the Rosita ISR processing plant in 2021 and 2022 and subsequently restarted the facility and commenced production late in 2023 (WNA, 2023a). In October 2022, Strata Energy (Peninsula Energy Ltd.) received a licence amendment to convert its Wyoming Lance ISR project to low pH lixiviants, and in 2023 to 2024 has been progressing in the construction of new processing circuits and wellfield development, with a planned early 2025 production start-up of the first low pH ISR (i.e. ISL acid) project in the United States (Peninsula, 2024). In December 2022, Ur-Energy announced plans to restart and ramp up its Wyoming Lost Creek ISR operation to a target production rate of 230 tU/yr (50% of licensed wellfield capacity), and subsequently achieved commercial production restart in May 2023 (Ur-Energy, 2023). In 2023, the US company enCore Energy acquired the Texas, Alta Mesa project in February and brought on a joint venture partner, the Australian company Boss Energy (30%), in December. Work on this project consisted of an upgrading of plant infrastructure and wellfield development, resulting in a June 2024 start-up announcement, with plans to achieve full operational capacity (577 tU/y) by 2026 (WNA, 2024f).

South America

After five years (2016 to 2020) of no uranium production, South America produced 43 tU in 2022 (29 tU in 2021) from the ramp up of the recently restarted Caetité Unit in Brazil. In the region, both Argentina and Brazil look to domestic uranium production to meet domestic demand and are the only countries that have reported historical uranium production.

From 1952 to 1997, Argentina produced 2 582 tU to meet domestic demand. With lower uranium prices, domestic production was no longer competitive, and the last facility in operation, the San Rafael Mining-Milling Complex, was placed on standby in 1997. With domestic uranium requirements now increasing as the country's nuclear generating capacity rises, there is incentive for domestic production. However, regulatory and environmental issues remain to be addressed before uranium production can resume.

In 2004 the National Atomic Energy Commission (CNEA) submitted an EIA for reopening the San Rafael mining-milling complex (Sierra Pintada mine). Mendoza provincial authorities rejected the proposal, requiring CNEA to first remediate the open-pit water and the milling wastes stored in drums before restarting production. In 2019, provincial authorities approved a 2013 update of a 2006 EIA addressing only the treatment of solid wastes and open-pit mine water. Currently, the CNEA is constructing evaporation ponds (three complete, one under construction) and defining the engineering for treatment of open-pit water and the stored milling wastes at the San Rafael complex. Before restarting uranium production at San Rafael, it will also be necessary to obtain provincial approval to amend the provincial law that prevents the use of sulphuric acid and other chemicals that may be used in the operation.

The CNEA continues developing conceptual and prefeasibility studies for the proposed mining of the Cerro Solo deposit (Chubut Province) and several laboratory-scale tests have been carried out to determine the most economically competitive milling process, including possible by-product molybdenum production. The project has been placed on standby because, in addition to technical considerations, a Chubut provincial law preventing open-pit mining remains in effect and a provincial regulatory framework for mining needs to be developed.

Brazil produced 43 tU in 2022, an increase from the 29 tU produced in 2021 as production begins to ramp up from the Caetité Unit, which restarted in 2020. Domestic production in Brazil is designated for domestic requirements with shortfalls between demand and domestic production met through market purchases. Planned uranium production increases are designed to supply all future reactor requirements.

The Caetité Unit (Lagoa Real uranium province), operated by Indústrias Nucleares do Brasil S.A. (INB), is the only uranium production facility currently in operation in Brazil. Production, through the heap leaching of ore from the Cachoeira open-pit mine, started in 1999 and continued until the facility was placed on standby in 2015, as the open-pit portion of the Cachoeira deposit was fully depleted. The Caetité Unit restarted in 2020 and is ramping up to a design capacity of 220 tU/y, through the heap leaching process of the ore of the Engenho open-pit mine.

The expansion of Caetité Unit to 678 tU/yr is progressing and production is expected to start in 2027. Planning for expansion includes production of the Engenho mine and other deposits of Lagoa Real Province, all by open-pit mining (the Cachoeira underground mine is not included in current plans, as had previously been the case), and involves replacement of the current heap leaching process by conventional milling. The overall investment in this expansion project is estimated to amount to USD 120 million.

The Santa Quitéria phosphate/uranium project (1 950 tU/yr design capacity), a partnership between INB and a Brazilian fertiliser producer, is progressing and the operation is scheduled to begin in 2027. Licensing of this project involves the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) and the National Commission of Nuclear Energy (CNEN), with licensing split into a non-nuclear part, involving milling and phosphate production, and a nuclear part, involving uranium concentrate production.

European Union

Uranium production in the European Union (EU) for 2022 amounted to 28 tU, compared to 44 tU reported for 2020. With the end of mining at Rozná in Czechia in 2017 (the last operating mine in the EU), and a new (2021) law in Spain that ends the issuance of new permits for exploitation of radioactive mineral deposits, EU production continues to decline as uranium recovery from mine remediation declines with remediation progress. However, the approval and completion of a uranium byproduct recovery plant in Finland promises a new long-term source of uranium and EU uranium production can be expected to trend to 200 tU/yr beginning in 2026.

Czechia produced 26 tU in 2022, 22 tU from remediation at the Stráz pod Ralskem former acid ISL production centre (since 1996 production has only been from remediation), and 4 tU from mine water treatment at two other former production facilities. Elsewhere in the EU, Hungary reported 2 tU in 2022, also recovered from ongoing mine water treatment in remediation activities. France and Germany had also previously been producing minor amounts as a by-product of mine remediation activities. However, France last reported any such production in 2017 and Germany in 2020. In Germany, at the Königstein mine, uranium will no longer be separated and recovered owing to the decreasing content of uranium and heavy metals in the flood waters in recent years.

In Finland, recent developments have set the stage for future production. In 2021, the Supreme Administrative Court validated the uranium extraction licence that the Finnish government granted in 2020 to Terrafame Oy to recover uranium as a by-product at Terrafame's operating mine in Sotkamo. In 2023 and the first part of 2024 Terrafame completed preparations for the extraction of uranium, and in June 2024 received a positive inspection decision from Finland's Radiation and Nuclear Safety Authority (STUK), clearing the way for commissioning and start-up of the facility (WNA, 2024a). After the ramp-up phase, the uranium recovery plant is estimated to operate at 200 tU/yr full capacity by 2026, with uranium production planned to continue alongside the primary production of other metals throughout the mine's operating period, which covers at least the next 30 years.

Europe (non-EU)

Output from non-EU countries in Europe in 2022 amounted to 2 628 tU, a 26% decrease from 2020. Production declined in Russia by 338 tU and in Ukraine by 591 tU over this two-year period. Production by non-EU countries in Europe in 2022 accounted for about 5% of total global production.

In 2022, uranium production in Russia, carried out by three enterprises that are part of the uranium mining company Uranium Holding ARMZ (JSC Atomredmetzoloto), amounted to 2 508 tU, of which 1 002 tU was obtained by traditional underground mining and 1 506 tU by ISL. Since 2020, uranium production in Russia by underground mining has decreased by 19%, whereas ISL production decreased by 6%.

All underground uranium mining was carried out at mine No. 1 and mine No. 8 of the PJSC Priargunsky Industrial Mining and Chemical Union (recoverable resources of 73 600 tU), with mined ore processed either at a hydrometallurgical plant (906 tU) or heap leaching site (96 tU). During 2020 to 2022, construction of the Mine No. 6 surface complex and infrastructure elements continued at Priargunsky (design capacity of 2 300 tU/yr) for the development of the Argunskoye and Zherlovoye deposits, with the start of mining scheduled for 2026.

JSC Dalur carries out ISL development of the Dalmatovskoye, Khokhlovskoye and Dobrovolnoye deposits (total recoverable resources of 8 700 tU) in the Kurgan Oblast, to maintain 600 tU/yr production capacity, with 585 tU produced in 2022. Pilot mining at the Dobrovolnoye deposit will commence in 2023 and commercial operation is planned for 2029. In the Republic of Buryatia, JSC Khiagda continued ISL uranium mining of deposits at the Khiagda ore field (recoverable resources of 23 400 tU), with 920 tU produced in 2022 and commercial mining started at the Kolichican deposit, while commercial mining at the Dybryn deposit will start in 2023.

In Ukraine, 2022 production amounted to 120 tU by conventional underground mining, a very sharp decline from the 711 tU produced in 2020, due to resource depletion at higher cost mines. The State Enterprise "Eastern Ore Dressing Complex" (VostGOK) operates one hydrometallurgical processing plant (in the town of Zhovti Vody), that processes ore from four underground mining units: Michurinske deposit, Tcentralne deposit, Vatutinske deposit (near town of Smolino), and the Novokostyantynivske deposit. The government approved the decision to shut down mining at the Smolinska mine for the period 2023 to 2027, due to mining resource depletion.

The Ukrainian government's uranium policy includes goals to improve the uranium resource base through the exploration of new uranium deposits and increase uranium production by mining existing uranium deposits. With, the armed conflict in Ukraine ongoing since 2022, it is very likely that such goals are impacted. In 2023, the Ukrainian operator of Nuclear Power Plants SE NNEGC "Energoatom" announced plans to import uranium from Cameco Corporation.

Africa

African production totalled 7 832 tU in 2022, a 9% decrease from 2020, and accounting for about 16% of global production. Production in Namibia, the world's third largest producer in 2022, continued to rise as the Husab operation continued to ramp up to full production capacity. In Niger, production declined substantially as the Akouta mine ceased production in 2021 after nearly 50 years of operation, and as of 2022, the Arlit mine is currently the only producing uranium operation in the country. With improved market conditions uranium production in Africa could surge, as idled mines in Namibia (Langer Heinrich, Trekkopje) and Malawi (Kayelekera) could be returned to production in a relatively short time and mine development projects in Botswana (Letlhakane), Mali (Falea), Mauritania (Tiris), Namibia (Etango, Tumas, Norasa, Marenica, Wings), Niger (Dasa, Madaouela, Imouraen), Tanzania (Mkuju River) and Zambia (Mutanga) could be developed, potentially providing significant production capacity. Development of many of these projects had been stalled due to poor market conditions, but in most cases, activity has quickly picked up again since 2021 and 2022. Occurring after the reporting period for this Red Book edition, a coup d'état in Niger in July 2023 and subsequent political events have led to disruptions and considerable uncertainties within Niger's uranium industry.

Malawi has had no production since the Kayelekera mine was idled in 2014. In August 2022, Lotus Resources Ltd released a Restart Definitive Feasibility Study. Based on the DFS, the Kayelekera restart is expected to require initial capital of USD 88 million, and 15 months of development prior to first production, for a 10-year life of mine at an average 770 tU/yr production rate. As of July 2024, a Final Investment Decision has not been made.

Uranium production in Namibia totalled 5 754 tU in 2021 (Husab 3 310 tU; Rössing 2 444 tU), and 5 612 tU in 2022 (Husab 3 357 tU; Rössing 2 255 tU). In 2023 production increased by 25% from 2022 and reached 6 985 tU (Husab 4 509 tU; Rössing 2 476 tU), a historical record for Namibia. Namibia has good potential for further production increases, considering existing mines, the Langer Heinrich mine restart in 2024, and new developments.

Rössing Uranium is one of the largest and longest operating uranium open-pit mines in the world. Recent mine plans foresaw a cessation of Rössing production at the end of 2026. However, a feasibility study to extend the life-of-mine production to 2037 is under way and the Ministry of Mines and Energy has already extended the Mining Licence to 2036. Based on the study, new investment may be considered from Q3 2023 onwards and contemplate several aspects such as pit and tailing storage facility extensions, plant refurbishment and infrastructure upgrades.

In July 2022 Paladin Energy Limited announced a Final Investment Decision confirming the restart of the Langer Heinrich mine, with first production targeted for early 2024. The Restart Plan has confirmed a 17-year project life with peak production of up to 2 300 tU/yr for the targeted 7 years of mining.

Trekkopje is planned as an open pit with heap leach processing at a production level of 2 54 tU/yr. Much of the initial capital development was completed prior to the project having been placed in care and maintenance in mid-2013. Since then, Orano has continued metallurgical testing, and realised potential for further improvements. Orano has made no announcements regarding resumption of the Trekkopje project.

Husab is one of the largest operating open-pit uranium mines in the world with a nameplate capacity of 5 700 tU/y. Mining started in March 2014, and the processing operation started towards the end of 2016. Since then, Husab Mine has been ramping up its operations reaching 3 310 tU in 2021, 3 357 tU in 2022 (negatively impacted due to 39 production days lost on account of water shortages) and 4 509 tU in 2023 and plans further production ramp up. In August 2023 Swakop Uranium reported that it plans to construct a pilot heap leach plant at Husab, to explore the economic feasibility of processing lower-grade uranium ore.

In addition to the existing operating and idled uranium mines, Namibia also has numerous projects that can be considered as prospective future production centres. Updates on these projects are included in the earlier section titled *Current activities and recent developments*. Decisions on advancing some of these projects are anticipated in the near-term. Bannerman Resources has reported it commenced early development works at the Etango Project (1 350 tU/yr) in anticipation of a Final Investment Decision (FID) during 2024. Reptile Mineral Resources has stated it anticipates an FID later in 2024 on the Tumas Project (1 400 tU/yr). Forsys anticipates an updated DFS in 2024 for its Norasa Uranium Project. And Headspring Investments Pty. anticipates regulatory approvals for start-up of an ISL pilot test for Project Wings.

Production in Niger totalled 2 248 tU (Arlit open-pit mine 1 996 tU; Akouta underground mine 252 tU) in 2021, and 2 020 tU (all from the Arlit mine) in 2022. On 31 March 2021, the Akouta mine, operated by Cominak, ceased production after more than 40 years of operation and 75 000 tU extracted. In October 2022, a new heap leach area was commissioned at Somaïr's Arlit production centre to allow for the processing of low-grade ore, helping to extend the life of mine. It will account for nearly a third of Somaïr's annual capacity (500 to 700 tU/yr). In September 2023, Somaïr halted yellowcake production at Arlit and brought forward plant maintenance initially planned for early 2024, due to political events that resulted in disruption of supplies of chemical products. Only mining operations continued.

In December 2020, Global Atomic Corporation (GAC) received government approval of its mining permit for the Dasa Project and three-year permit extensions for each of its six exploration properties in Niger. The excavation of a box cut for ramp access to the Dasa deposit was completed in 2022, construction of the surface infrastructure started, and underground development of the mine started in November of 2022. Dasa is fully permitted for production, with GAC projecting that first uranium delivery to utilities will commence in 2025.

In June 2024 Orano announced that Niger's authorities had withdrawn the operating permit for the Imouraren uranium mine (WNA, 2024c; Orano, 2024). In July 2024 GoviEx announced that the government had withdrawn its mining rights to the Madaouela, project (WNA, 2024d; GoviEx, 2024). Since the Akouta mine shutdown in 2021, uranium production in Niger was expected to remain near 2022 levels (approximately 2 000 tU) until mines under development in the country, such as Imouraren, Dasa and Madaouela, are brought into production. The political events since July 2023, however, have interrupted production from Arlit, the single operating mine, and disrupted ownership rights to development projects.

Production in South Africa is estimated to have totalled 192 tU in 2021 and 200 tU in 2022. Most of South Africa's historical production has been as a by-product of gold (from the quartz-pebble conglomerate deposits and associated tailings) or, to a minor extent, copper (from the Palabora copper-bearing carbonatite). Uranium is currently produced from Vaal River operations by processing the reef material from the Moab Khotsong (gold) mine. The Moab

Khotsong underground mine, in the northern part of South Africa, represents one of the largest gold and uranium reserves in South Africa (total identified recoverable resources of 8 360 tU).

Most of the uranium projects in South Africa are controlled by gold mining companies. Harmony Gold Mining Company controls the Moab Khotsong mine, the Mponeng projects, Mine Waste Solutions project, Vaal River and Klerksdorpgoldfield surface tailings. In 2022, Sibanye-Stillwater Limited assumed control of the Beatrix (Beisa) underground mine, the Cooke surface operations (tailings), and the Driefontein, Kloof and Randfontein mines. Shiva Uranium Pty controls Dominium and Rietkuil deposits. Under favourable uranium market conditions, future production centres could include the Beisa (underground mine) and Cooke (tailings) projects.

Middle East, Central and Southern Asia

Production in the Middle East, Central and South Asia region amounted to 25 399 tU in 2022, an 8% increase from 2020, and accounting for about 51% of global production. Production is principally by the world's largest producer, Kazakhstan, which accounted for 43% of global production in 2022; however, the region also includes the fifth largest producer, Uzbekistan, and the ninth largest, India, accounting for 7% and 1% of global production respectively. Iran (21 tU) and Pakistan (50 tU) each contribute only 0.1% or less of global production. India, Iran and Pakistan produce uranium for their own use and in each case production meets only a part of their domestic requirements.

Uranium production in India reached 450 tU in 2021 and 488 tU in 2022. Note that for this Red Book edition, India provided a comprehensive country report including reporting of 2021 to 2023 production, whereas for past editions production was not reported. The Uranium Corporation of India Ltd (UCIL) operates six underground uranium mines (Jaduguda, Bhatin, Narwapahar, Turamdih, Bagjata, and Mohuldih), one open-pit mine (Banduhurang), and two processing plants in the Singhbhum East district of Jharkhand state. In addition, UCIL operates a uranium mine and processing plant (Tummalapalle) in the YSR district (formerly Kadapa) of Andhra Pradesh. Ore produced at the Jaduguda, Bhatin, Narwapahar and Bagjata mines is processed at the Jaduguda mill, commissioned in 1968, that can treat about 2 500 t/day of dry ore. Uranium ore from the Turamdih, Banduhurang and Mohuldih mines is processed at the 3 000 t/day Turamdih mill, commissioned in 2009, and currently being expanded to process 4 500 t/day dry ore. The uranium processing plant at Tummalapalle utilises indigenously developed high pressure and temperature alkali leaching technology. The plant was put into operation in 2017 to process 3 000 t/day ore, and expansion to 4 500 t/day ore is planned.

Iran did not provide a report. The IAEA Secretariat prepared a report and estimates based on previous Red Book editions, trade publications, and industry website. According to the Atomic Energy Organization of Iran (AEOI), eight uranium mines were operating in 2023, some of the open-pit operations using heap leaching. AEOI also indicate that Iran's uranium reserves are much larger than previously estimated, and the country plans to operate six more uranium mines by the end of the first quarter of 2024. A uranium processing facility, near Ardakan, began operating in 2017 with a nominal production capacity of 50 tU/yr, supplied with ore from the Saghand uranium mine.

Jordan does not have firm plans to produce uranium. The Jordan Uranium Mining Company is investigating the aspects of uranium production, including installing and commissioning a pilot-scale plant in 2021 to optimise the hydrometallurgical processing and operating parameters for uranium extraction from the Central Jordan Uranium Project deposit and to generate the technical data needed to prepare a bankable feasibility study.

Uranium production in Kazakhstan, was 21 834 tU in 2021 and 21 279 tU in 2022, an increase of 9% from 2020, and accounting for 43% of global production. As of 1 January 2023, the aggregated capacity of 14 existing uranium production centres in Kazakhstan was 25 200 tU/yr. Uranium was produced at the Kanzhugan, Moinkum, Akdala, Mynkuduk, Inkai, Budenovskoye, North and South Karamurun, Irkol, Zarechnoye, Semizbay, Northern Kharasan deposits. All uranium deposits were mined by ISL using sulphuric acid to produce uranium-bearing solutions. The Budenovskoye LLP started pilot mining in 2023 at areas 6 and 7 of the Budenovskoye deposit and plans to move to commercial ISL production in 2024. According to the feasibility study, mine capacity will reach 6 000 t/yr.

With by far the largest share (40%) of the world's lower-cost (<USD 80/kgU) resource base, with 93% of those identified uranium resources associated with existing and committed production centres, and with more than 25 000 tU/yr of existing approved production capacity, Kazakhstan is expected to remain the world's largest producer for the foreseeable future. Since 2018, JSC NAC Kazatomprom flexed down all Kazakhstan production by 20% below subsoil use agreements, to better match supply and demand in the uranium market. In August 2022, Kazatomprom announced plans to increase Kazakhstan uranium production in 2024 to 10% below subsoil use agreements (WNA, 2022), and in September 2023 announced plans to increase production further in 2025 to return production at all joint ventures and subsidiaries to 100% of the levels specified in their subsoil use agreements (WNA, 2023b). On 12 January 2024, Kazatomprom warned that due primarily to sulphuric acid shortages, the company expected production for 2024 would be adjusted (Kazatomprom, 2024) and on 1 February 2024, provided guidance that 2024 uranium production volumes are expected to be 21 000 to 22 500 tU (WNA, 2024e).

Pakistan did not provide a report for this edition; however, information provided by the Pakistan Atomic Energy Commission (PAEC), including production data, assisted the IAEA Secretariat in preparing a country report. Small scale uranium mining is being carried out at selected sites. In 2021 and 2022 uranium production totalled 55 tU and 59 tU, respectively. A major portion of the uranium deposits, at various locations in Sulaiman Range, has been mined out. The deposits discovered at Nangar Nai, Bannu Range, have been tested for ISL mining, as they are hosted in poorly consolidated sandstones where conventional mining methods are considered impracticable and hazardous.

Uzbekistan uranium production amounted to 3 526 tU in 2021 and 3 561 tU in 2022, an increase of 1% from 2020, and accounting for 7% of global production. From 2015 to 2022, Uzbekistan maintained annual production at 3 300 tU to 3 500 tU. Since 1995, Uzbekistan has been producing uranium using only ISL and has developed and implemented two new technologies of acid ISL for ores with high carbonate content, significantly reducing acid consumption and in turn operating costs. In 2022, 18 uranium deposits were in operation and 4 more deposits are planned for development during 2022 to 2026. Mineralisation occurs at depths between 120 to 500 metres.

In January 2022, the Navoiy Mining and Metallurgy Combinat was split into three independent entities: Navoi Mining and Metallurgical Plant (production of precious metals), Navoiyuran (mining and processing of natural uranium and rare earth metals), and Navoi Mining and Metallurgical Plant Foundation. Navoiyuran produces uranium by ISL at three mining divisions: Uchkuduk Mining Unit (former Northern Unit) operates the Kendyktube and Mailisai deposits; Nurabad Mining Unit (former Southern Unit) operates the Sabyrsai deposit; and Zafarabad Mining Unit (former Unit No. 5) is the largest division of the three, and operates the Northern Bukinai, Istikolk, Ketmenchi, Sugraly, Tokhumbet, Kanimekh and other deposits. All mining units produce uranium concentrates on-site that are sent by rail to the hydrometallurgical plant, located in Navoi, for further processing and purification.

In July 2022, Uzbekistan's President signed a resolution to increase the country's uranium production from 3 500 tU to 7 100 tU by 2030. Navoiyuran's ability to reach this target will depend on its ability to rapidly increase its resource base to continue replacing ISL deposits that are being exhausted. Current identified resources are not sufficient to maintain current production levels in the long term. From 2025 to 2030, Navoiyuran plans to modernise operating mines, technologically re-equip and expand existing uranium production facilities.

East Asia

China, the only producing country in East Asia, reported production of 1 540 tU in 2021 and 1 550 tU in 2022, accounting for just over 3% of global production, the eighth largest producer in 2022. From 2013 to 2022, China has maintained annual production between 1 500 tU and 1 650 tU and it expects to produce 1 600 tU in 2023.

In response to production cost challenges brought by sustained low uranium prices, state-owned Chinese uranium companies completed a reorganisation from 2019 to 2022. Several conventional underground uranium mines with depleted uranium resources or with high production costs were either permanently closed (Lantian) or idled and placed on care and maintenance (Chongyi, Qinglong and Fuzhou). Meanwhile, the country's uranium industry continued to increase focus on ISL mining of sandstone uranium deposits in northern China, including further expansion of ISL production capacity in Xin Jiang (Yining) and Inner Mongolia (Tongliao, Erlian Basin). As a result, China's uranium production capacity remained steady, but is now dominated by ISL mining in northern China and supplemented by underground mining in southern China.

Pacific

Australia, the only producing country in the Pacific region, reported production of 3 798 tU in 2021 and 4 555 tU in 2022, a 26% decrease from 2020. Australia contributed just over 9% of global production in 2022 and was the world's fourth-largest producer in 2022. On 8 January 2021, the Ranger mine, located in the Northern Territory and operated by Energy Resources of Australia Ltd., ceased production after 40 years and approximately 112 000 tU produced. The Ranger mine project area will now undergo extensive rehabilitation work that is expected to be completed by 2035. As a result of the closure, as of 1 January 2023, Australia had two operating uranium mines, Olympic Dam (BHP Ltd) and Four Mile (Quasar Resources Pty Ltd), both in South Australia.

The breccia complex-hosted Olympic Dam is Australia's largest uranium mine. In 2022 it contributed around two-thirds (2 813 tU) of Australia's uranium production, as a by-product to primary copper production. Plans for a large expansion have been scaled back and BHP plans to instead steadily increase capacity under existing approvals. The Four Mile ISL mine, in production since 2014, comprises two significant sandstone uranium deposits, Four Mile East and Four Mile West, with uranium-bearing resin from a local satellite plant pumped to the Beverley processing plant for elution, precipitation and drying as uranium concentrate. The Beverley and Beverly North mines are operated by Heathgate Resources Pty Ltd. Beverly was Australia's first ISL mine and started in late 2000.

Also in South Australia, the Honeymoon uranium ISL mine (owned at the time by Uranium One Inc.), began production in 2011 and went into care and maintenance in 2013 due to low uranium prices. The new owner, Australian company, Boss Energy released an Enhanced FS and in June 2022 and restarted ISL mining operations in April 2024, targeting production of up to 1 100 tU/yr.

The Western Australia projects may be prospective future production centres. Updates on these projects are included in the earlier section titled *Current activities and recent developments*. However, none of these projects have an imminent Final Investment Decision. Deep Yellow's Mulga Rock Project, potentially the furthest advanced, has announced plans to commence a revised DFS in 2024 with expected completion in 2025 (Deep Yellow, 2024).

Ownership

Table 1.19 shows the ownership of uranium production for all 17 countries that produced uranium in 2022. Total production share owned by the various categories changed only marginally since 2020. In 2022, 57% of production was attributed to domestic mining companies compared to 56% in 2020. Domestic government-owned entities' share decreased from 45% in 2020 to 42% in 2022, and conversely domestic privately-owned companies share increased from 11% to 15%, primarily because of an increase in production from Canada, a decline in production from Ukraine and the shutdown of the Akouta mine in Niger. Non-domestic mining companies' 43% share of production in 2022 was similar to the 42% of 2020. It should be noted that whereas the relative share of government vs. private non-domestic mining companies is not reported by Australia and the United States, IAEA Secretariat estimates of these splits were applied in this edition, based on publicly available information. Overall, 75% of 2022 world production was related to government-owned entities and 25% to private companies

Table 1.19 provides insight into the structure of the uranium industry across different countries. In ten of the 17 uranium producing countries, production is 100% by domestic government-owned entities. Most of these ten use their production to meet or offset some of their domestic demand, except for Uzbekistan, where the purpose is to sell uranium into world markets. At the other end of the spectrum, four of the 17 countries have no domestic government ownership of the uranium industry – Australia, Canada, South Africa, and the United States. In these countries, uranium operations are generally majority-owned by domestic privately-owned companies, with varying degrees of non-domestic (private or government) ownership. Three of the 17 countries have a mix of domestic government-owned production and non-domestic ownership – Kazakhstan, Namibia, and Niger. In the case of Namibia and Niger, the operator and majority-owner of the uranium operations are the non-domestic entities with minority ownership by the domestic government companies. Kazakhstan is unique, as the domestic government-owned company currently owns a majority of the country's total uranium production, is the operator or holds a significant minority position in each operation and exerts significant control over the country's uranium industry.

Table 1.19. **Ownership of uranium production**

(as of 1 January 2023, based on 2022 production output)

Country	Domestic mining companies				Non-domestic mining companies				Total
	Government-owned		Privately-owned		Government-owned		Privately-owned		
	tU	%	tU	%	tU	%	tU	%	tU
Australia[a]	0	0	2 813	62	0	0	1 742	38	4 555
Brazil	43	100	0	0	0	0	0	0	43
Canada	0	0	4 093	55	2 939	40	347	5	7 380
China	1 550	100	0	0	0	0	0	0	1 550
Czechia	26	100	0	0	0	0	0	0	26
Hungary	2	100	0	0	0	0	0	0	2
India	488	100	0	0	0	0	0	0	488
Iran, Islamic Rep of*	21	100	0	0	0	0	0	0	21
Kazakhstan	11 417	54	0	0	7 037	33	2 825	13	21 279
Namibia*	412	7	0	0	5 143	92	56	1	5 612
Niger	739	37	0	0	1 281	63	0	0	2 020
Pakistan	50	100	0	0	0	0	0	0	50
Russia	2 508	100	0	0	0	0	0	0	2 508
South Africa*	0	0	200	100	0	0	0	0	200
Ukraine	120	100	0	0	0	0	0	0	120
United States[b]	0	0	75	100	0	0	0	0	75
Uzbekistan	3 561	100	0	0	0	0	0	0	3 561
Total	**20 937**	**42%**	**7 181**	**15%**	**16 400**	**33%**	**4 970**	**10%**	**49 490**
Total world production by:									
Government-owned companies	20 937	42%	---	---	16 400	33%	---	---	37 337 (75%)
Privately-owned entities	---	---	7 181	15%	---	---	4 970	10%	12 151 (25%)

* Secretariat estimate. (a) Secretariat estimate of split of non-domestic ownership, as for reasons of confidentiality, Australia does not disclose government vs private ownership information. (b) Secretariat estimate of the split between domestic and non-domestic ownership, as US data withheld to avoid disclosure of individual company data.

Employment

Although the data are incomplete, Table 1.20 shows that employment levels at existing uranium production centres declined by 3% from 2020 to 2022, owing to a decline in employment reported primarily by Australia, Czechia, and Kazakhstan, partially offset by increased employment in Canada. No official employment figures were reported for Namibia, Niger, South Africa and Uzbekistan.

With the recent much improved market outlook and increased activity in the uranium industry, as restarts of mines currently in care and maintenance and other production expansions planned in numerous countries are completed, employment is expected to increase in the longer term, quite significantly in some countries, offset partially by production efficiencies through changes in methods and innovations, and by steady reductions in the countries engaged only in reclamation (i.e. Czechia, Germany) as mine remediation progresses.

Table 1.21 shows employment directly related to uranium production (excluding head office, research and development, pre-development activities, etc.) in selected countries. Figures show that total employment increased by close to 2%, owing primarily to substantial increases reported by Canada and Uzbekistan, partially offset by reductions from Namibia and some other countries.

Table 1.20. **Employment in existing production centres**

(as of 1 January 2023, for listed countries, person-years)

Country	2016	2017	2018	2019	2020	2021	2022	2023 preliminary
Argentina[(a)]	65	58	54	55	51	NA	NA	NA
Australia[(b)]	3 630	4 488	4 559	3 198	4 600	4 300	4 300	4 500
Brazil	680	680	500	550	550	532	537	570
Canada[(c)]	2 246	1 418	1 844	1 824	1 934	1 842	2 381	NA
China	6 750	5 950	2 350	2 290	2 280	2 260	2 240	2 220
Czechia	1 955	1 672	1 557	1 556	1 546	1 066	1 067	1 068
Germany[(a)]	1 043	1 031	1 010	982	911	857	800	750
India	4 741	4 722	4 629	4 672	4 642	4 533	4 456	4 514
Iran, Islamic Rep of	340	290	280*	280*	280*	280*	280*	280*
Kazakhstan[(d)]	8 222	25 224	20 801	20 684	21 186	20 825	20 558	NA
Namibia	4 331	4 881	NA	NA	NA	NA	NA	NA
Niger	3 935	3 843	3 011	NA	NA	NA	NA	NA
Russia	6 077	5 696	6 263	6 163	6 103	6 002	6 099	7 351
South Africa	NA	NA	NA	NA	NA	NA	NA	NA
Ukraine	4 426	4 450	4 275	3 701	3 741	3 721	3 642	3 644
United States[(e)]	462	324	234	155	NA	125	91	NA
Uzbekistan	NA	NA	NA	NA	NA	NA	NA	NA
Total	**48 903**	**64 727**	**51 367**	**46 110**	**47 824**	**46 343**	**46 451**	**24 897**

* Secretariat Estimate. NA = Data not available.

(a) Employment related to decommissioning and mine rehabilitation only.

(b) Olympic Dam does not differentiate between copper, uranium, silver and gold production. Employment has been estimated for uranium-related activities.

(c) Employment at mine sites and head offices.

(d) Total number of Kazatomprom employees reported from 2017 onward.

(e) US data withheld in 2020 to avoid disclosure of individual company data.

Table 1.21. **Employment directly related to uranium production and productivity**

(as of 1 January 2023, for listed countries)

Country	2020		2021		2022	
	Production employment (person-years)	Production (tU)	Production employment (person-years)	Production (tU)	Production employment (person-years)	Production (tU)
Australia[(a)]	2 440	6 195	2 170	3 798	2 170	4 555
Brazil	350	0	184	29	197	43
Canada[(b)]	746	3 878	1 787	4 747	1 930	7 380
China	1 450	1 600*	1 440	1 540	1 430	1 550
Czechia	793	34	560	34	555	26
Iran, Islamic Rep of	95*	21*	95*	21*	95*	21*
Kazakhstan	7 060	19 477	6 710	21 834	6 934	21 279
Namibia	3 319	5 412	2 754	5 754	2 716	5 612
Niger	NA	2 991	NA	2 248	NA	2 020
Russia	4 700	2 846	4 425	2 635	4 668	2 508
South Africa	NA	250	NA	192	NA	200
Ukraine	1 332	711	1 295	496	1 267	120
United States[(c)]	NA	76*	83	8	NA	75
Uzbekistan	7 500	3 512	7 700	3 526	8 372	3 561
Total	**29 785**	**47 003**	**29 203**	**46 862**	**30 334**	**48 950**

* Secretariat estimate. NA = Data not available.

(a) Olympic Dam does not differentiate between copper, uranium, silver and gold production. Employment has been estimated for uranium-related activities.

(b) Employment at mine sites only.

(c) Secretariat estimate of 2020 production based on industry information, as US data withheld to avoid disclosure of individual company data.

Production methods

Historically, uranium had been produced mainly using open-pit and underground mining techniques coupled with conventional uranium processing. Other mining methods include ISL (sometimes referred to as ISR); co-product or by-product recovery from copper, gold and phosphate operations; heap leaching and in-place leaching (also referred to as stope or block leaching). Stope/block leaching involves the extraction of uranium from broken ore without removing it from an underground mine, whereas heap leaching involves the use of a leaching facility on the surface after the ore has been mined. Small amounts of uranium are also recovered from mine water treatment and environmental restoration activities.

Over the past two decades, ISL mining, which uses either acid or alkaline solutions to extract the uranium directly from the deposit, has become increasingly important. The uranium dissolving solutions are injected into and recovered from the ore-bearing zone using a system of wells. ISL technology is currently being used to extract uranium from sandstone deposits only and in recent years has become the dominant method of uranium production.

The distribution of production by type of mining from 2020 through 2023 is shown in Table 1.22. The category "other methods" includes recovery of uranium from water treatment during reclamation and decommissioning activities, and production from processing refinery wastes and alternate feed materials.

ISL technology continues to dominate uranium production, largely because of the rapid growth of this low-cost method of production in Kazakhstan, and to a lesser extent in Australia, China, Russia and Uzbekistan. World uranium production by ISL amounted to nearly 60% of total global production in 2022, followed by underground mining at 18% and open-pit mining at 16%. Mine closures, start-ups and restarts of idled facilities typically explain short-term changes in the distribution. For example, the restart of the McArthur River mine in Canada (idled since 2018) brings back 6 925 tU/yr of underground production starting in 2023. Similarly, the completion and closure in 2021 of the Akouta mine in Niger and the Ranger mine in Australia, removed a significant amount of open-pit production from the mix.

Table 1.22. **World production by production method**

(as of 1 January 2023, per cent)

Production method	2020	2021	2022	2023 preliminary
Open-pit mining	18.5	16.9	15.9	15.6
Underground mining	15.9	15.3	18.0	23.3
ISL	58.2	63.1	59.8	55.4
In-place leaching	0.0	0.0	0.0	0.0
Co-product/by-product	7.0	4.5	6.1	5.5
Heap leaching	0.0	0.0	0.0	0.0
Other	0.0	0.0	0.0	0.0
Total	**100.0**	**100.0**	**100.0**	**100.0**

Projected production capabilities

To assist in developing projections of future uranium availability, member countries were asked to provide projections of *production capability* through 2050 (Table 1.23). Projections for 2030 to 2050 are included for *existing and committed production centres* (A-II columns) and for *existing, committed*, *planned and prospective production centres* (B-II columns) in the <USD 130/kgU category for countries that are either currently producing uranium or have plans and the potential to do so in the near future. Note that both the A-II and B-II scenarios are supported by currently identified (RAR and IR) resources, in the <USD 130/kgU category for all but two countries, whereas India reports resources on a cost unassigned basis, and Pakistan resources are reported in the <USD 260/kgU category. Also note that actual production seldom, if ever, matches full production capability.

Of the 23 countries listed in Table 1.23, only Australia, Brazil, Canada, and Czechia reported projected production capabilities fully to 2050. Finland reported production projections to 2050 rather than capability. Kazakhstan and Russia reported production capability through 2040, whereas Malawi and Ukraine reported only to 2035. No estimates of production capabilities were received from any of the other fourteen countries listed in the table. As a result, numerous Secretariat estimates are incorporated in the table. Firstly, country-specific estimates up to 2040, based on data submitted for past Red Book editions, company reports and other public data, are included for most of the fourteen countries that provided no estimates. Secondly, as almost no countries reported 2045 and 2050 production capability, high-level estimates of the world totals (based on resource availability and depletion for major producers) are incorporated for the world total estimate only, leaving the non-reporting countries entries as NA. Note that totals for 2045 and 2050 therefore do not equal the sum of the listed country entries in the table.

Table 1.23. **World production capability to 2050**

(as of 1 January 2023, tonnes U/year, from identified recoverable resources at costs up to USD 130/kgU)

Country	Uranium Production Capability Projections									
	2030		2035		2040		2045**		2050**	
	A-II	B-II	A-II	B-II	A-II	B-II	A-II	B-II	A-II	B-II
Argentina	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Australia	4 020	11 500	5 700	10 000	4 000	13 000	4 020	4 600	4 020	4 020
Botswana*	0	1 440	0	1 440	0	1 440	0	NA	0	NA
Brazil[(a)]	0	2 630	0	2 630	0	2 630	0	2 630	0	680
Canada	15 000	30 000	15 000	30 000	15 000	30 000	15 000	30 000	15 000	30 000
China*	2 000	2 400	2 000	3 000	1 500	3 500	NA	NA	NA	NA
Czechia[(b)]	40	40	30	30	20	20	10	10	10	10
Finland*	0	250	0	250	0	250	NA	NA	NA	NA
India[(c)]*	960	1 300	1 300	1 300	1 300	1 300	NA	NA	NA	NA
Iran, Islamic Rep of*	70	80	70	80	70	80	NA	NA	NA	NA
Kazakhstan	26 000	29 000	14 000	23 000	9 000	14 000	NA	NA	NA	NA
Malawi	1 000	NA	1 000	NA	NA	NA	NA	NA	NA	NA
Mauritania*	0	770	0	770	0	770	0	770	0	770
Mongolia*	0	800	0	1 200	0	1 600	NA	NA	NA	NA
Namibia*	7 200	7 200	7 200	9 800	7 200	9 800	NA	NA	NA	NA
Niger[(d)]*	4 000	5 500	4 000	8 000	4 000	8 000	NA	NA	NA	NA
Pakistan[(c)]*	59	59	45	45	45	45	NA	NA	NA	NA
Russia	4 900	4 900	4 000	4 000	1 500	1 500	NA	NA	NA	NA
South Africa*	1 000	3 000	1 000	3 000	NA	NA	NA	NA	NA	NA
Tanzania*	0	0	0	3 000	0	3 000	0	NA	0	NA
Ukraine	1 500	1 700	1 500	1 700	NA	NA	NA	NA	NA	NA
United States*	1 500	2 400	350	1 200	350	1 200	NA	NA	NA	NA
Uzbekistan*	3 500	3 500	2 500	3 500	0	1 500	NA	NA	NA	NA
Total**	**72 749**	**108 469**	**59 695**	**107 945**	**43 985**	**93 635**	**35 000**	**72 000**	**26 000**	**60 000**

A-II = Production capability of existing, idled and committed centres supported by identified resources recoverable at <USD 130/kgU.

B-II = Production capability of existing, idled, committed, planned and prospective centres supported by identified resources recoverable at <USD 130/kgU.

* Secretariat estimate.

** Secretariat estimates for 2045 and 2050 totals. As most countries did not report 2045 and 2050 production capability (noted as NA), the Secretariat generated high-level estimates of the world totals for non-reporting countries based on resource availability and depletion for major producers. Totals for 2045 and 2050 do not therefore equal the sum of the listed country entries.

(a) A-II category is 0 at costs up to USD 130/kgU. Engenho mine is currently producing but at >USD 130/kgU and <USD 260/kgU. B-II category excludes Caetité expansion.

(b) Production from remediation.

(c) Production costs not stated but considered high.

(d) Subsequent to political change in July 2023, Niger authorities in June 2024 withdrew the permit to exploit the Imouraren deposit, and in July 2024 withdrew the mining rights for the Madaouela project, raising significant uncertainty regarding planned and prospective production centres (included in B-II capability estimates).

The projected total production capability (rounded to nearest 500 tU) for 2030 is 72 500 tU for existing and committed production centres (A-II), and 108 500 tU when also including planned and prospective centres (B-II). The reported production capability of existing and committed production centres (A-II) for 2025 (not included in Table 1.23) is about 71 000 tU. Expected 2023 production of 54 345 tU thus represents approximately 76% of production capability (assuming A-II production capability estimate for 2025 is a good proxy for 2023 capability). For comparison, in previous editions where calculated, expected production typically ranged between 90% and 75% of production capability.

After adding production capability through the 2003 to 2011 uranium industry expansion on the expectation of continued demand growth, the Fukushima Daiichi shock and sudden demand destruction resulted in a difficult decade for the industry. Typical of sudden demand shocks, even as demand fell, supply continued to grow as large, committed projects continued to completion and started production, such as the Cigar Lake mine in Canada, the continued expansion of production in Kazakhstan, and the Husab mine in Namibia. Over the ensuing years supply side response decisions idled numerous mines (most notably McArthur River mine in Canada) and scaled back production in others (e.g. Kazakhstan mines), reducing annual production by 25% from a high of approximately 63 000 tU in 2016 to a low of approximately 47 500 tU in each of 2020 and 2021. Clearly this results in a situation with excess production capability, even as annual production now begins to recover from the recent low.

The significantly higher estimate of B-II capability also is explained by the last decade. Faced with oversupply and existing mine closures, prospective projects were indefinitely delayed, resulting in a growing "backlog" of sorts of prospective projects as few projects were committed. Since the recovery began in 2020, activity on these pre-existing deferred projects has picked up again and work on newer projects also continues (updates in earlier section titled *Current activities and recent developments*). With many of these projects anticipating Final Investment Decision within the next few years, a clearer picture of expected timeframes will likely emerge.

Projections beyond 2030 show generally decreasing global production capabilities as A-II category estimates decline in response to depletion of resources at existing and committed production centres. B-II production capability remains flat through 2035 before demonstrating a lagged decline due to assumed development of projects.

Recent committed mines and expansions

As expected, following a prolonged period of low market prices, production cuts at existing facilities, and the resulting excess production capability, there were limited new production plans unveiled and the list of committed new mines and expansions (Table 1.24) remains thin. Since the first production from the Husab mine in Namibia in 2016, no new major developments have been completed and some have been delayed. However, three projects are underway.

Table 1.24. **Recent committed mines and expansions**

(as of 1 January 2023, nominal production capacity, tonnes U/year in parentheses)

Country	Production centre	2024	2025	2026	2027	2028	2029
Finland	Terraframe (Talvivaara)(1)	C (200)					
Niger	Dasa(2)		C (1 400)				
Russia	Priargunsky (Mine 6)		Ex (2 300)				

C = Committed.

Ex = Expansion.

1) By-product of nickel, cobalt and zinc production.

2) Underground development started in November 2022, commercial production expected to begin in 2025.

In Finland, the uranium recovery plant at the Talvivaara deposit was completed and approved for operation in June 2024, clearing the way for start-up of by-product recovery of uranium and subsequent ramp-up to 200 tU/yr full capacity by 2026. In Russia, construction of the surface complex and infrastructure elements of new mine No. 6 at the Priargunsky production centre began in 2018. Completion, scheduled for 2025, will increase annual production capacity of this operation by 2 300 tU. In Niger, the Dasa project was approved, excavation of a box cut for ramp access to the Dasa deposit was completed in 2022, construction of the surface infrastructure started, and underground development of the mine started in November of 2022. Project development has since continued and as of July 2024, first uranium production and delivery to utilities is expected in 2025.

With no other firmly scheduled new mines or expansions and considering recent closures of depleted long-running mining operations in Australia (Ranger) and Niger (Akouta), as idled mines are reopened to meet increasing demand, there is a strong likelihood that excess capacity of the past number of years will quickly be taken up and new committed projects will become necessary to replace depleting operations and fill continued growth.

Planned and prospective mines and expansions

An impressive list of planned and prospective mines could be brought into production through 2050 (Table 1.25), but as with existing and committed expansions in Table 1.24, few firm dates of completion have been provided. The potential production rates range from a few hundred tU/yr to approximately equalling the output of the world's largest uranium mine. Listed projects are across 19 different countries, with the counties hosting relatively more substantive production rate projects including Australia, Botswana, Brazil, Canada, Kazakhstan, Mauritania, Namibia, Niger, Russia, Tanzania, Ukraine, the United States and Zambia.

There are, however, many differences between the prospective mines on the list. Some are in jurisdictions (at country level, or at state/province level) that are not supportive of uranium mining. Some jurisdictions are riskier from a geopolitical or security basis, and as the events of 2023 in Niger serve to illustrate, such outlooks can change quickly. Furthermore, some prospective mines are currently being actively advanced as projects, whereas others have effectively been "on the list" for many years but are not being actively advanced. Since few of these have a firm date for first production, most will not be developed until uranium market prices, or uranium demand, remain at levels justifying the investments required to increase production. And each prospective mine will have its own unique technical, environmental and financial parameters that will determine the market signals or other uranium demand criteria required to commit the project for development.

The total nominal production capacity of approximately 80 000 tU/yr (Table 1.25), lends confidence that with appropriate sustained market signals, total annual production capacity could increase substantially in the medium term. However, this is not to suggest that total production capacity could be increased by this amount. Uranium resources base and related mine life of these potential projects, staged replacement of depleting uranium resources as other mines close, competition for labour and other project development resources and access to capital are just some of the factors that will impact the rate of total production capacity growth.

While there is uncertainty surrounding the development of prospective and planned production centres, given the depressed market conditions of recent years, the number of potential production capability additions listed in Table 1.25 underscores the availability of uranium deposits of commercial interest. Since these sites span several stages of approvals, licensing and feasibility assessments, it can reasonably be expected that some will take several years to be brought into production and others may never be. Notwithstanding the time it takes to bring new deposits into production, some of these prospective mine developments will be required to replace production centres that reach the end of mine life as well as to meet demand growth.

Table 1.25. **Planned and prospective mines**

(as of 1 January 2023 with updates to July 2024*)

Country	Mine	Type	Nominal production capacity (tU/yr)	Starting year
Argentina	Cerro Solo	OP	250	NA
	Sierra Pintada	OP	150	NA
	Amarillo Grande	OP	520	NA
	Laguna Salada	OP	300	NA
Australia	Yeelirrie	OP	3 265	NA
	Kintyre	OP	2 290	NA
	Mulga Rock	OP	1 346	NA
	Wiluna	ISL	500	NA
Botswana	Letlhakane	OP	1 440	NA
Brazil	Santa Quitéria	OP	1 950	2027
	Caetité Expansion	OP	678	2030
China	Ordos	ISL	NA	2026
Canada	Arrow[(a)]	UG	8 200	NA
	Phoenix[(a)]	ISL	3 200	NA
	Triple R[(b)]	UG	3 500	NA
	Midwest[(c)]	OP	2 300	NA
	Gryphon	UG	2 900	NA
	Millennium	UG	2 750	NA
	Kiggavik	OP/UG	3 000	NA
	Heldeth Túé	ISL	800	NA
Denmark/Greenland[(d)]	Kvanefjeld	OP	425	NA
India	Gogi	UG	130	2024
	Lambapur-Peddagattu	OP/UG	130	2024
	KPM (Kylleng)	OP	340	2028
Kazakhstan	Budenovskoe 6,7	ISL	6 000	2024
Mauritania	Tiris	OP	770	NA
Mongolia	Badrakh	ISL	1 500	NA
	Emeelt	UG	700	NA
	Gurvansaihan	ISL	400	NA
Namibia	Etango	OP	1 350	NA
	Norasa	OP	2 000	NA
	Tumas	OP	1 400	NA
Niger[(e)]	Dasa	UG	1 400	2025
	Imouraren	OP	5 000	NA
	Madaouela	OP	950	NA
Peru	Macusani	OP	2 350	NA
Russia	Elkon	UG	5 000	2040

Continued on next page.

Table 1.25. **Planned and prospective mines** *(cont'd)*

(as of 1 January 2023 with updates to July 2024*)

Country	Mine	Type	Nominal production capacity (tU/yr)	Starting year
Tanzania	Mkuju River	OP	3 000	2030
Ukraine	Safonivske	ISL	150	NA
	Severinska	UG	1 200	NA
United States	Shirley Basin	ISL	770	2026
	Dewey-Burdock	ISL	385	2026
	Moore Ranch	ISL	1 155	NA
	Reno Creek	ISL	770	NA
	Jab & Antelope	ISL	770	NA
	Burke Hollow	ISL	385	NA
	Goliad	ISL	385	NA
	Churchrock	ISL	385	NA
	Crownpoint	ISL	385	NA
Zambia	Mutanga	OP	920	NA
	Lumwana	OP	650	NA
Total			**80 494**	

* As noted in country reports (as of 1 January 2023) or from public data up to July 2024. In several cases, start-up dates are not known (NA). (a) Environmental assessment permitting process well advanced. (b) Environmental assessment permitting process recently started (EIS submitted in Mar 2024). (c) Alternative mining methods under investigation. (d) Government passed a law prohibiting exploration and exploitation of uranium as of December 2021. (e) Subsequent to political change in July 2023, Niger authorities in June 2024 withdrew the permit to exploit the Imouraren deposit, and in July 2024 withdrew the mining rights for the Madaouela project.

Idled mines

Due to the recent lengthy period of low uranium prices in an oversupplied market, producers were motivated to reduce production to reduce supply to, in turn, put upward pressure on prices. While some producers reduced production, others opted to close operations entirely until market conditions improve sufficiently to justify reopening. These temporarily closed operations, referred to as idled mines (Table 1.26), are defined as those with associated identified uranium resources and processing facilities that have all the necessary licences, permits and agreements for operation and have produced commercially in the past, but were not producing as of 1 January 2023.

As shown in Table 1.26, annual production capacity could be increased relatively rapidly if the listed idled mines are brought back into service. Although each mine operation is unique in terms of operational costs and a threshold price for reopening, the ability to raise capital as required to resume operation and to meet regulatory requirements, idled mines could be returned to production faster, given that all permits and licences remain in place. Decisions to resume production depend principally on increased market prices. With the right market signals, idled mine facilities, associated with a total of at least 202 000 tU in local resources (recoverable), could potentially bring as much as approximately 22 000 tU annually to the market if all are brought back into production. At least some of these facilities can reasonably be expected to be brought back online before new mines are established. This is already happening; the McArthur River/Key Lake operations, having restarted in late 2022, no longer appear on the list. Also, in this edition the bottom section of Table 1.26 lists mines that, although still idled as of 1 January 2023, had a committed restart plan in progress towards resuming production within the 2023 to 2025 period.

The McArthur River (Canada) return to operating status removed 9 600 tU/yr licensed capacity from idled status and has increased global annual production by approximately 7 000 tU/yr as of 2024. The Langer Heinrich (Namibia) restart in early 2024 removes 2 000 tU/yr production capacity from idled status but is ramping up to peak production of up to 2 300 tU/yr for 7 years of its 17-year life-of-mine plan. Similarly, in Australia, the Honeymoon ISL operation restart, also in early 2024, removes 770 tU/yr from idled status, and it is ramping up to about 1100 tU/yr within 3 years. These three cases highlight that listed production capacity in Table 1.26 does not exactly equate with production – in some cases the listed capacity may be a maximum license limit and in other cases a nominal design capacity. Meanwhile, in the United States, two ISR operations in Texas (Rosita, Alta Mesa) have restarted by mid-2024 and are ramping up production, and two in Wyoming (Lance, Lost Creek) are also progressing restarts. On a combined basis, these four restarts are removing 2 425 tU/yr production capacity from idled status. In total, since the uranium price turned, signalling an end to a challenging decade for producers, approximately 15 000 tU/yr of production capacity that had been idled has now been (or is being) returned to operating status.

Table 1.26. **Idled mines***

(as of 1 January 2023 with updates to July 2024**)

Country	Production centre (mine)	Type	Year idled	Production capacity (tU/yr)	Resources (tU)
No announced definitive restart					
Canada	Rabbit Lake	UG	2016	6 500	27 000
China	Chongyi[(a)]	UG	2017	200	NA
	Qinglong[(a)]	UG	2018	100	NA
	Fuzhou[(a)]	UG	2022	350	NA
Malawi	Kaylekera	OP	2014	1 270	14 400
Namibia	Trekkopje[(b)]	OP	2013	3 000	20 030
Niger	Azelik (Somina)[(c)]	OP/UG	2014	700	9 680
United States[(d)]	La Palangana (Hobson)	ISL	2015	385	NA
	Smith Ranch/Highland	ISL	2016	2 100	12 540
	Crow Butte	ISL	2017	385	6 040
	Willow Creek	ISL	2018	1 000	13 770
	Nichols Ranch	ISL	2020	770	3 130
Totals				**16 760**	**106 590**
Recently restarted or committed pending restart in progress* **					
Australia	Honeymoon	ISL	2013	770	23 300
Namibia	Langer Heinrich	OP	2018	2 000	36 830
United States[(d)]	Rosita	ISL	2008	315	NA
	Alta Mesa	ISL	2016	570	7 850
	Ross CPP (Lance)	ISL	2019	770	20 650
	Lost Creek	ISL	2020	770	7 030
Totals				**5 195**	**95 660**

* Idled mines are those with associated identified uranium resources and processing facilities that have all necessary licences, permits and agreements for operation and have produced commercially in the past. ** As noted in country reports (as of 1 January 2023) or from public data up to July 2024. ***As reported in public data. Restarts (first production) range from late 2023 to early 2025. (a) China country report notes that once the international uranium market rebounds, the suspended uranium production centres are expected to restart production. (b) Although not fully satisfying the definition of an idled mine (no commercial production), it is included here because it produced 251 tU and 186 tU in 2012 and 2013 (respectively) as part of two pre-commercial pilot tests. A care and maintenance team regularly provides upkeep of the mine's infrastructure so that it can be recommissioned and brought on stream when market conditions are more favourable. (c) Technical difficulties contributed to decisions to stop production. (d) information on US production centres is secretariat estimate based on company and industry available information, as US country report provides aggregate information.

The upper section of Table 1.26, which lists idled mines with no committed restart announced, highlights the opportunity to add more uranium production, albeit with some caution. The production capacity listed for each of Rabbit Lake and Smith Ranch/Highland is the licensed capacity and the resource base at both operations does not support production at those levels. The Trekkopje project is not strictly an idled mine but a partially completed project, thus requiring substantial investment to bring it to operating status. Technical difficulties contributed to the decision to stop production at Azelik, not just cost or market reasons as most other idled mines. Taken together, it is reasonable to assume that in total, this group of remaining idled mines has the potential to add production at less than the listed production capacity (50% to 60% is a reasonable estimate), that some of these potential restarts would require a higher threshold price for reopening than some of the new projects, and that some may never restart.

Conclusions

Nearly 8 000 000 tonnes of recoverable in-ground uranium resources of economic interest have been identified (recoverable at <USD 260/kgU). Whereas at <USD 130/kgU, approximately 75% of this total remains of economic interest, and at <USD 80/kgU, less than 25% is considered economic. Arguably, the <USD 40/kgU category is no longer relevant, accounting for a little over 8%, and few countries continue to report any resources in this cost category. An important exception is Kazakhstan, where about 57% of identified uranium resources are reported to be recoverable at <USD 40/kgU.

There are, however, many factors affecting the likelihood of recovering these uranium resources and when. For example, fully 17% of global identified resources are attributed to the Olympic Dam deposit, and as uranium is a co-product at Olympic Dam, continued recovery of these resources can be counted on with high confidence, but ability to modify the rate of production in response to uranium demand changes is limited. Some resources are in jurisdictions not currently favourable of uranium mining, some in countries with no or little experience, whereas other resources are in mining friendly jurisdictions. Political risk and stability are important factors in assessing likelihood of when resources are developed – the events since 2023 in Niger, a country that hosts nearly 6% of global identified resources, has already had an impact on the country's uranium industry. Some resources are in countries with policy to produce uranium domestically to meet all, or some, of domestic demand, whereas other resources are located in the global supplier countries (Australia, Canada, Kazakhstan, Namibia, South Africa, Uzbekistan) or those aspiring to be.

In-ground uranium resources will be brought into production when market conditions lend confidence that a given project will return value. Conversely, poor market conditions not only hold back new supply, but also slow investment in uranium exploration, which could affect the delineation of additional lower-cost resources in the longer term. Historically, significant proportions of identified resources have never been extracted, while, on average, the extraction of identified resources has taken one to two decades or more (see, for example, IAEA (2020), Figure 2.75), in addition to several decades for the delineation of undiscovered resources.

The post-Fukushima Daiichi decade (2011 to 2021) was challenging for the uranium industry. The uranium price dropped to well below the marginal cost of production, investment in new projects largely came to a standstill, exploration was severely curtailed, and numerous operations were idled or production output reduced. The reporting period for this edition of the Red Book (calendar years 2021 and 2022) marks the start of a long-awaited recovery phase. The uranium spot price, which had been USD 25/lb U_3O_8 a year earlier, was at about USD 30/lb U_3O_8 (USD 80/kg U) at the start of 2021 and had climbed to about USD 50/lb U_3O_8 (USD 130/kg U) by the start of 2023, and continued to climb through 2023 to a high in January 2024 of USD 106/lb U_3O_8 (USD 275/kg U).

The exploration and mine development expenditures and activities, and the mine production reported in this edition capture the industry response to this improving market after a decade downturn. The early stage of a rebound in exploration and mine development is clearly underway with some long-stalled projects anticipating final investment decisions in the upcoming years. Approximately 50% of the idled production capacity has been, or is in process of being, returned to production; however, the remaining idled capacity can be anticipated to require significantly higher threshold prices and return less production.

Looking ahead, ongoing geopolitical tensions continue to shape the industry, which increase supply security considerations, in turn encouraging the build-up of domestic supplies in some nuclear generating countries and favouring supply from allied or neutral countries. Given the global focus on climate change and the need to greatly increase carbon-free energy generation, growing interest and support for nuclear energy is anticipated to continue to underpin a healthy uranium industry. As a result, some level of demand growth is expected, especially if the joint declaration made by now more than 30 countries and first launched at the 28th Conference of the Parties of the United Nations Framework Convention on Climate Change (COP28) to triple their nuclear energy capacities by 2050, is realised, and if as envisioned there is widespread deployment of small modular reactors. Continued strong uranium prices will be required to deliver the new projects necessary to maintain and increase global production, to incentivise investment in exploration to replace depleted resources and identify new resources, and to support investment in research and development of new and innovative extraction techniques to unlock value from unconventional uranium resources.

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Chapter 2. **Uranium demand and adequacy between supply and demand**

This chapter summarises the current status and projected growth in global nuclear electricity generating capacity and commercial reactor-related uranium requirements up to 2050. The adequacy between uranium supply and demand is analysed and important developments related to the world uranium market are described.

Nuclear generating capacity and reactor-related uranium requirements

On 1 January 2023, a total of 438 commercial nuclear reactors were operational[1] globally in 32 countries, and 58 reactors were under construction.

During 2021 and 2022, 11 reactors were connected to the grid, construction started on 18 reactors and 15 reactors were permanently shut down. Table 2.1 summarises the status of the world's nuclear power plants as of 1 January 2023. The global nuclear power plant fleet generated a total of about 2 683 TWh of electricity in 2021 and about 2 595 TWh in 2022 (see Table 2.2).

World annual uranium requirements amounted to around 59 000 tU as of 1 January 2023.

Global nuclear programmes

OECD member countries

As of 1 January 2023, 283 reactors were operational in 19 OECD member countries and constituted about 65% of the world's nuclear electricity generating capacity. During 2021 and 2022, a total of 16 reactors were under construction in OECD member countries with two additional construction starts in Türkiye. In this same period, 12 reactors were permanently shut down in Belgium, Germany, the United Kingdom and the United States.

Up until 2021, several currently operating reactors, mainly in OECD member countries, were set on a path for early decommissioning due to economic challenges and energy policy decisions. However, in 2022 and 2023 since then, some countries have significantly shifted their energy policies in favour of nuclear energy. This trend is driven by a combination of factors, including security of energy supply and addressing climate change. In those countries . As a result, some nations are revisiting their energy strategies to incorporate or expand their nuclear capabilities.

The OECD reactor-related uranium requirements amounted to around 38 270 tU as of 1 January 2023.

1. Including reactors in suspended operation (27 units).

Table 2.1. **Nuclear data summary**

(as of 1 January 2023)

Country	Operational reactors	Generating capacity (GWe net)	Reactors under construction	Reactor grid connections in 2021-2022	Reactor shutdowns in 2021-2022	Reactors using MOX	2022 uranium requirements (tU)*
Argentina	3	1.6	1	0	0		144
Armenia	1	0.4	0	0	0		64
Bangladesh	0	0.0	2	0	0		0
Belarus	1	1.1	1	0	0		178
Belgium	6	4.9	0	0	1		790
Brazil	2	1.9	1	0	0		386
Bulgaria	2	2.0	0	0	0		343
Canada	19	11.9	0	0	0		1 715
China(a)	54	52.2	20	5	0		10 117
Czechia	6	3.9	0	0	0		658
Egypt	0	0.0	2	0	0		0
Finland	5	4.4	0	1	0		720
France	56	61.4	1	0	0	22	7 000
Germany	3	4.1	0	0	3		649
Hungary	4	1.9	0	0	0		307
India	23	6.9	8	1	0	1	1 350
Iran (Islamic Republic of)	1	0.9	1	0	0		160
Japan	33	31.7	2	0	0	1	1 766
Korea	25	24.5	3	1	0		4 214
Mexico	2	1.6	0	0	0		412
Netherlands	1	0.5	0	0	0	1	77
Pakistan	6	3.3	0	2	1		560
Romania	2	1.3	0	0	0		208
Russia	37	29.6	3	0	1	1	4 400
Slovak Republic	4	1.9	2	0	0		600
Slovenia	1	0.7	0	0	0		149
South Africa	2	1.8	0	0	0		294
Spain	7	7.1	0	0	0		1 109
Sweden	6	6.9	0	0	1		1 110
Switzerland	4	3.0	0	0	0		476
Türkiye	0	0.0	4	0	0		0
Ukraine	15	13.1	2	0	0		1 466
United Arab Emirates	3	4.0	1	2	0		773
United Kingdom	9	5.9	2	0	6		941
United States	92	94.7	2	0	2		15 578
Total World	**438**	**394**	**58**	**12**	**15**	**26**	**59 018**
Total OECD	**283**	**271**	**16**	**2**	**12**	**24**	**38 271**
Total Non-OECD	**155**	**123**	**42**	**10**	**3**	**2**	**20 747**

* When not reported by the country, data are internal estimates by the Secretariat. MOX is not included in uranium requirement figures.

(a) The following data for Chinese Taipei are included in the world total but not in the total for China: three reactors in operation, 2.9 GWe net; 304 tU* as 2022 uranium requirements; no reactor under construction, none started up and one shut down during 2021 and 2022.

Source: i) Government-supplied responses to a questionnaire; ii) IAEA Power Reactor Information System (accessed May 2024), and iii) IAEA Energy, Electricity and Nuclear Power Estimated for the period up to 2050 (IAEA, 2022a, 2023).

Table 2.2. **Electricity generated at nuclear power plants**

(TWh)

Country	2018	2019	2020	2021	2022
Argentina	7	8	10	7	5
Armenia	2	2	3	2	3
Belarus	0	0	0.3	5	4
Belgium	27	41	33	48	42
Brazil	15	15	13	13	13
Bulgaria	15	16	16	16	16
Canada	94	95	92	96	93
China[(a)]	277	330	345	383	418
Czechia	28	29	28	31	31
Finland	22	23	22	23	24
France	396	382	339	361	279
Germany	72	71	61	65	33
Hungary	15	15	15	15	15
India	35	41	40	40	42
Iran (Islamic Republic of)	6	6	6	3	6
Japan	49	66	43	71	56
Korea	127	139	153	151	168
Mexico	13	11	11	12	11
Netherlands	3	4	4	4	4
Pakistan	9	9	10	16	22
Romania	11	10	11	10	10
Russia	191	196	202	222	223
Slovak Republic	14	14	14	14	15
Slovenia	6	6	6	5	5
South Africa	11	14	12	10	12
Spain	53	56	56	54	56
Sweden	66	64	47	51	50
Switzerland	25	25	23	19	23
United Arab Emirates	0	0	2	10	19
Ukraine[(b)]	80	78	72	86	NA
United Kingdom	59	51	46	42	44
United States	808	809	790	772	772
Total World[(c)]	**2 563**	**2 657**	**2 556**	**2 683**	**2 595**
Total OECD	**1 878**	**1 902**	**1 783**	**1 832**	**1 720**
Total Non-OECD	**685**	**755**	**773**	**851**	**875**

(a) The following data for Chinese Taipei are included in the world total, but not in the total for China: 26.7 TWh in 2018; 31.1 in 2019, 30.3 in 2020, 26.8 TWh in 2021, and 22.9 TWh in 2022.

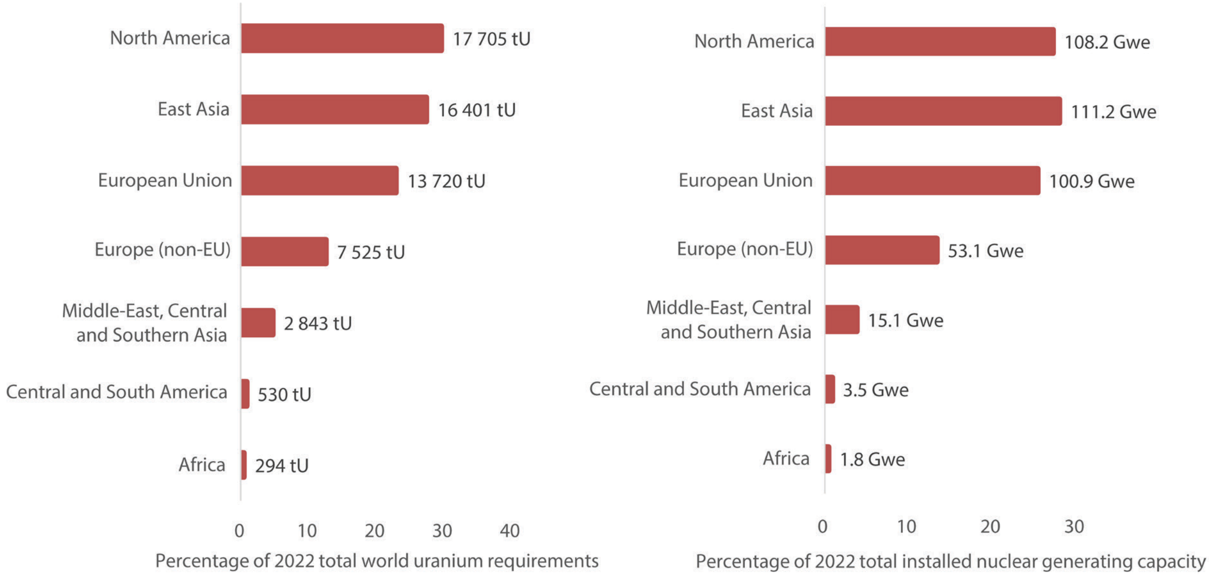
(b) Ukrainian operational data was not available for the year 2022.

(c) All missing data are internal estimates by the Secretariat.

Source: i) Government-supplied responses to a questionnaire; ii) IAEA Energy, Electricity and Nuclear Power Estimated for the period up to 2050 (IAEA, 2022a, 2023).

Figure 2.1. **World uranium requirements (59 018 tU) and total installed nuclear generating capacity (394 GWe)**

(as of 1 January 2023)



European Union

The EU taxonomy Regulation (EU) 2020/852 establishes uniform criteria for determining the degree of environmental sustainability of investments. On 9 March 2022, the European Commission (EC) adopted Delegated Regulation (EU) 2022/1214, which includes criteria for classifying nuclear energy as an environmentally sustainable investment and recognises that nuclear energy can contribute to the decarbonisation of the European Union's economy.

In February 2024, the European Commission launched the SMR Industrial Alliance which aims to facilitate and accelerate the development, demonstration, and deployment of small and advanced modular reactors in Europe by the early 2030s and to ensure a strong EU supply chain, including a skilled workforce. In Belgium, six nuclear power plants provided about 45% of their domestic electricity generation in 2022. Belgium intended to phase out nuclear power by 2025, but those plans were reconsidered and a new law granting a ten-year extension to Doel units 4 and Tihange unit 3 was passed in March 2022. In addition, the government plans to dedicate EUR 100 million over four years to investigate the potential to build new small modular reactors (SMRs).

In Bulgaria, following the closure of four older reactors by the end of 2006, only two units remain operational at the Kozloduy Nuclear Power Plant and provided 32.5% of domestic electricity production in 2022. To compensate for the loss of nuclear generating capacity and to regain its position as a regional low-carbon electricity exporter, the government plans to build new reactors. In May 2019, the government sought strategic investors to revive the Belene project to build two new reactors. In January 2021, the government approved a plan for the potential building of a new nuclear power plant at the existing Kozloduy site and announced discussions with external partners for the potential roll-out of SMRs. In January 2023, in its energy strategy to 2053, the government approved plans to construct 4 new nuclear reactors by 2053 at the Kozloduy and Belene sites. Two AP1000 units at the Kozloduy site are proposed to be built by Westinghouse. In October 2023 the decision to develop the Belene plant was reversed. Bulgaria is also moving away from its past reliance on Russian nuclear fuel and as a part of the supply diversification process, the country signed an agreement with Westinghouse to supply fuel to unit 5 at Kozloduy, and with Framatome to supply fuel for unit 6.

In Czechia, a total of six reactors were operational on 1 January 2023, with an installed capacity of 3.9 GWe net and providing around 37% of domestic electricity production in 2022. In May 2015, the Czech government announced a national energy policy that favours an ambitious increase in nuclear power to about 50-55% by 2050 to reduce carbon emissions. Four new reactors are proposed to be built at two nuclear power plants (2 at the Dukovany site and 2 at the Temelin site) with the target date for the start of commercial operation of the first unit in 2036. In addition, in June 2020, ČEZ stated that it expects to invest about USD 2.3 billion over the next three decades to extend the operating lifetime of the four reactors at Dukovany by a further 20 years to a total of 60 years. In January 2024, the Czech government invited French utility company Electricité de France (EDF) and Korea Hydro and Nuclear Power (KHNP) corporation to provide binding bids for construction of up to four new units. In July 2024, KHNP was selected as the preferred bidder. There is also political support in Czechia to explore new SMR builds in the future. In November 2023, the government approved the Czech SMR Roadmap, where 45 potential SMR host sites were identified.

In Finland, five units with a total generating capacity of 4.4 GWe were operational on 1 January 2023, providing about 35% of domestic electricity generation in 2022. Teollisuuden Voima Oyj (TVO) owns and operates the three units at the Olkiluoto nuclear power plant. The Olkiluoto 3 unit (OL3) construction has suffered numerous delays and cost overruns. TVO was granted an operating licence in 2019 and in April 2020 applied for permission to load fuel. OL3 was connected to the grid in March 2022. The project for the new nuclear site in Pyhäjoki to build a new reactor provided by a consortium with Rosatom was terminated in 2022. There is political support in Finland to consider both new SMR builds as well as new large power plant deployments in the future. Finland has also made significant progress in the management of radioactive waste. Its nuclear waste management company Posiva Oy submitted the application for an operating licence for the world's first deep geological repository for spent fuel at the Olkiluoto site, known as the Onkalo Nuclear Waste Disposal Facility.

In France, 56 operational reactors with a total capacity of 61.4 GWe generated around 63% of domestically produced electricity in 2022. Construction of a new EPR at the Flamanville Nuclear Power Plant began in late 2007. In May 2024 repairs to welds in the Flamanville 3 EPR were completed and deemed compliant by the French Nuclear Safety Authority (ASN). Fuel loading started in May 2024 and grid connection is planned for autumn 2024. In February 2020, unit 1 at Fessenheim was closed, followed by the closure of unit 2 in June 2020. The closure of the Fessenheim reactors was part of the energy policy objective to reduce the share of nuclear power to 50% by 2035. However, in February 2022, France announced plans to build six new EPR-2 units by 2050 and to consider building a further eight to maintain its energy security and to meet climate goals. In January 2023 France abandoned the objective to reduce the share of nuclear power to 50% by 2035, instead, planning to maintain it at more than 50% by 2050.

In Germany, three reactors were operational on 1 January 2023, producing about 6% of domestic electricity generation in 2022. Following the Fukushima Daiichi Nuclear Power Plant accident, the German Cabinet announced that it was accelerating the nuclear phase-out by permanently shutting down the reactors. The Grohnde, Gundremmingen C and Brokdorf power plants were permanently shut down in 2021, and the three most recently built facilities – Isar 2, Emsland and Neckarwestheim were to be permanently shut down by the end of 2022. In November 2022, the German parliament voted that Germany's three remaining nuclear power reactors, still operating in 2022, should continue operating until mid-April 2023 to ensure the security of electricity supply. As a consequence of this decision, all of the remaining German reactors were shut down on 15 April 2023.

In Hungary, four operational VVER reactors at the Paks Nuclear Power Plant (1.9 GWe net capacity) accounted for 47% of the country's electricity generation at the end of 2022. In January 2020, the government approved the new National Energy Strategy 2030 and the National Energy and Climate Plans 2030. The preservation of nuclear generation capacity by replacing and extending the lifespan of existing units at the Paks Nuclear Power Plant nearing the end of their lifetime is one of the key strategic measures for further decarbonisation of the electricity sector. In December 2022, parliament approved plans to extend the operating lifetimes of the four reactors at Paks to 70 years. In August 2022, the Hungarian Atomic Energy Authority issued the construction licence for the two new VVER-1200 reactors at the Paks site. The construction phase was expected to commence in 2022-2023 but was pushed back to early 2025. The units are now scheduled to start operating in 2032. All of Hungary's nuclear fuel supply is currently contracted from TVEL in Russia. In October 2024, Framatome signed a long-term fuel supply contract for Hungary's four existing reactors at the Paks Nuclear Power Plant, starting in 2027.

In the Netherlands, the single operational reactor (0.5 GWe of net capacity) supplied 3% of domestically generated electricity in 2022. The government of the Netherlands has stated in the National Climate Agreement that nuclear power is one of the options for the country's future energy mix. In 2021, the government thus announced plans to construct two new reactors. The government of the Netherlands aims to cut carbon emissions by 50% by 2030 compared to 1990 levels and in its draft Climate Fund for 2024, it has allocated a total of EUR 320 million for various nuclear projects, including the construction of two new large reactors and the development of SMRs.

In Poland, which as of 2023 has no nuclear generating capacity, coal-fired plants generate 70% of domestic electricity. The government continues to advance plans to construct 6 to 9 GWe of new nuclear power generation in the next 20 years. The legal framework for the development of nuclear power was established in 2011 and the Council of Ministers instructed the Ministry of Economy to prepare a new national strategy concerning radioactive waste and spent fuel management. In 2021, the government recommitted to launching a nuclear programme by adopting the Energy Policy of Poland until 2040 (EPP2040), which aims to start construction on the first 1.0-1.6 GWe reactor by 2033. A total of 6 units with a combined capacity of 6-9 GWe should be constructed by 2043 and should provide about 20% of the country's electricity generation. The construction of three Westinghouse AP1000 units in Pomerania at the Lubiatowo-Kopalino site is due to begin in 2026, with commissioning of the first unit in 2033, followed by connection to the grid of subsequent reactors every 2-3 years. In December 2023, a decision-in-principle was granted by the Polish government for the construction of up to 24 BWRX-300 SMR reactors at six possible sites, with plans to build the first block of SMRs by 2030.

In Romania, two Canadian Deuterium Uranium (CANDU) pressurised heavy water reactors (PHWRs) at the Cernavoda Nuclear Power Plant provided around 20% of the electricity generated in the country in 2022. Nuclearelectrica, the state-owned utility that operates the Cernavoda Nuclear Power Plant, has announced plans to refurbish unit 1 of the plant by 2028 in order to extend its operational lifetime for another 30 years. The project to complete Cernavoda units 3 and 4 is now also proceeding and Nuclearelectrica has estimated that unit 3 will start commercial operation by 2031, followed by unit 4 in 2032. In November 2024, during the COP 29 climate conference, an engineering, procurement and construction management contract was signed with the FCSA Joint Venture – comprising Fluor, AtkinsRéalis, Ansaldo Nucleare, and Sargent & Lundy Energie – for the completion of units 3 and 4 of Romania's Cernavoda Nuclear Power Plant. In October 2020, an intergovernmental agreement was signed with the United States by which the United States intends to support the construction of two new Cernavoda reactors and help refurbish unit 1. A similar agreement was signed with Canada in 2021. In March 2019, a Memorandum of Understanding was signed with NuScale Power to evaluate the potential for SMRs in Romania. In November 2021, Romania announced the potential roll-out of SMRs in the country by 2028. The NuScale VOYGR-6 power plant is proposed to be built at the Doicești site within the Muntenia region.

In the Slovak Republic, a total of four reactors were operational as of 1 January 2023 and provided 59% of the country's electricity in 2022. Construction of two additional units (with the net capacity of 0.44 GWe each) at the Mochovce Nuclear Power Plant has been delayed as a result of design safety improvements and technology updates. Mochovce 3 was first connected to the grid on 31 January 2023, while Mochovce 4 is still under construction.

In Slovenia, the single nuclear reactor in operation (Krško, with 0.70 GWe capacity) is jointly owned and operated with Croatia by Nuklearna Elektrana Krško (NEK). The Krško reactor began commercial operation in 1983 and was recently granted a 20-year lifetime extension to 2043. The single unit accounted for about 43% of the electricity generated in Slovenia in 2022, although a proportion of this is exported to partially meet Croatia's electricity requirements. An ambitious programme of safety upgrades at the Krško plant was rolled out after the Fukushima Daiichi Nuclear Power Plant accident and was completed in 2021.

In Spain, seven operational nuclear reactors with a total net capacity of 7.1 GWe generated 20% of domestic electricity supply in 2022. The Ministry for the Ecological Transition and the Demographic Challenge granted permissions: in July 2020, for Almaraz 1 and 2 to operate until 2027 and 2028, respectively, and for Vandellós 2 to operate until 2030; in March 2021, for Cofrentes to operate until 2030; in September 2021, for Ascó 1 to operate until 2030 and for Ascó 2 to operate until 2031; and in November 2024, for Trillo to operate until 2034. In May 2020, the State Company for Radioactive Waste and Decommissioning, Enresa, applied for the phase 1 dismantling authorisation of the Santa Maria de Garoña Nuclear Power Plant. In March 2021, the government approved the national energy and climate plan, which includes the phasing out of nuclear energy between 2027 and 2035.

In Sweden, six operational reactors (with 6.9 GWe net capacity) provided about 30% of domestic electricity supply in 2022. At the end of 2019, Ringhals 2 was shut down after 44 years of operation and the Ringhals 1 reactor finally ceased operations on 31 December 2020. In June 2019, the Swedish Radiation Safety Authority approved Forsmark 1 and 2 to operate for a further ten years, until 2028. For the remaining reactors, plans remain to continue operation for up to 60 years. In November 2023, the Swedish government announced plans for the country's nuclear energy expansion. The country intends to build two large-scale units by 2035 and the equivalent of ten new reactors, including SMRs, by 2045. The updated energy policy replaced the "100% renewable" electricity target by 2040 with a "100% fossil-free" target, and legislation changes now allow new units to be built.

North America

In Canada, 19 operating CANDU PHWRs provided about 13% of the county's electricity needs in 2022. The province of Ontario has 18 of those operating nuclear power reactors across three power plants: Pickering, Darlington and Bruce. In 2023 the government announced plans to start pre-development work and add up to 4.8 GWe of new large-scale nuclear capacity at Bruce Power's existing site. A CAD 26 billion refurbishment plan for Ontario's nuclear reactors will see the sequential refurbishment of four units at the Darlington site and six units at the Bruce site. The refurbishment of the Darlington Nuclear Generating Station began with work on the first reactor in 2016 and is expected to be completed by 2026. The Bruce project started with unit 6 in early 2020 and will be completed by 2033, extending the operational lifespan to 2064. Ontario's third operating nuclear power plant, Pickering, was originally scheduled to shut down in 2020, but the Canadian Nuclear Safety Commission (CNSC) extended the plant's licence to at least 2026. In January 2024, the Canadian government announced plans to refurbish units 5-8 of the Pickering plant. The refurbishment is expected to be completed by the mid-2030s and will extend the operational lifespan for additional 30 years. The federal government and other partners have advanced efforts in priority areas, such as advancing SMR research and development and exploring business partnerships for potential deployment in the late 2020s. The CNSC continues to work to ensure readiness so as to regulate SMRs in Canada. As of June 2021, 12 SMR technology companies had applied to the CNSC for the Pre-Licensing Vendor Design Review process. In January 2023, Ontario Power Generation (OPG), GE Hitachi, SNC-Lavalin, and Aecon signed a contract to develop, engineer and construct a BWRX-300 SMR at OPG's Darlington New Nuclear Project site. The unit is expected to be constructed by late 2028 and start supplying power to the grid in 2029. In July 2023, an announcement was made to build three additional BWRX-300 units at the Darlington site, with these units expected to be connected to the grid between 2034 and 2036.

In Mexico, the two units at the Laguna Verde Nuclear Power Plant (a total of 1.6 GWe net capacity) provided 4.5% of the electricity generated in the country in 2022. Laguna Verde units received permission from the national regulator to operate at the extended power uprate level (120%). In July 2020, Mexico's nuclear regulator approved a 30-year extension to the operating licence of Laguna Verde 1, allowing it to operate until July 2050, and a similar application for a lifetime extension was submitted for unit 2 in 2020.

In the United States, 92 reactors were operational as of 1 January 2023, making it the world's largest producer of nuclear power and contributing 18% of the total electricity generated in the country in 2022. Vogtle-3 AP1000 was connected to the grid in March 2023 and Vogtle-4 in March 2024. In April 2020, Indian Point 2 was shut down four years before the expiry of its operating licence, followed by Indian Point 3 in 2021. Duane Arnold-1 (601 MWe) was shut down in October 2020 and Palisades in 2022. A total of 11 GWe of nuclear capacity in 11 states has thus been shut down prematurely between 2013 and 2022. However, states and utilities are acting in support of nuclear power. For example, the New Jersey Board of Public Utilities voted in 2021 to extend zero emissions credits for nuclear power plants and the Illinois state legislature passed a law that includes about USD 700 million in subsidies over five years to keep the Byron, Dresden and Braidwood nuclear power plants in operation. As of March 2024, 6 reactors have received the operating period licence for up to 80 years and 14 reactors are still under review. In parallel, in 2023, Holtec initiated the process to seek regulatory approval to restart the previously permanently shut down Palisades reactor, with plans to bring it back online by the end of 2025. The US Department of Energy is investing nearly USD 2 billion to support the licensing, construction and demonstration of this first-of-a-kind reactor by 2028. In August 2022, the Inflation Reduction Act was enacted with provisions to support existing and new nuclear developments with investment and tax incentives for both large existing units and newer advanced reactors, as well as funding for developing the domestic supply chain of HALEU fuel and hydrogen production. In February 2022, the Prohibiting Russian Uranium Imports Act came into force. The legislation prohibits the import of Russian-produced unirradiated LEU as well as unirradiated LEU that has been obtained in lieu of banned uranium until the end of 2040. Recognising the critical role of Russian uranium in the global nuclear industry, the law grants waivers to US nuclear plants and utilities to prevent reactor shutdowns and for national security. This waiver process is valid until 1 January 2028 and it establishes annual import limits, starting at 476 metric tonnes in 2024 and decreasing annually.

East Asia

Prospects for nuclear growth are greater in East Asia than in any other region of the world, principally driven by the rapid growth of nuclear capacity in China. Recent changes in the official energy strategy of Japan and Korea have made national reliance on domestic nuclear energy a top priority.

In China, 54 operational reactors with a total installed capacity of 52.2 GWe provided about 5% of the national electricity production in 2022 (56 in 2024). A total of 20 reactors were under construction as of 1 January 2023 (29 in 2024). In the period 2021 to 2022, 4 new reactors were connected to the grid, including the High Temperature Gas-Cooled Reactor-Pebble-bed Module (HTR-PM) at the Shidaowan site in December 2021. Construction of the ACP100 SMR demonstration project at the Changjang site also started. Projected nuclear growth remains strong in China and the country is moving ahead with the planning and construction of new nuclear power plants and the development of domestic Gen III and Gen IV technologies. The government plans to add significant nuclear generating capacity to meet rising energy demand and limit greenhouse gases and other atmospheric emissions since poor air quality, mainly due to emissions from coal-fired plants, is a significant health issue. As China aims to increase its installed nuclear capacity, it is also aiming to become self-sufficient with respect to nuclear fuel supply, and it has initiated several domestic projects, often in co-operation with foreign suppliers, to meet this goal.

In Japan, nuclear energy in 2022 provided only around 6% of domestic electricity generation (from over 30% before 2011). With most of Japan's 33 nuclear power plants out of service, Japanese utilities have been importing large amounts of oil and natural gas for electricity generation, driving electricity prices and greenhouse emissions upward. Nevertheless, the finalisation in 2015 of a new long-term energy policy that envisions nuclear power contributing 20-22% of total energy supply in 2030 represented an important step for a sustained nuclear comeback. In December 2022, the Japanese government adopted a plan to secure a stable electricity supply while working towards carbon neutrality. It entails maximising the use of its existing nuclear fleet (by restarting as many of existing reactors as possible and extending the lifespan of ageing units), coupled with the development of advanced reactors. The new policy also allows for reactors to operate for more than 60 years (compared to the 40-year limit before). Sendai 1 and 2 were the first reactors to restart in 2015, and as of June 2024, a further 10 have restarted. Currently, 13 reactors are in the restart approval process. Reactors that have restarted are also required to construct bunkered backup control centres within five years of regulatory approval to restart. The NRA approved 20-year licence extensions for Takahama 3&4 in May 2024 and for Sendai 1&2 in November 2023. A 20-year licence extension was granted to Tokai 2 BWR in November 2018, to Takahama units 1&2 in June 2016, and to Mihama 3 in November 2016.

In Korea, 25 operational reactors produced around 30% of the total electricity generated in 2022. Construction of three reactors (4.0 GWe additional capacity) was underway. Shin-Hanul unit 1 was connected to the grid in mid-2022 followed by the Shin-Hanul unit 2 at the end of 2023. An energy transition policy was announced in October 2017, outlining a long-term phasing out of nuclear power. However, the newly elected government in 2022 has since changed this policy and set instead a target for nuclear energy to provide a minimum of 30% of electricity in 2030 and 35% by 2036. The government's 10th Electricity Plan (2022-2036) also set the target for exporting 10 new nuclear power units by 2030. The draft of the 11th Basic Electricity Supply and Demand Plan, announced in May 2024, proposed the acceleration of deployment of nuclear power by building three nuclear power plants and one SMR by 2038.

Although Mongolia does not currently have nuclear generating capacity, it has signalled an interest in the use of small and medium-sized reactors.

Europe (non-EU)

This region is undergoing strong growth with several nuclear reactors under construction. Many countries in this region continue to support nuclear power and overall growth in nuclear generating capacity is expected.

In Armenia, the single operational reactor (Metsamor 2, with 0.4 GWe capacity) provided 31% of the electricity generated in the country in 2022. In 2015, the nuclear power plant began a large-scale life extension maintenance programme with the help of Rosatom. In October 2021, the Armenian Nuclear Regulatory Authority (ANRA), the national regulator, extended the operating licence to 2026. A further ten-year life extension was approved by the government in March 2023. According to the Armenian energy sector development plan, construction of one new unit is envisaged.

In Belarus, one operational VVER-1200 reactor (Ostrovets 1) supplied by Rosatom's Atomstroyexport provided 11.7% of the electricity generated in the country in 2022. Ostrovets 1 was connected to the grid in November 2020. The second VVER-1200 reactor, Ostrovets 2, was connected to the grid in May 2023.

In Russia, 37 operational reactors provided about 20% of the total electricity generated in the country in 2022. Russia has brought 10 reactors online in the period 2011-2023, including the two Akademik Lomonosov floating nuclear power plants. In 2021, a contract was signed to build four new floating power units (FPUs), each with a capacity of up to 106 MW, to supply energy to the Baimsky Mining and Processing Plant. As of 1 January 2023, three nuclear reactors were under construction in Russia. In March 2024 construction started on the Leningrad II-3 pressurised water reactor (PWR) unit at the Sosnovy Bor site. In 2021, Rosatom was granted a construction licence for the BREST-OD-300 reactor, a lead-cooled fast reactor. The reactor is due to start operating in 2026 and is part of a pilot demonstration programme aimed at closing the nuclear fuel cycle. In April 2023, a construction licence was also granted for the first land-based SMR in Russia (a water-cooled RITM-200N 55 MW reactor) near Ust-Kuyga in Yakutia. It is planned to be commissioned in 2028.

In Switzerland, four operating reactors produced 36.5% of the electricity generated in the country in 2022. Switzerland's first nuclear power plant, Mühleberg, with an approximate output power of 373 MW, was permanently shut down on 20 December 2019. In 2017, a public referendum was organised for the new Energy Strategy 2050. Under the new law, permits for the construction of new nuclear power plants and basic changes to existing nuclear power plants are prohibited. The existing nuclear power plants may remain in operation for as long as they are declared safe by the Federal Nuclear Safety Inspectorate. In September 2024, the government announced plans to lift the ban on building new nuclear units.

In Türkiye, the government continues to advance its nuclear development programme as its economy faces rapidly escalating electricity demand. Construction of the country's first nuclear power reactor, and the first of four VVER-1200 units at Akkuyu, started in April 2018. Construction of the second and third reactor units at Akkuyu began in 2020 and 2021, respectively. In 2021, preparations began for the construction of the fourth unit. The project is financed and built by Russia under a build-own-operate model. In March 2021, Akkuyu Nuclear, a subsidiary of Russia's Rosatom, received two loans from Sovcombank to finance the construction of the Akkuyu Nuclear Power Plant, with the first unit expected to be in operation in 2025. The Turkish government is also considering building new nuclear units in the future.

In Ukraine, 15 reactors with a combined net installed capacity of 13.1 GWe were operational on 1 January 2023. The government's support for the nuclear industry is strong, with both nuclear newbuilds and existing reactor life extensions being planned. The national energy programme foresees that nuclear energy will continue to generate about 50% of total electricity production by 2035. With the start of the Russia-Ukraine war in 2022, the Zaporizhzhia plant in south-eastern Ukraine became the first operating civil nuclear power plant ever to come under armed attack. Ukraine had been receiving most of its nuclear services and nuclear fuel from Russia. In June 2022, an agreement was signed with Westinghouse that will see the company provide all fuel for the Ukrainian reactors. In addition, Westinghouse plans to build 9 AP1000 units in Ukraine, starting with 2 new units at Khmelnitsky nuclear power plant and complete the construction of third and fourth units at the Khmelnitsky site that are based on VVER-1000 technology. As part of broader efforts to diversify Ukraine's nuclear fuel supply and ensure energy security amid the ongoing conflict with Russia, in 2023 the country signed a significant contract with Cameco. In 2023, Ukraine also entered into an agreement with Urenco for EUP.

In the United Kingdom, 9 operational reactors with a combined capacity of 5.88 GWe net as of 1 January 2023 provided around 14% of the total domestic electricity generation in 2022. Within the next decade, most of the current UK fleet will be shut down. In recent years, the UK government has taken a series of actions to encourage nuclear new build. EDF and the development vehicle NNB Generation Company HPC Limited are constructing two EPRs at Hinkley Point C (3.2 GWe). The reactors are planned to be connected to the grid in 2029 and 2030, respectively. In January 2021, the United Kingdom also entered negotiations with EDF in relation to building two EPR units at the Sizewell C site in Suffolk. A nuclear site licence for the Sizewell C project was granted in May 2024. In addition, the United Kingdom's advanced gas-cooled reactor (AGR) nuclear power stations have been scheduled to progressively reach the end of their operational lives by 2030. The two-unit Dungeness B was shut down in June 2021, while Hunterson B-1 in Scotland ceased operations in November 2021, followed by unit 2 shutting down in January 2022. Hinkley Point B-1 and B-2 units were permanently shut down in August 2022 and in July 2022, respectively. In December 2024, EDF announced life extensions to some of the current UK Advanced Gas Cooled Reactor nuclear power plants. Heysham 1 and Hartlepool will now operate for an additional year until March 2027, while Heysham 2 and Torness will operate for an additional two years to March 2030. The government is investing more than GBP 100 million of innovation funding into advanced nuclear research and development to help the development of SMRs and advanced modular reactors (AMRs) in the United Kingdom.

Middle East, Central and Southern Asia

Nuclear generating capacity in this region is expected to grow in the coming years as governments continue to implement plans to meet rising electricity demand without increasing greenhouse gas emissions.

In Bangladesh, a contract with Rosatom was ratified in 2012 to build two reactors at the Rooppur site. Under the terms of the agreement, Russia will reportedly provide support for construction and infrastructure development, supply fuel for the entire lifetime of the reactors and take back spent fuel. The first safety-related concrete for unit 1 was poured in 2017, with the pour for unit 2 occurring in 2018. The first nuclear unit is expected to start supplying energy to the grid in 2025. Additionally, the government expressed interest in building two more nuclear units at the Rooppur site.

In India, 23 reactors were operational on 1 January 2023, providing about 2.5% of domestic electricity generation in 2022. Agreements in 2008 that granted India the ability to import uranium and nuclear technology have resulted in improved reactor performance. However, concerns about nuclear liability legislation have slowed the development of agreements on imported technology. As of 1 January 2023, construction of eight new reactors was in progress, with three indigenous PHWRs, four VVERs and one sodium fast reactor. In 2024, the Kakrapar-4 PHWR unit was connected to the grid. Fuel loading began in March 2024 at the 500-MWe prototype fast-breeder reactor (PFBR) located at Kalpakkam, Tamil Nadu, marking a milestone and representing a second stage of the country's three-stage nuclear programme. As other countries with PHWR fleets have done, India has started the process of refurbishing its reactors to allow for extended operation. The national plan, announced in April 2023, is to increase nuclear capacity from 6 780 MWe to 22 480 MWe by 2031, with nuclear energy providing nearly 9% of India's electricity by 2047.

In the Islamic Republic of Iran, one operational 900 MW reactor (Bushehr-1) supplied by Atomstroyexport provided 1.8% of domestic electricity production in 2022. The second reactor, Bushehr-2, also of Russian design, has been under construction since 2017 and is expected to start commercial operation in 2028. The government plans to develop additional nuclear capacity in order to reduce its reliance on fossil fuels. Initial construction work on the IR-360 unit at the Darkhowin/Darkhovain site as well as on 5 000 MWe Iran-Hormoz plant was announced in 2022 and 2024, respectively.

In Pakistan, six reactors (with 3.26 GWe net capacity) were operational on 1 January 2023, supplying about 16% of domestic electricity production in 2022. Two HPR1000 reactors at Karachi were connected to the grid in March 2021 and March 2022. As part of an effort to address chronic power shortages, a growing population and increasing electricity demand, the government established the Energy Security Action Plan with a target of installing additional nuclear generating capacity by 2030. The Pakistan Atomic Energy Commission signed a contract with China (CNNC) in 2017 for a Hualong One reactor, the country's third of the kind after two units were installed at Karachi. China's Import and Export Bank is expected to provide a major part of the financing for the unit, Chashma-5.

In the United Arab Emirates, three 4 GWe units provided around 13% of the domestic electricity production in 2022. In 2009, the Emirates Nuclear Energy Corporation (ENEC) announced that it had selected a bid from a Korean consortium to build four APR1400 reactors, to be built at the Barakah site. The first reactor was connected to the grid in August 2020, followed by the second and third reactors in September 2021 and October 2022, respectively. In March 2024, one PWR that had been under construction at the Barakah Nuclear Power Plant was connected to the grid. The construction of two further units at Barakah as well as a second nuclear power plant has been proposed.

Other countries in the region, currently without nuclear power plants, have been considering the development of such facilities.

Jordan currently has no nuclear generating capacity. A plan to construct two 1 000 MWe reactors to generate electricity and desalinate water, and to develop the country's uranium resources, moved forward, driven by rising energy demand and the need to reduce energy imports, which account for over 95% of national needs. However, the project to build the two VVER reactors has since been cancelled and the country is now considering SMRs instead. In 2018, Jordan signed several co-operation agreements with CNNC, Rolls-Royce, NuScale, X-energy and Rosatom.

Kazakhstan continued to be the world's largest uranium producer in 2022, but the country has no active nuclear power generation capacity. In May 2014, Russia and Kazakhstan signed a preliminary co-operation agreement regarding the construction of a new nuclear power plant with generating capacity of between 300 and 1 200 MWe. In August 2023, the government announced that Ulken village in the Almaty region is considered the main option for the location of a nuclear power plant. In October 2024, a referendum was held in Kazakhstan, during which a significant majority of voters supported the construction of a nuclear power plant. In addition to the large nuclear power plant, the government is also considering adding SMRs to its nuclear fleet.

Saudi Arabia is seeking to build its first nuclear power plant and has solicited information from various vendors from China, France, Korea, Russia and the United States. In January 2021, the energy minister said that the country is committed to becoming carbon neutral and that it aimed to produce 50% of its electricity from renewables by 2030, with the remaining 50% supplied by natural gas. The country plans to first construct two 1.4 GWe PWR nuclear units and then expand the nuclear fleet to 17 GWe by 2040.

In Uzbekistan, the world's fifth largest uranium producer as of 2022, a ten-year plan for the electricity sector was developed in 2020 with the Asian Development Bank and the World Bank. It aims to develop up to 30 GW of additional power capacity by 2030, including 5 GW of solar power, 3.8 GW of hydro energy, 2.4 GW of nuclear energy, and up to 3 GW of wind power. In May 2020, the country's Ministry of Energy published a report on its strategy for electricity generation through 2030, which forecasts 15% of the country's electricity coming from nuclear energy by 2030, with 8% from solar and 7% from wind. In 2018, the Uzbek Agency for the Development of Nuclear Energy (UzAtom) signed an agreement with Russia's Rosatom to build Uzbekistan's two first VVER-1200 PWRs. In addition, in May 2024, Uzbekistan and Russia signed a contract to construct a six-unit SMR nuclear power plant with a total capacity of 330 MW. In September 2024, the protocol was signed signifying the start of works at the construction site.

Central and South America

Governments in Argentina and Brazil continue to support nuclear power, suggesting some growth in nuclear generating capacity in the long term despite other countries in the region reportedly turning away from nuclear energy following the Fukushima Daiichi accident.

In Argentina, three reactors were operational on 1 January 2023, accounting for about 5% of domestic electricity production in 2022. The Embalse reactor returned to service in 2020 following a three-year upgrade and refurbishment programme that will allow it to operate for a further 30 years. Atucha 1, which currently has a licence to operate until 2024, is expected to have its licence extended for 20-25 years, with the three-year refurbishment work starting in 2024. Work continues on the Carem-25 SMR at the site adjacent to the Atucha Nuclear Power Plant. In July 2021, a contract was signed between Nucleoelectrica (NA-SA) Argentina and the country's National Atomic Energy Commission to complete construction of the Carem-25 within three years. There are also plans to build the third PHWR at Atucha by 2032.

In Brazil, two reactors (Angra 1 and 2, with 0.5 GWe and 1.3 GWe net capacity, respectively) were operational on 1 January 2023, providing about 2% of electricity generated in the country in 2022. Construction of the Angra-3 reactor (1.2 GWe net) was restarted in 2022 after being suspended in 2015 but operations were once again suspended in 2023. The national long-term electricity supply plan includes installing 10 GWe of nuclear generating capacity in the next 30 years to help meet rising energy demand.

Other countries in the region, including Bolivia, Chile and Cuba, do not have nuclear power plants but have been considering their deployment.

Africa

Nuclear capacity remained constant in Africa, with the region's only two operational reactors located in South Africa. However, government plans to increase nuclear generating capacity are projected to drive growth in this region.

In South Africa, two operational units (for a total of 1.86 GWe net capacity) accounted for about 4.5% of the total electricity generated in the country in 2022. Early in 2020, South Africa's government issued a nuclear energy roadmap calling for the development of 2.5 GWe of new nuclear capacity, including SMRs, to bolster employment, enhance energy security and reduce carbon emissions. The bidding process was launched in March 2024 but was then paused in August 2024. According to the South Africa's National Infrastructure Plan 2050, released in March 2022, the country plans to add 9.6 GWe of new nuclear capacity in the coming decades.

In Egypt, as of 1 January 2023, two (out of four) VVER-1200 units at the country's first nuclear power plant at the El Dabaa site were under construction. Units 1&2 began construction in 2022, while construction of unit 3 and unit 4 started in May 2023 and January 2024, respectively. Egypt's energy minister and Russia's Rosatom had previously signed several contracts, including a "turnkey" contract that provided for the supply of nuclear fuel for the plant's 60-year operating period. Previously, the Egyptian President had issued a decree approving a USD 25 billion loan from Russia to Egypt covering 85% of the project costs.

Although no other countries in Africa have nuclear power plants, several have expressed interest in recent years in developing nuclear power for electricity generation and desalination, including Algeria, Ghana, Kenya, Morocco, Namibia, Niger, Nigeria, Rwanda, Tanzania, Tunisia and Uganda. In 2022, the President of Ghana approved plans to construct its first 1 GWe nuclear power plant. Ghana is also interested in adopting SMR technology.

South-eastern Asia

No reactors were operational in this region at the end of 2022, but several countries are considering nuclear development plans, as the region continues to experience strong economic growth. Concerns about climate change, security of energy supply and energy mix diversification along with volatile fossil fuel prices are driving nuclear development policies, but political support has generally been weak owing to public safety and cost concerns.

Malaysia adopted a target of 2 GWe of nuclear generating capacity in 2011, driven by an emerging gap in electricity production and the need to diversify the energy mix. However, it was reported that the programme was postponed as a result of public distrust following the Fukushima Daiichi Nuclear Power Plant accident. Work continues through efforts to promote public acceptance, adopt the necessary regulations, sign required international treaties and obtain low-cost financing.

Thailand currently relies on natural gas to generate up to 70% of its electricity. In an earlier power development plan, Thailand planned to commission its first nuclear power plant in 2020. However, the project faced delays following Japan's Fukushima Daiichi Nuclear Power Plant accident in 2011. Currently, Thailand is considering the construction of SMRs.

In Viet Nam, the government had a goal in the years 2000 for nuclear power to supply as much as 25% of domestic electricity production by 2050, due largely to increasing electricity demand. In 2015, Rosatom and Electricity of Vietnam signed a framework agreement for the construction of unit 1 at the proposed Ninh Thuan Nuclear Power Plant. However, shortly thereafter, in November 2016, the Vietnamese Parliament voted to abandon its nuclear programme in favour of gas and coal. In 2022, the Viet Nam's Ministry of Industry and Trade proposed developing nuclear energy towards 2045.

The governments of Indonesia, the Philippines and Singapore have considered the use of nuclear power to help meet rising electricity demand despite some concerns about large-scale natural hazards. In December 2022, Indonesia announced that it aims to start developing its first nuclear power plant by 2039.

Pacific

This region has no commercial nuclear capacity at present. Current policy prohibits the development of commercial nuclear energy in Australia.

Projected nuclear power capacity and related uranium requirements to 2050

Factors affecting nuclear capacity and uranium requirements

Reactor-related requirements for uranium over the short term are fundamentally determined by installed nuclear capacity. Since near-term capacity is made up of reactors that are either already in operation or under construction, short-term requirements can be projected with greater certainty. However, even with a fixed installed nuclear capacity, uranium requirements also depend on other factors linked to the performance and operation of installed nuclear power plants and fuel cycle facilities. These factors include fuel cycle length, enrichment level, discharge burn-up, as well as strategies employed to optimise enrichment services according to the price of natural uranium (NatU), as reflected in the level of tails assay chosen in the enrichment phase (the tails assay selected by the enrichment provider is dependent on many factors, including the ratio between natural uranium and enrichment services prices). Generally, increased uranium prices have provided an incentive for utilities to reduce uranium requirements by specifying lower tails assays at enrichment facilities, to the extent possible.

Following the Fukushima Daiichi Nuclear Power Plant accident, excess capacity in the enrichment market incentivised operators to “underfeed” enrichment facilities by extracting more ^{235}U from the uranium feedstock (lower tails assays). This reduces the amount of natural uranium required to produce contracted quantities of enriched uranium and, in turn, may create a surplus of natural uranium feedstock. In recognition of these market trends, and since the 2012 edition of the Red Book, uranium requirements for the operational lifetime of projected new reactors in this publication have been reduced from 175 tU/GWe/yr, the original assumption being a tails assay of 0.30%, to 160 tU/GWe/yr, under the new assumption of a tails assay of 0.25% over the lifetime of the reactor. In the absence of data provided by governments, this is the uranium requirement factor which has been applied in this edition of the Red Book. These assumptions are valid for the commercial light water reactors (LWRs) currently in operation, most of which implement a once-through fuel cycle. These uranium requirements are also highly dependent on the discharge burnup of the fuel and the level of enrichment. It is important to note that new, advanced reactor technologies that may be deployed in the future, and which consider different fuels, fuel burnups, and fuel cycle choices, may have different requirements (see Box 2.1 on SMRs and HALEU).

Energy availability and capacity (or load) factors also play an important role in determining uranium requirements. Load factors of reactors in operation today tend to be of around 80%. In 2022, the average energy availability factor calculated for all the reactors in commercial operation reactors in the world was of 80.6% (IAEA, 2022b).

World uranium requirements, which are defined in the Red Book as anticipated acquisitions, not necessarily consumption, are expected to increase in the coming years as a significant amount of capacity currently under construction comes online, particularly in Asia. Installation of new nuclear capacity will increase uranium requirements, not only because of the additional reactor capacity that will have to be fuelled but also because first load fuel requirements are around 60% higher than reloads for plants in operation. The strong performance and economic competitiveness of existing plants has made their retention and improvement desirable in many countries. This has resulted in a trend to keep existing plants operating for as long as can be achieved safely, and upgrading existing generating capacity where possible (i.e. up-rating and enabling long-term operation).

Box 2.1. **SMRs and high-assay low-enriched uranium (HALEU)**

High-assay low-enriched uranium (HALEU), enriched between 5% and 20%, is expected to play a significant role in the deployment of small modular reactors (SMRs), particularly those incorporating advanced nuclear technologies such as Generation IV designs. Many SMR developers are selecting HALEU for its ability to meet critical operational needs, making it essential for unlocking the potential of numerous SMR designs in both energy and industrial applications. Additionally, resource efficiency will be pivotal in supporting the long-term growth of nuclear power.

In September 2024, the NEA published *High-Assay Low-Enriched Uranium: Drivers, Implications, and Security of Supply (*NEA, 2024b) to provide policymakers in NEA member countries with evidence-based analysis on HALEU adoption. The report examines the driving forces and implications of HALEU use, advances a strategic vision for its role in achieving energy goals, and addresses considerations related to safety, security and natural resource utilisation. It also offers guidance for developing HALEU-based or HALEU-ready fuel cycles. Some of the key drivers and implications include:

Enabling compact core designs

Many SMRs utilise compact core designs, requiring higher uranium enrichment to achieve and sustain a critical configuration (i.e. a sustained, controlled nuclear fission chain reaction). HALEU's higher enrichment levels are essential for many of these reactor core designs, allowing them to achieve a smaller physical footprint.

Enabling higher burn-up and longer operational cycles

HALEU enables SMRs to achieve higher burn-up rates, resulting in more efficient fuel use and longer periods between refuelling. This is particularly beneficial for remote or off-grid locations where refuelling logistics can be expensive and complex. Fewer refuelling requirements reduce operational downtime and costs, while also lowering risks associated with frequent fuel handling.

Enabling higher outlet temperatures for industrial applications

SMRs designed for industrial applications such as hydrogen production, desalination, or district heating rely on HALEU-based fuel designs that can deliver high outlet temperatures. This makes HALEU-fuelled SMRs versatile for a range of high-temperature processes, expanding their use beyond electricity generation.

Alternative to plutonium in initial fast reactor cores

HALEU also provides a viable alternative to plutonium for initial cores in fast reactors, especially in countries without existing plutonium stocks.

Impact on natural uranium consumption and fuel cycle considerations

The use of HALEU has important implications for natural uranium consumption and other front-end of the fuel cycle requirements (like conversion and enrichment capacities). Due to its higher enrichment levels, HALEU-fuelled SMRs may require more natural uranium feedstock per unit of energy produced compared to conventional light water reactors (LWRs). Key factors to consider when assessing the impact of HALEU on natural uranium consumption are both enrichment levels and fuel burn-up rates. Careful consideration of these parameters will be essential for ensuring a more efficient use of uranium resources in the future.

As nuclear capacity expands – potentially tripling by 2050 – this increased demand from HALEU-fuelled SMRs highlights the urgent need for effective resource management strategies. The once-through fuel cycle, where spent fuel is disposed of after a single use, may not be sustainable in the context of significant nuclear growth and resource limitations. Advanced fuel cycles, including recycling and reprocessing, offer a more efficient use of uranium resources. A full evaluation of the fuel cycle, from mining, conversion and enrichment to waste management, is essential when considering HALEU fuels. Early analysis of waste characteristics is required to ensure compatibility with existing disposal solutions or to develop new approaches if necessary.

As nuclear energy grows, international co-operation will be critical to ensuring a secure supply of HALEU, optimising fuel cycles, and aligning regulatory frameworks. Maximising resource efficiency will also be key in supporting the long-term growth of nuclear power.

Projections to 2050

Projections of nuclear capacity and reactor-related uranium requirements rely on official responses from member countries to questionnaires circulated by the NEA/IAEA to Uranium Group members[2]. Because of the uncertainty in nuclear programmes from 2022 onwards, high and low-case scenarios are provided. The low-case scenario assumes current market and technology trends continue with few additional changes in policies and regulations affecting nuclear power and includes implementation of phase-out or reduced nuclear generation policies, if these exist. The high case assumes that current rates of economic and electricity demand growth continue. It also assumes changes in country policies towards the mitigation of climate change and recognition of nuclear power as an important contributor to decarbonisation strategies.

Table 2.3. **Installed nuclear generating capacity to 2050***

(GWe net)

Region	2021	2022	2025 low	2025 high	2030 low	2030 high	2035 low	2035 high	2040 low	2040 high	2045 low	2045 high	2050 low	2050 high
European Union	100.2	100.9	96.7	98.3	91.5	95.9	91.1	109.6	92.7	120.5	97.4	133.3	83.5	133.7
North America	109.8	108.2	107.1	107.1	108.8	109.5	110.9	112.9	115.0	126.7	105.1	126.7	88.6	141.8
East Asia	107.7	111.2	111.4	124.1	123.5	157.8	147.8	195.3	167.1	253.9	182.1	304.9	212.1	353.9
Europe (non-EU)	54.5	53.1	53.7	53.7	57.8	61.9	70.9	81.1	91.5	102.8	104.4	115.7	104.4	124.0
Central and South America	3.5	3.5	3.1	3.1	4.7	5.4	6.5	8.9	6.9	12.3	7.4	15.1	7.4	17.4
Middle East, Central and South Asia	12.9	15.1	18.0	23.3	28.9	34.2	46.5	59.4	56.3	85.9	67.0	95.7	67.0	101.5
South Eastern Asia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	5.0	0.0	7.0
Africa	1.8	1.8	1.8	1.8	2.9	4.0	6.2	7.3	9.2	18.3	11.3	19.3	11.3	20.3
Pacific	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
World Total	**390.6**	**393.9**	**391.8**	**411.5**	**418.3**	**468.8**	**479.9**	**574.6**	**538.8**	**724.3**	**574.7**	**815.7**	**574.3**	**899.6**

* NEA/IAEA estimate based on government-supplied responses to a questionnaire and data established by a group of experts (IAEA/NEA) and published in IAEA, 2024 and WNA, 2023. Because of rounding, totals may not add up.

These projections reflect a high degree of uncertainty, since the role that nuclear power will play in the future generation mix in some countries has not yet been determined. Over the short term, in both the low and high case, competitive challenges from other electricity generation sources, along with nuclear policy hurdles, will continue to affect nuclear growth in some regions of the world.

Several currently operating reactors, mainly in OECD member countries, were set, up to 2021, on a path for early decommissioning due to economic challenges or policy decisions. However, since late 2021, several countries have significantly shifted their policies in favour of nuclear energy. This trend is driven by a combination of factors, including concerns regarding security of energy supply and the urgency of addressing climate change. In those countries, nuclear power is seen as a critical component in ensuring energy security, reducing carbon emissions,

2. When data is not provided by member countries, estimations are made by the NEA/IAEA Secretariat. These estimations consider various official sources, including values published in the IAEA report *Energy, Electricity and Nuclear Power Estimates for the Period up to 2050* (IAEA, 2024), and data from the WNA Nuclear Fuel Report (WNA, 2023).

and maintaining stable energy supplies. As a result, numerous nations are revisiting their energy strategies to incorporate or expand their nuclear capabilities.

The low-case scenario projects an increase in global nuclear capacity from around 397 GWe at the beginning of 2023 to approximately 574 GWe by 2050, representing a 45% increase. Both low- and high-case scenarios indicate that most of the growth will be concentrated in East Asia.

The current high-case scenario projects a global growth factor of around 2.3 compared to 2023 installed capacity, largely driven by East Asia's expansion, with world nuclear capacity expected to reach 900 GWe by 2050. By 2035, the high-case scenario projects a 45% increase over 2023 levels, suggesting that significant expansion efforts are already underway, and more are anticipated in several countries (see Table 2.3). Compared to the Red Book 2022 projections, this edition forecasts a 37% increase in the low-case scenario and a 7% increase in the high-case scenario by 2040.

Nuclear capacity projections vary considerably from region to region. The East Asia region is projected to experience the largest increase and could result in total capacity of between 212 GWe and 354 GWe, in the low and high cases, respectively. In terms of new capacity, this would represent an increase between about 90% and 220% compared with a capacity of around 111 GWe at the end of 2022.

Other regions projected to experience significant nuclear capacity growth include the Middle East and the Central and Southern Asia region, notably with India's ambitious expansion plan and several potential newcomer countries (Kazakhstan, Saudi Arabia or Uzbekistan). In the high-case scenario, nuclear capacity in non-EU member countries on the European continent is projected to increase considerably, with 124 GWe of capacity projected by 2050 in the high case, more than doubling 2022 capacity. More modest growth is projected in Africa, Central and South America and the South-eastern Asia regions.

For North America, the projections see nuclear generating capacity decreasing by 2050 in the low case to around 89 GWe and increasing to around 142 GWe in the high case.

As in the case of nuclear capacity, uranium requirements vary considerably from region to region, reflecting projected capacity increases and possible inventory building. Annual uranium requirements are projected to be largest in the East Asia region, where increased installed nuclear generating capacity (particularly in China) drives most of the growth in uranium needs. World reactor-related uranium requirements by the year 2050 are projected to increase to a total of between 90 000 tU/yr in the low case and around 142 600 tU/yr in the high case (see Table 2.4).

Table 2.4. **Annual reactor-related uranium requirements to 2050***

(tonnes U per year)

Region	2022	2025 low	2025 high	2030 low	2030 high	2035 low	2035 high	2040 low	2040 high	2045 low	2045 high	2050 low	2050 high
European Union	13 720	11 703	14 252	14 851	16 303	14 505	18 690	14 746	20 016	15 695	22 007	13 390	21 900
North America	17 705	17 088	17 138	17 120	17 267	17 440	17 885	18 445	19 670	16 765	20 189	14 123	22 603
East Asia	16 401	18 125	22 953	20 060	25 448	23 648	30 788	26 736	40 624	29 136	48 784	33 936	56 624
Europe (non-EU)	7 525	8 810	8 820	9 648	10 362	11 446	13 104	14 116	15 704	14 616	16 204	14 616	17 532
Central and South America	530	568	568	873	961	1 656	2 108	1 244	2 240	1 335	2 783	1 335	3 238
Middle East, Central and South Asia	2 843	3 192	3 702	4 649	5 565	7 549	9 622	9 126	13 870	10 838	15 438	10 838	16 366
South Eastern Asia	0	0	0	0	0	0	0	0	640	0	800	0	1 120
Africa	294	294	294	470	646	998	1 168	1 478	2 928	1 808	3 088	1 808	3 248
Pacific	0	0	0	0	0	0	0	0	0	0	0	0	0
World Total	**59 018**	**59 779**	**67 728**	**67 671**	**76 552**	**77 242**	**93 365**	**85 891**	**115 692**	**90 192**	**129 293**	**90 045**	**142 631**

* NEA/IAEA estimate (rounded to nearest whole number). Because of rounding, totals may not add up.

Figure 2.2. **Projected nuclear generating capacities to 2050**
(low and high projections)

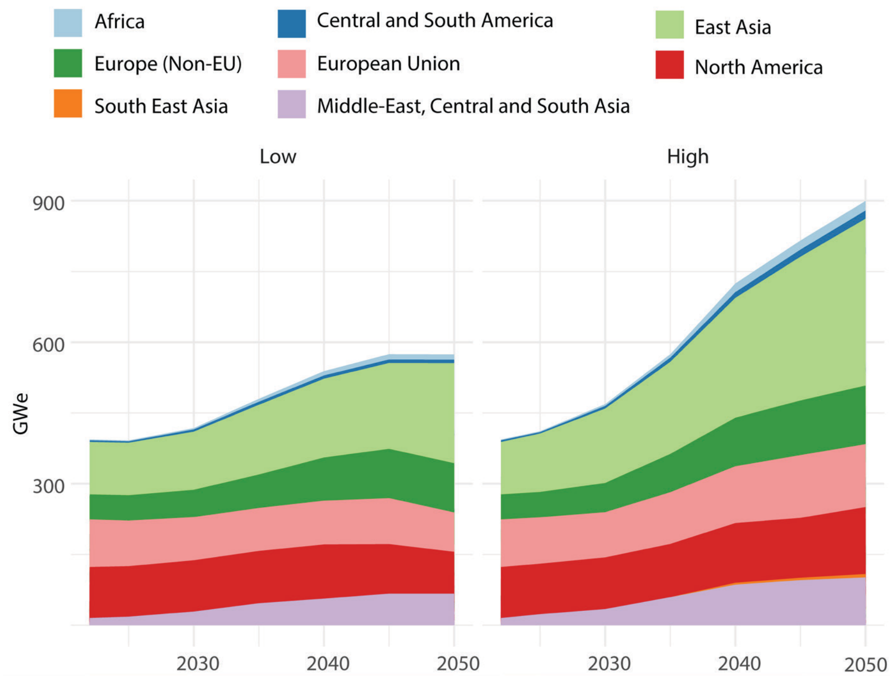
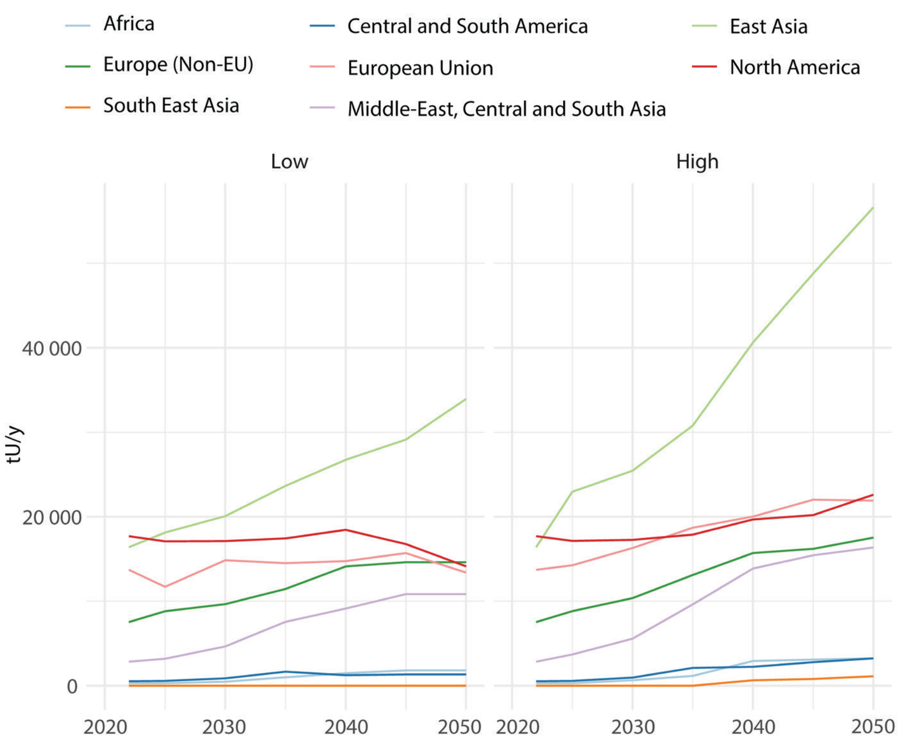


Figure 2.3. **Projected annual reactor-related uranium requirements to 2050**
(low and high projections)



Uranium supply and demand adequacy

Uranium supply, sourced from both primary production and secondary supply, has consistently met demand for decades, with no shortages reported since the last edition of this report. However, geopolitical uncertainties persist, raising concerns about potential future disruptions to international nuclear fuel supply chains. In response, several OECD member countries are exploring diversification strategies to secure their energy supply.

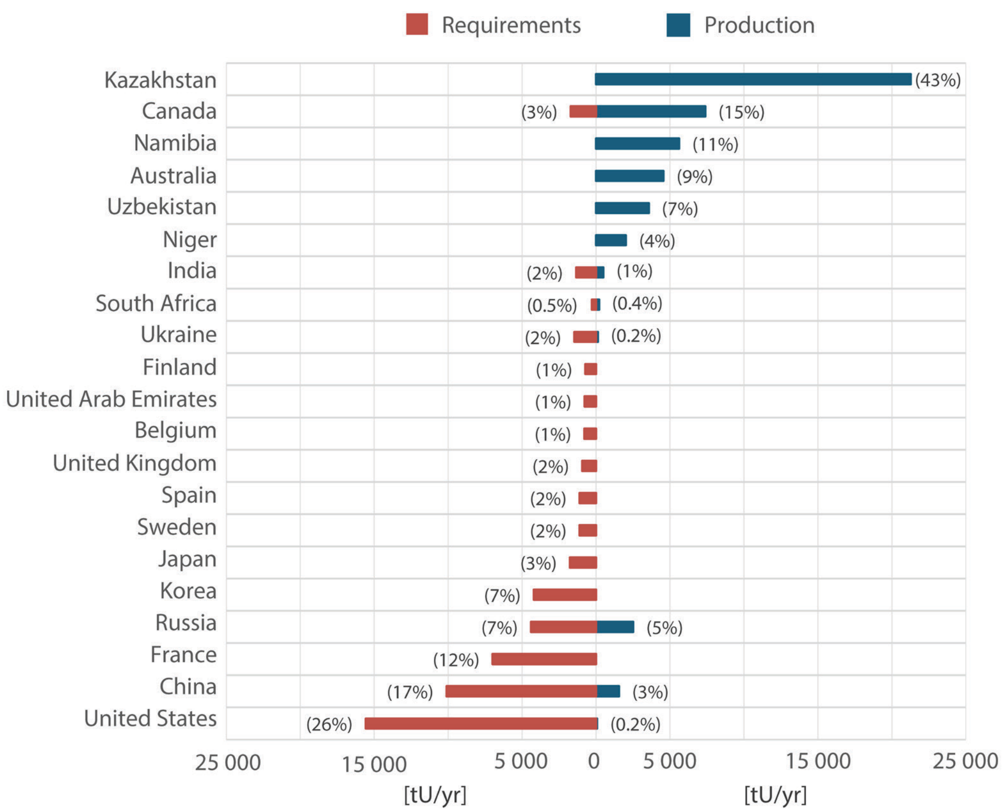
As of 2023, of all countries with installed nuclear generating capacity, only Canada produced enough uranium to meet its domestic requirements (see Figure 2.4). All other countries with nuclear power rely on imported uranium or secondary sources, making international trade of uranium a crucial and established component of the market. Given the uneven geographical distribution between producers and consumers, the safe and secure shipment of nuclear fuel must continue without unnecessary delays and impediments. The challenges some producing countries face regarding international shipping requirements and transfers to international ports have always been a concern, and these are now heightened further by the current geopolitical situation.

Primary sources of uranium supply

Uranium was produced in 17 countries in 2022 and 2023, with total global production amounting to 49 490 tU in 2022 and 54 597 tU in 2023 (see Table 1.18).

Figure 2.4. **Uranium production and reactor-related requirements for major producing and consuming countries (percentages of total shown)**

(data as of 1 January 2023)

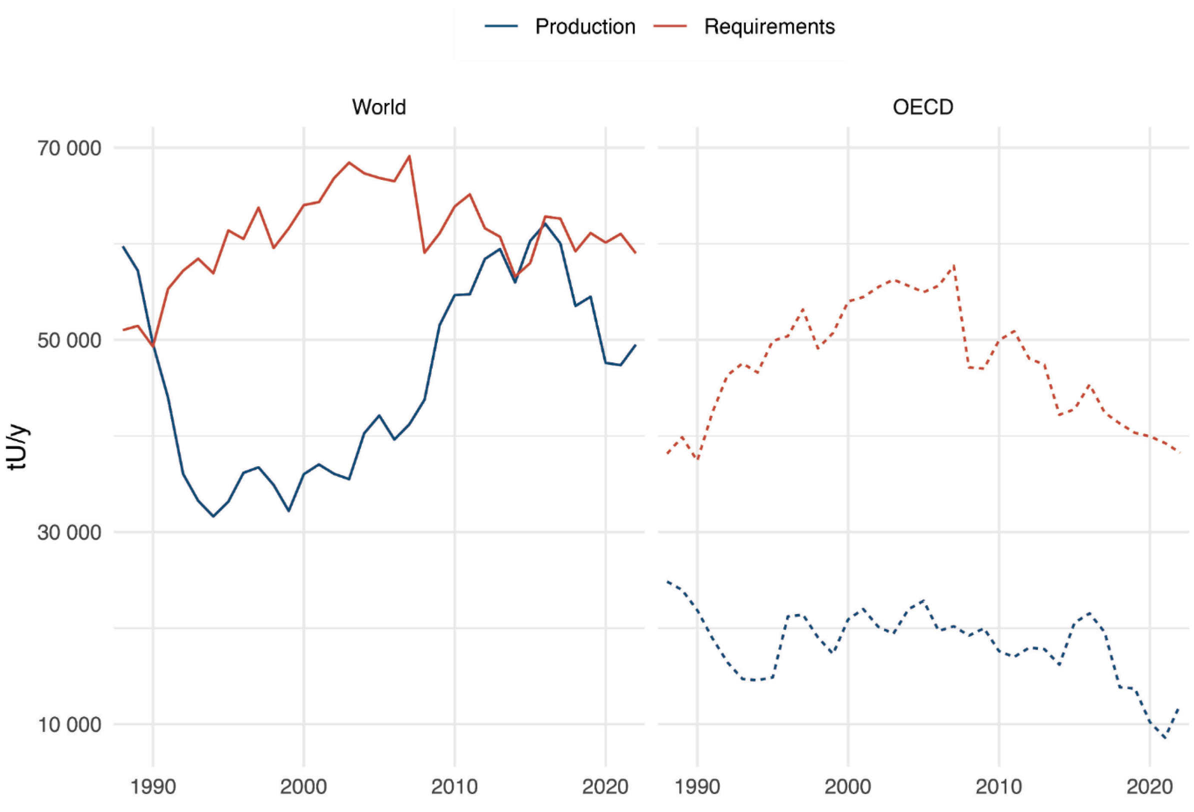


Kazakhstan remains the world's largest producer of uranium through 2023, being responsible for around 43% of world uranium production in 2022. The top six producing countries in 2022 (Kazakhstan, Canada, Namibia, Australia, Uzbekistan and Russia, by order of production) accounted for around 90% of world production, while over 99% of world uranium production took place in the top 10 uranium producing countries (Kazakhstan, Canada, Namibia, Australia, Uzbekistan, Russia, Niger, China, India and South Africa, by order of production).

Apart from Canada, all other countries with nuclear power must make use of imported uranium or secondary sources and, as a result, the international trade and transport of uranium is a necessary and established aspect of the uranium market. Given the uneven geographical distribution between producers and consumers, the safe and secure shipment of nuclear fuel will need to continue without delays and impediments. The difficulties that some producing countries have encountered with respect to international shipping requirements and transfers to international ports have therefore always been a matter of concern.

Because of the availability of secondary supplies, primary uranium production volumes have been significantly below world uranium requirements for some time. In 2022, world uranium production (49 490 tU) represented around 85% of 2022 world reactor requirements (59 018 tU). In OECD member countries, the gap between production and requirements has changed little in the past years. In 2022, OECD member countries' production of 12 038 tU provided only around 30% of their requirements (38 271 tU). Remaining reactor requirements were met by imports and secondary sources.

Figure 2.5. **OECD and world uranium production and requirements**



Secondary sources of uranium supply

Uranium is unique among energy fuel resources in that, historically, a significant portion of demand has been supplied by secondary sources. These secondary sources include: stocks and inventories of natural and enriched uranium, both civilian and military in origin; nuclear fuel from the reprocessing of spent reactor fuels and from surplus military plutonium; underfeeding; and uranium produced by the re-enrichment of depleted uranium.

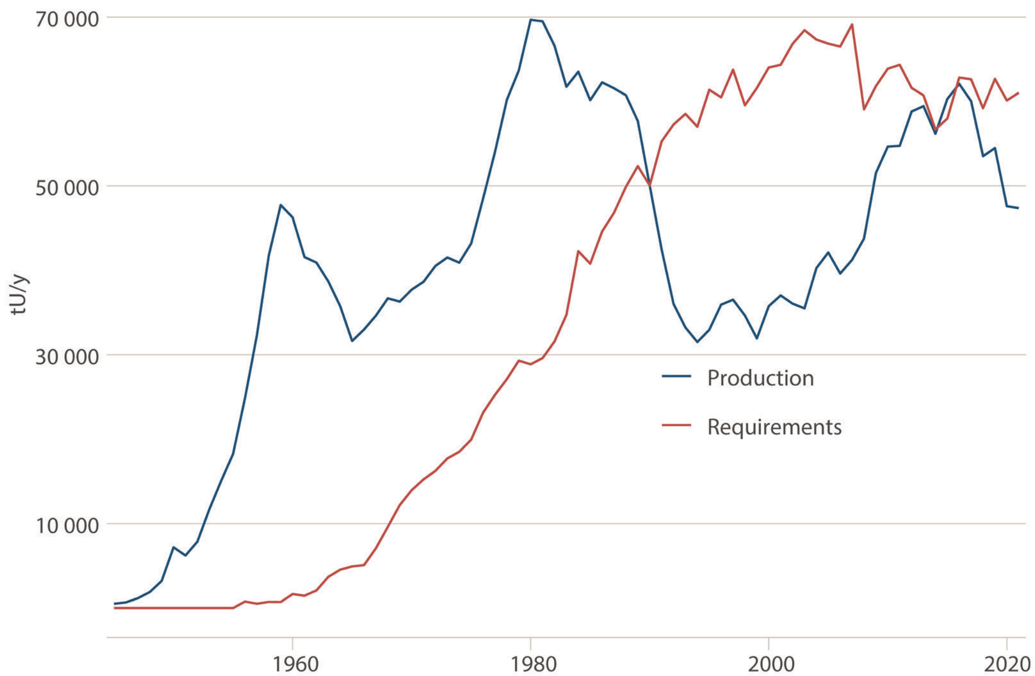
Despite the importance of secondary uranium supplies, information on the size of these stocks remains limited, as many countries, due to commercial and security factors, do not disclose detailed data on stockpiles held by producers, consumers or governments.

Natural and enriched uranium stocks and inventories

From the beginning of commercial exploitation of nuclear power in the late 1950s to 1990, uranium production consistently exceeded commercial requirements (see Figure 2.6). This was mainly the consequence of a lower than projected growth rate of nuclear generating capacity combined with high levels of production for strategic purposes. This period of overproduction created a stockpile of uranium potentially available for use in commercial power plants. After 1990, production fell well below demand and secondary supplies fed the market. Since 2008, requirements increased slightly before declining again in the last few years owing to unplanned reactor closures in Germany and Japan following the Fukushima Daiichi Nuclear Power Plant accident. Uranium production since 2007 has generally increased and has partially closed the gap between production and reactor requirements. The decline in requirements in 2018 was likely related to the reduced number of reactors being refuelled in Japan. More recently, producers have responded to the sustained uranium market downturn by temporarily shutting some operations and scaling back uranium production at other mines, causing a slight gap between supply and demand to reappear. The drop in 2020 production is also due to the COVID-19 pandemic, when occupational health and safety considerations forced mines to suspend operations temporarily.

Figure 2.6. **World annual uranium production and requirements**

(1949-2023)

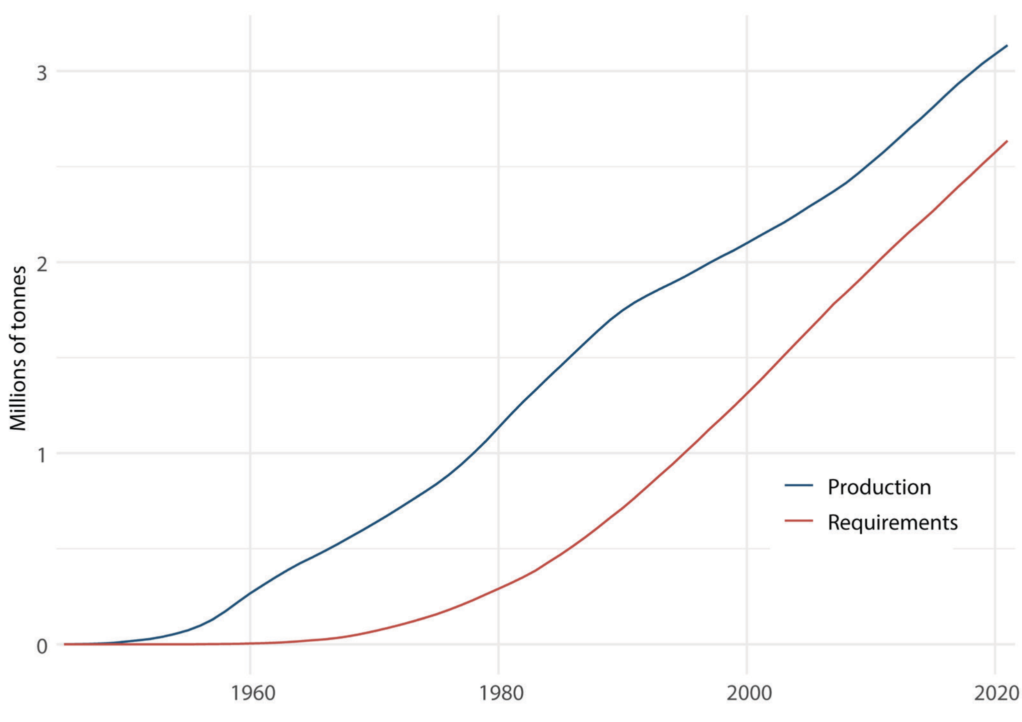


Following the political and economic changes in Eastern Europe and the former Soviet Union in the early 1990s, steps were taken to move towards the development of an integrated global commercial market. More uranium is now available from the former Soviet Union, most notably from Kazakhstan, but also from Russia and Uzbekistan. Despite these developments and more information being available on the amount of uranium held in inventory by utilities, producers and governments, uncertainties remain regarding the size and the mobility of these inventories, as well as the availability of uranium from other potential secondary supply sources. Although it is still too early to analyse the long-lasting consequences with respect to the global uranium market, it is clear that the geopolitical crisis triggered by the Russia-Ukraine war may create additional barriers to the exchange of Russia's stocks in the international market. In May 2024, the United States passed the Prohibiting Russian Uranium Imports Act, which bans the import of Russian-produced LEU until the end of 2040. Recognising the importance of Russian uranium in the global nuclear industry, the law provides waivers for US nuclear plants/utilities to prevent reactor shutdowns and for national security, valid until 1 January 2028. These waivers set annual import limits, dictated by the allowances in the Russian Suspension agreement, starting at 476 metric tons in 2024 and decreasing each year.

Data from past editions of this publication, along with information provided by member countries, give a rough indication of the maximum level of the potential inventories commercially available when considering cumulative production and requirements for uranium at the global level. This leaves an estimated remaining stock of around 525 000 tU, which is a rough estimate of the upper limit of what could potentially become available to the commercial sector (see Figure 2.7). This base of already mined uranium has essentially been distributed into two sectors, with the majority used and/or reserved for the military and the remainder used or stockpiled by the civilian sector. However, since the end of the Cold War, increasing amounts of uranium, previously reserved for strategic purposes, have been released to the commercial sector.

Figure 2.7. **World cumulative uranium production and requirements**

(1949-2023)



Civilian inventories include strategic stocks, pipeline inventory and commercial stocks available to the market. In recent years, material held by financial investors in the form of physical uranium trusts has been an increasingly significant part of the inventory. Utilities are believed to hold most commercial stocks because many operate in jurisdictions with policies that require them to carry the equivalent of one to several years of natural uranium requirements. Despite the importance of this secondary source of uranium, information about the size of these stocks is limited as few countries provide detailed information on stockpiles held by producers, consumers or governments.

In the United States, at the end of 2023 (still reported as preliminary data), total commercial inventories (utilities, traders and producers' stocks) were 58 847 tU (EIA, 2023). Around 72% of the commercial inventories were held by owners and operators of commercial reactors. Enriched uranium inventories held by utilities (including fuel elements in storage) in 2023 (around 22 312 tU) were up around 20% from their 2019 values.

In the European Union, uranium inventories (no longer including UK inventories) held by utilities at the end of 2022 totalled 35 710 tU, equivalent to around three years' fuel supply, and down around 3% since the previously reported value in 2021 (see Table 2.5).

Uranium requirements are growing rapidly in East Asia, in particular in China. By 2050, demand in this region is expected to surpass (both in the low- and high-case scenario) that of North America and the EU combined. Questionnaire responses received during the compilation of this edition revealed little about national inventory policies in the East Asia region. Based on import statistics, it is estimated (WNA, 2023) that as of 1 January 2023, China had an accumulated inventory of 125 000 tU, while India held an inventory of about 17 000 tU. The depletion of secondary supply has led many countries to hold on to their existing inventories.

Table 2.5. **Uranium inventories held by EU and US utilities**

(tonnes natural U equivalent at the end of the year)

Year	Inventories held by EU utilities	Inventories held by owners and operators of the US nuclear power plants
2015	51 892	46 589
2016	51 514	49 217
2017	49 004	47 635
2018	45 342	42 759
2019	42 912	43 385
2020	42 396	41 024
2021	36 810*	41 732
2022	35 710*	39 388
2023	NA	42 307[(a)]

Source: ESA Annual Report, 2020, 2021, 2022, 2023; US EIA Uranium Marketing Annual report 2020, 2021, 2022, 2023, 2024.

* Note the EU data no longer includes UK inventories as of 2021 figures.

(a) Preliminary data.

In recent years, commercial entities other than utilities have been holding quantities of uranium for investment purposes. Although commercially confidential, variable and largely dependent on uranium price dynamics, the US Energy Information Administration notes that US-based traders and brokers held about 12 894 tU at the end of 2023 (EIA, 2023), which represents an almost sixfold increase compared to the same levels at the end of 2015.

Large stocks of uranium, previously dedicated to the military in both the United States and Russia, have become available for commercial applications, bringing a significant secondary source of uranium to the market. Despite the programmes outlined below, the remaining inventory of HEU and natural uranium held in various forms by these governments is significant, although official figures on strategic inventories are not available. If additional disarmament initiatives are undertaken to further reduce strategic inventories, several years of global supply of uranium for commercial applications could be made available.

HEU from Russia

Russia and the United States signed a 20-year, government-to-government agreement in February 1993 for the conversion of 500 t of Russian HEU from nuclear warheads to LEU suitable for use as nuclear fuel (referred to as the Megatons to Megawatts agreement). Centrus, formerly the United States Enrichment Corporation (USEC), is the executive agent for this agreement and purchased the enrichment component of the LEU, about 5.5 million SWU per year, from Techsnabexport (TENEX) of Russia. Under a separate agreement, the natural uranium feed component of the HEU purchase agreement was sold under a commercial arrangement between three western corporations (Cameco, Areva and Nukem) and TENEX. Deliveries under this government-to-government agreement were finalised at the end of 2013.

HEU from the United States

In 2015, the US Department of Energy (DOE) reported 15 t of unallocated HEU. The US National Nuclear Security Administration (NNSA) plans to conduct a HEU down-blending offering for tritium (DBOT) programme in the fiscal years 2019-2025.

Fuel banks

Efforts by governments and international agencies have resulted in actions to create nuclear fuel banks – another form of inventory.

Driven by rising energy needs, non-proliferation and waste concerns, governments and the IAEA have made several proposals aimed at strengthening non-proliferation by establishing multilateral enrichment and fuel supply centres.

In December 2010, the first LEU reserve was inaugurated in Russia at the International Uranium Enrichment Centre in Angarsk under IAEA auspices. This LEU reserve is comprised of 120 t LEU in the form of UF_6 enriched to 2%-4.95% ^{235}U. Under IAEA safeguards, the reserve will be made available to IAEA member states whose supplies of LEU are disrupted for reasons unrelated to technical or commercial issues. The LEU reserve is not intended to distort the functioning of the commercial market, but rather to reinforce existing market mechanisms of member states.

Also in December 2010, the IAEA Board of Governors authorised the IAEA Director-General to establish a LEU bank to serve as a supply of last resort for nuclear power generation. The IAEA reserve is a backup mechanism to the commercial market if an eligible member state's supply of LEU is disrupted and cannot be restored by commercial means. In May 2015, Kazakhstan signed a draft agreement with the IAEA to host the IAEA LEU bank at the Ulba Metallurgical Plant, which on 31 January 2017 entered into force. The IAEA LEU bank is a physical reserve of up to 90 metric tons of low-enriched uranium suitable to make fuel to power a typical light water reactor for three years. In 2018, the IAEA signed contracts to purchase LEU, paving the way towards the establishment of the IAEA LEU Bank in 2019. The IAEA LEU Bank was established and became operational on 17 October 2019. The establishment and operation of the IAEA LEU bank is fully funded by voluntary contributions. Donors have provided a total of USD 150 million to establish the LEU Bank and operate it for at least ten years.

Nuclear fuel produced by reprocessing spent reactor fuels and surplus weapons-related plutonium

The constituents of spent fuel from nuclear power plants are a potentially substantial source of fissile material that could displace primary uranium production. When spent fuel is discharged from a commercial reactor, it is potentially recyclable since more than 90% of the original material is essentially made up of uranium-238, along with the plutonium and remaining uranium-235. The recycled plutonium can be reused in reactors licensed to use mixed oxide (MOX) fuel. The uranium recovered through reprocessing of spent fuel, known as reprocessed uranium (RepU), is not routinely recycled; rather, it is stored for future reuse.

The use of MOX fuel has not significantly impacted global uranium demand. This is because only a relatively small number of reactors utilise MOX fuel, and even those reactors do not typically use MOX to fuel 100% of the reactor's core.

As of January 2023, there were 26 reactors, or around 6% of the world's operating fleet, that used MOX fuel, in France, Japan, India and the Netherlands (see Table 2.1). Reprocessing and MOX fuel fabrication facilities exist or are under construction in France, India, Japan and Russia. China is also building a pilot plant, to be operational in the mid-2020s, that will be capable of processing about 200 tonnes of heavy metal per year.

Following on basic research and MOX fuel fabrication for experimental reactors by the Japan Atomic Energy Agency (JAEA), Japan Nuclear Fuel Ltd (JNFL) began testing plutonium separation at the Rokkasho reprocessing facility in 2006. Japanese utilities began using MOX initially in fuel manufactured overseas. The use of imported MOX fuel was to be followed by the use of MOX produced at JNFL's MOX fuel fabrication facility (JMOX) adjacent to the Rokkasho reprocessing plant. JMOX construction began in 2010. Under the latest schedule, the start of operation is expected around 2024.

Annual MOX production in France varies below this licensed capacity of 195 tHM, in accordance with contracted quantities. Most of the MOX production is used to fuel French nuclear power plants (a total of about 120 t/yr; 960 tNatU) and the remainder is delivered abroad under long-term contract arrangements.

A MOX fuel fabrication facility established by Mining and Chemical Combine (MCC) Zheleznogorsk, a Rosatom subsidiary, was officially started in 2015. Russia has no commercial reactors using MOX fuel, but its BN-800 fast reactor at Beloyarsk nuclear power plant has been fully loaded with MOX since September 2022.

The Euratom Supply Agency (ESA) reported that the quantity of plutonium contained in the MOX fuel loaded into nuclear power plants in the EU was 3 007 kg in 2022, which is about 40% less than in 2021 (ESA, 2023). Use of plutonium in MOX fuel reduced natural uranium requirements in the EU by an estimated 277 tU in 2022. In the 1996-2022 period, MOX fuel use in EU reactors has displaced a cumulative total of 26 199 tU through the use of 241.2 t of Pu (ESA, 2023). Since the great majority of global MOX use occurs in Western Europe, this figure provides a reasonable estimate of the impact of MOX use worldwide on uranium requirements during that period. Responses to the questionnaire provide some additional data on the production and use of MOX (see Chapter 3).

Uranium recovery through reprocessing of spent fuel, known as RepU, has been conducted in the past in several countries, including Belgium and Japan. It is now routinely undertaken only in France and Russia, principally because the production of RepU requires dedicated conversion, enrichment and fabrication facilities. Available data indicate that it represents less than 1% of projected annual world requirements. Reprocessing could become a more significant source of nuclear fuel supply in the future if China successfully commercialises the process. It was reported that China planned to move beyond conducting research and development of reprocessing and recycling technologies to build and operate a large-scale commercial facility with a capacity of about 800 tHM/yr in order to achieve maximum utilisation of uranium resources, given the country's rapidly rising requirements.

MOX produced from surplus weapons-related plutonium

In September 2000, the United States and Russia signed the Plutonium Management and Disposition Agreement that committed each country to dispose of 34 t of surplus weapons-grade plutonium at a rate of at least 2 tonnes per year in each country, once production facilities are in place. Both countries agreed to dispose of the surplus plutonium by fabricating MOX fuel suitable for irradiation in commercial nuclear reactors.

In the United States, the MOX fuel was to be fabricated at the DOE's Savannah River complex in South Carolina. The DOE's NNSA awarded a contract for construction of the Mixed Oxide Fuel Fabrication Facility (MFFF) in 2001 and construction was officially started in 2007. In mid-2013, however, it was reported that the project had encountered technical difficulties and was running over budget. Since 2014, the project has seen progressive cuts to its funding as the DOE's National Nuclear Safety Administration embarked on a review of its plutonium disposition strategy. The DOE NNSA terminated the MOX project in October 2018 after Russia – which had agreed to dispose of the material in fast reactors – suspended the agreement in October 2016.

Uranium produced by re-enrichment of depleted uranium tails[3] and uranium saved through underfeeding

Depleted uranium stocks represent a significant source of uranium that could displace primary production. However, the re-enrichment of depleted uranium has been limited since it is only economic in enrichment plants with spare capacity and low operating costs.

The world stock of depleted uranium in 2023 is of around 2.2 million tonnes, with around 50 000 tonnes of depleted uranium being added yearly to already substantial stockpiles in the United States, Europe and Russia (WNA, 2023). Following the construction of new centrifuge enrichment facilities and declining demand since the Fukushima Daiichi Nuclear Power Plant accident, spare enrichment capacity is currently available, and it has been reported that tails assays are being driven downward at enrichment facilities to underfeed the centrifuge plants and create additional uranium inventory.

EU enrichers are now putting in place long-term strategies to manage enrichment tails remaining from enrichment activities, including deconversion of UF_6 to the more stable form U_3O_8. Currently, deconversion takes place in France. Outside the EU, Urenco's tails management facility at Capenhurst in the United Kingdom became operational in 2021.

In Russia, TVEL's JSC Electrochemical Plant (ECP) in Zelenogorsk in Krasnoyarsk Region has an annual installed capacity of 10 thousand tonnes. The plant is supplied by Orano under the contracts signed in 2005 (for the first unit) and in 2019 (for the second W2-ECP unit, currently under construction).

In the United States, the DOE and the Bonneville Power Administration initiated a pilot project to re-enrich 8 500 tonnes of the DOE's enrichment tails inventory. Between 2005 and 2006, this project produced approximately 1 940 tU equivalent for use between 2007 and 2015 at Northwest Energy's 1 190 MWe Columbia generating station. In mid-2012, Northwest Energy and USEC, in conjunction with the DOE, developed a new plan to re-enrich a second portion of the DOE's high assay tails. The resulting LEU is to be used to fuel Northwest Energy's Columbia generating station through 2029.

3. Depleted uranium is the by-product of the enrichment process, with less ^{235}U than natural uranium. Normally, depleted uranium tails contain between 0.25% and 0.35% ^{235}U compared with the 0.711% proportion of ^{235}U found in nature.

GE-Hitachi Global Laser Enrichment proposed to build and operate a tails processing plant using SILEX laser enrichment technology on land adjacent to the closed Paducah gaseous diffusion enrichment plant in the United States. Successful development of laser enrichment could potentially result in an additional supply of uranium to the market in the longer term. The commercial operations are expected to commence in the late 2020s. Some other commercial enrichment providers (e.g. Urenco) have indicated an interest in using centrifuge enrichment capacity for tails re-enrichment.

Underfeeding

The potential for *underfeeding* of enrichment plants is also a source of secondary supply. Underfeeding reduces the amount of uranium required to produce contracted quantities of enriched uranium and, in turn, creates a stockpile of uranium that can be sold. It is estimated that global underfeeding and depleted uranium re-enrichment contribute up to 7 000 tU of supply per year (WNA, 2023).

In recent years, secondary supply has shown a downward trend resulting from the end of the "Megatons to Megawatt" agreement. The share of global secondary supply is currently around 12% (8 000 tU/yr) and is likely to decrease to about 7% (8 000 to 9 000 tU/yr) by 2040 (WNA, 2023).

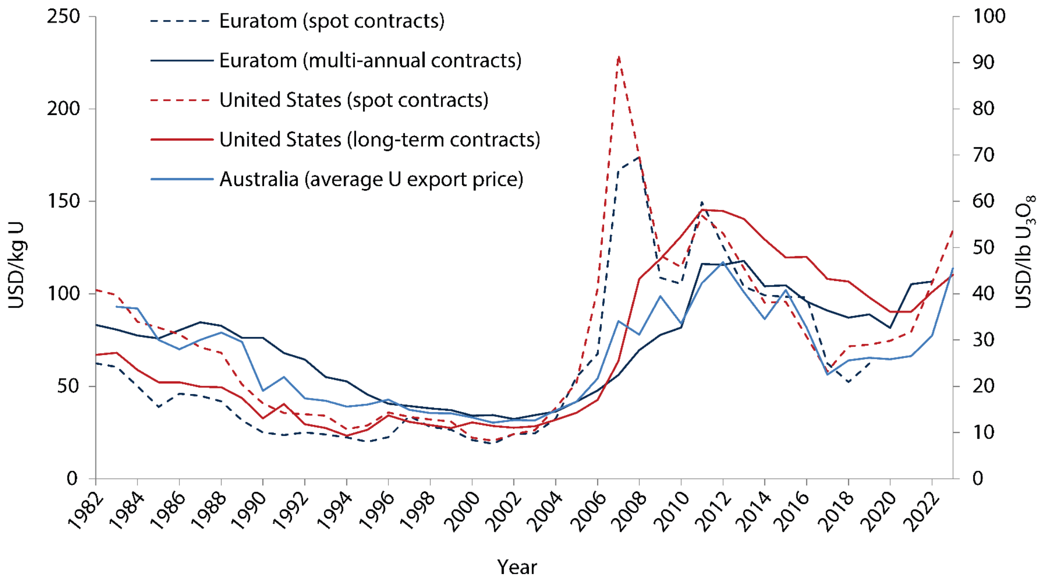
Uranium market developments

Uranium prices

Some national and international authorities (Australia, the United States and Euratom), publish price indicators to illustrate uranium price trends for both long-term and short-term (spot price) contract arrangements. Australian data record average annual prices paid for exports, whereas Euratom (ESA) and US data show costs of uranium purchases in a particular year. Canada and Niger published export prices for some years, but neither continue to do so. Figure 2.8 displays this mix of annual prices reported for both short-term and longer-term purchases and exports.

Figure 2.8. **Uranium prices for short- and long-term purchases and exports**

(1982-2023)



Source: ESA, 2023, EIA, 2024, Department of Industry, Science and Resources, 2024.

The overproduction of uranium, which lasted through 1990 (see Figure 2.6), combined with the availability of secondary sources, resulted in uranium prices trending downward from the early 1980s through the mid-1990s, bringing about significantly reduced expenditures in many sectors of the world uranium industry, including exploration and production. The bankruptcy of an important uranium trading company resulted in a modest recovery in prices from late 1994 through mid-1996, but the regime of low prices returned shortly thereafter. Beginning in 2002, uranium prices started to increase, eventually rising to levels not seen since the 1980s. They then rose more rapidly through 2005 and 2006, with spot prices reaching a peak through 2007 and 2008, and fell off rapidly, recovering somewhat in 2011 and declining in 2012 up until 2017 and 2018 (see Figures 2.8 and 2.9). In contrast, EU and US long-term price indices continued to rise until 2011 before levelling off in 2012, and then started to decline until 2020 and 2021. In 2022, the long-term uranium price started to recover, reaching levels not seen in almost a decade. Fluctuations in these indicators do not rival the peak in the spot market in 2007 and 2008 nor the degree of declining prices since 2011, as they reflect contract arrangements made earlier under different price regimes. The Australia average export price has generally followed the trend of other long-term price indices, but with greater variation since it is a mix of spot and long-term contract prices.

In addition to this information from government and international sources, spot price indicators for immediate or near-term delivery (less than one year), which typically amount to 15% to 25% of all annual uranium transactions, are provided by the industry trade press, such as TradeTech and the Ux Consulting Company LLC (UxC) (see Figure 2.9).

Figure 2.9. **Uranium spot price dynamics**

(TradeTech Exchange Value trend, 2002-2024)

Source: Trade Tech (www.uranium.info).

Note: The Exchange value is Trade Tech's judgement of the price at which spot and near-term transactions for significant quantities of natural uranium concentrates could be conducted as of the last day of the month.

A variety of factors have been advanced to account for the spot price dynamics between 2003 and 2024, including problems experienced in nuclear fuel cycle production centres that highlighted dependence on a few critical facilities in the supply chain, as well as changes in the value of the US dollar, the currency used in uranium transactions. The expected expansion of nuclear power generation in countries such as China, India and Russia, combined with the recognition by many governments of the role that nuclear energy can play in enhancing security of energy supply, contributed to the strengthening market through 2007. Market speculation helped accelerate upward price movement at that time. The downturn in the spot price since June 2007 began with the reluctance on behalf of traditional buyers to purchase at such high prices and the global financial crisis that stimulated sales by distressed sellers needing to raise capital.

In late 2007, the uranium spot price began a gradual decline that settled in 2009 in a range between USD 40/lb U_3O_8 (USD 104/kgU) and USD 50/lb U_3O_8 (USD 130/kgU). Proposed US government inventory sales appeared to offset rising demand as government programmes in China and India to increase nuclear generating capacity began to be implemented. In the second half of 2010, the spot price began to rally once again on news that China was active in the long-term market, stimulating speculative activity on perceptions of tightening supply-demand. However, the Fukushima Daiichi Nuclear Power Plant accident precipitated an initial rapid decline in price. Projects to increase uranium production, implemented before the accident, resulted in increasing production even as demand weakened and the market became saturated with supply, putting further downward pressure on prices through to the end of 2019. In addition, the excess uranium inventories and the decline in uranium needs as a result of the substitution of enrichment (underfeeding) contributed to the downdraught in uranium prices. Significant uranium production cuts were made during 2018-2019 (e.g. McArthur River mine in Canada) contributing to high spot purchasing levels as producers and traders bought material to cover near-term delivery commitments. The significant rise in the spot price seen in March and April 2020 was precipitated largely by additional curtailments to primary production brought on by the COVID-19 pandemic. Numerous mines suspended operations both due to the imposed restrictions and under voluntary preventative measures. The next surge in the uranium spot price was triggered by the start of the Russian-Ukraine war in 2022. Due to increased geopolitical risks, many utilities relying on Russian-sourced enriched uranium started to look for alternative supplies. The increase of spot uranium prices in 2022 was also influenced by the potential sanctions on Russian uranium and logistical issues associated with the Russian-Ukraine war. Indeed, in May 2024, the United States passed the Prohibiting Russian Uranium Imports Act, which bans the imports of low-enriched uranium from Russia.

Apart from geopolitical factors and their impact on the supply chains, another driver that has affected the rise in prices in the last couple of years is the growing interest worldwide in nuclear energy and thus the anticipation of increased uranium demand. This is due to the recognition of importance of nuclear energy in achieving net zero emission targets. In December 2023, more than 20 countries made a joint declaration during the 28th Conference of the Parties of the United Nations Framework Convention on Climate Change (COP28) in Dubai to triple installed nuclear capacity by 2050. This declaration, now signed by over 30 countries, marks a significant milestone in the history of nuclear energy by officially calling for the acceleration of deployment of low-emission technologies, including nuclear, to help achieve carbon neutrality.

The uranium market could be further affected by developments on both the demand and supply side. Asia is the most critical market for new reactors, and new uranium production will be needed in the coming decades. Additional demand factors include Japanese restarts and successful global new builds, led by governments' decisions to increase nuclear power capacity on the road to net zero emissions and energy security. Some of the key considerations on the supply side in the shorter-term include sanctions on Russian uranium, Kazakhstan's supply disruptions due to shortages of sulfuric acid, and a conflict-related disruption of exports from Niger.

Policy measures in the EU and uranium prices

Since its establishment in 1960 under the Euratom Treaty, the Supply Agency of the European Atomic Energy Community (ESA) has pursued a policy of diversification of sources of nuclear fuel supply to avoid overdependence on any single source. Within the European Union, all uranium purchase contracts by EU end users (i.e. nuclear utilities) must be concurred by the ESA. Based on its contractual role and its close relations with industry, the ESA monitors the market with a particular focus on supplies of natural and enriched uranium to the EU. The ESA continues to stress the importance of maintaining an adequate level of strategic inventory and using market opportunities to increase inventories, where possible. It also recommends that utilities cover the majority of their needs under long-term contracts with diverse suppliers and it continues to promote transparency and predictability in the market.

In response to the start of the Russia-Ukraine war in February 2022, the European Commission published the REPowerEU Plan, which advocates for a rapid reduction of dependence on Russian fuels, including nuclear, and states the importance of diversification options for member states reliant on Russian nuclear fuel (ESA, 2023).

Uranium purchased for EU reactors came from diverse sources in 2022 (ESA, 2023). The top four providers amounted to more than 91% of all uranium purchased by EU utilities. In decreasing order of percentage of uranium provided, these were: Kazakhstan (26%), Niger (25%), Canada (21%), and Russia (16%). Uranium of European origin delivered to EU utilities covered less than 1% of the EU's total purchases (ESA, 2023).

Since uranium is sold mostly under long-term contracts and the terms are not made public, the ESA traditionally publishes two categories of natural uranium prices on an annual basis, i.e. multi-annual and spot, both being historical prices calculated over a period of many years. With at least some uranium market participants seeking greater price transparency, the ESA introduced a new natural uranium multi-annual contracts index price (MAC-3) in 2009. This index price, developed to better reflect short-term changes in uranium prices and to more closely track market trends, is a three-year moving average of prices paid under new multi-annual long-term contracts for uranium delivered to EU utilities in the reporting year (see Table 2.6).

Table 2.6. **ESA average natural uranium prices**

(2011-2022)

Year	Multi-annual contracts		Spot contracts		New multi-annual contracts (MAC-3)	
	EUR/kgU	USD/lb U_3O_8	EUR/kgU	USD/lb U_3O_8	EUR/kgU	USD/lb U_3O_8
2011	83.45	44.68	107.43	57.52	100.02	53.55
2012	90.03	44.49	97.80	48.33	103.42	51.11
2013	85.19	45.32	78.24	39.97	84.66	43.25
2014	78.31	40.02	74.65	38.15	93.68	47.87
2015	94.30	40.24	88.73	37.87	88.53	37.78
2016	86.62	36.88	88.56	37.71	87.11	37.09
2017	80.55	35.00	55.16	23.97	80.50	34.98
2018	73.74	33.50	44.34	20.14	74.19	33.70
2019	79.43	34.20	55.61	23.94	80.00	34.45
2020	71.37	31.36	***	***	75.51	33.17
2021	89.00	40.49	***	***	92.75	42.19
2022	101.28	41.02	***	***	76.19	30.86

Source: ESA, 2023.

Note: *** In 2020 the ESA spot price was not calculated because there were not enough transactions (less than 3) to calculate the index. Before 2021: data for EU-27 + UK.

Since uranium is priced in US dollars, fluctuation of the EUR/USD exchange rate influences the level of the price indices calculated. The average EUR/USD rate in 2022, according to the European Central Bank, stood at 1.05, which was 11% lower than in the previous year.

Supply and demand to 2050

Comparison of uranium production and requirements to 2050

Market conditions are the primary driver of decisions to develop new or expand existing primary production centres. Since the last edition of this report, uranium market prices have significantly increased, and plans for increasing production capability continued through 2023. A number of countries, notably, Brazil, Canada, China, India, Namibia, Niger, Russia and South Africa, have plans for significant additions to future production capability. Some other countries, notably Botswana, Finland, Mauritania, Mongolia and Tanzania, are working towards producing uranium in the near future. These developments are important as global demand is projected to increase in the longer term, and the share of secondary sources is expected to decline.

After the long pause in nuclear development following the Fukushima Daiichi Nuclear Power Plant accident, along with the continuing decline of market prices and the COVID-19 pandemic, uranium production levels started to recover, reaching about 54 500 tU in 2023, an increase of 12% compared to the 2020 production levels. Following improved market conditions, some mines in care and maintenance have been reactivated to ensure supply to a growing global nuclear fleet: Canada's McArthur River mine was restarted in November 2022, after being idled for four years. In Namibia, after being placed in care and maintenance in 2018, the Langer Heinrich Mine achieved its first concentrate production and drumming in March 2024, following the successful restart of the project. Langer Heinrich is expected to be in operational ramp-up during 2025, with the mining of new ore to begin in 2026.

In 2022, the nuclear industry experienced severe geopolitical disruptions. Civil unrest in Kazakhstan, which supplies over 40% of the world's uranium, and the Russian-Ukraine war caused significant fuel supply concerns and led to a uranium market transformation that continues to this day. Moreover, following political changes in July 2023, Niger authorities revoked Orano's (France-based) permit to exploit the Imouraren deposit in June 2024 and withdrew the mining rights from GoviEx Uranium (Canada-based) for the Madaouela project in July 2024, creating significant uncertainty about planned and prospective production centres.

Within this context and despite uncertainties and challenges in securing investment for mine development, producers have expanded production capacity in recent years. At the same time, governments are establishing the necessary frameworks, such as legislation and regulations, in countries that have not previously hosted uranium production.

Should uranium demand rise as projected (see Figure 2.10), producers may still face significant challenges in bringing new production facilities online. Recent years have shown that many of these challenges can be unpredictable, including geopolitical factors, such as instability in Niger, the Russian-Ukraine war and global events such as pandemics. Furthermore, technical difficulties at certain facilities, stricter regulatory requirements, and growing expectations from host governments – such as higher taxes and contributions to regional socio-economic development – could further delay the timely development of new mines or uranium production centres.

To ensure a steady supply of uranium and support the development of new resources in the medium to long term, it is crucial to initiate new projects with an understanding of the typically long lead times associated with mine development. Future projects would also benefit from targeted research and innovation efforts aimed at improving uranium exploration methods and developing new, advanced processing techniques.

The gap between uranium production and requirements that has existed since the 1990s has consistently been bridged by drawing down secondary supplies. Around 2014, producers nearly closed this gap between global production and reactor needs, although this was also due to a temporary reduction in demand caused by reactor closures and the idling of reactors in Japan following the Fukushima Daiichi Nuclear Power Plant accident. More recently, as market conditions improve and the cuts and disruptions from the COVID-19 pandemic in 2020 recede, the gap between global production and reactor requirements has begun to narrow. Projections in this publication point, however, towards this gap increasing again in the coming years. This is largely owing to the recent changes in nuclear energy policies worldwide which now anticipate significant nuclear energy growth at the global level in the high-case scenarios.

The availability and mobility of secondary sources, particularly the level of available stocks and how long they will last before depletion, is one of the key uncertainties that may impact the uranium market. The possibility that a portion of the potentially large inventories, including military stockpiles, will continue to enter the market cannot be discounted. These uncertainties may complicate investment decisions regarding new production capabilities. Nevertheless, as secondary sources of uranium are generally expected to follow a downward trend due to inventory depletion, reactor requirements will increasingly need to be met by primary production.

Figure 2.10 illustrates the comparison between projected uranium requirements for both low- and high-demand scenarios, and low- and high-production scenarios, up to 2050:

- **Low-production scenario**: If all existing and committed mines operate at or near their stated production capacity (low production scenario A-II[4]), low demand is expected to be met until 2031. However, for high demand, a production shortfall is anticipated to emerge around 2027.
- **High-production scenario**: If planned and prospective production capabilities are included (high-production scenario B-II[5]), high demand could be met by primary production until 2037. In this scenario, low demand would be satisfied until 2042.

It should also be noted that actual mine production typically reaches on average no more than 85% of a mine's nominal production capacity. Global production has historically fluctuated between approximately 75% and 90% of nominal production capacity over the past few decades.

Projections beyond 2030 show generally decreasing global production capabilities as A-II category estimates decline in response to the depletion of resources at existing and committed production centres. B-II production capability remains flat through 2035 before demonstrating a lagged decline due to the assumed development of projects.

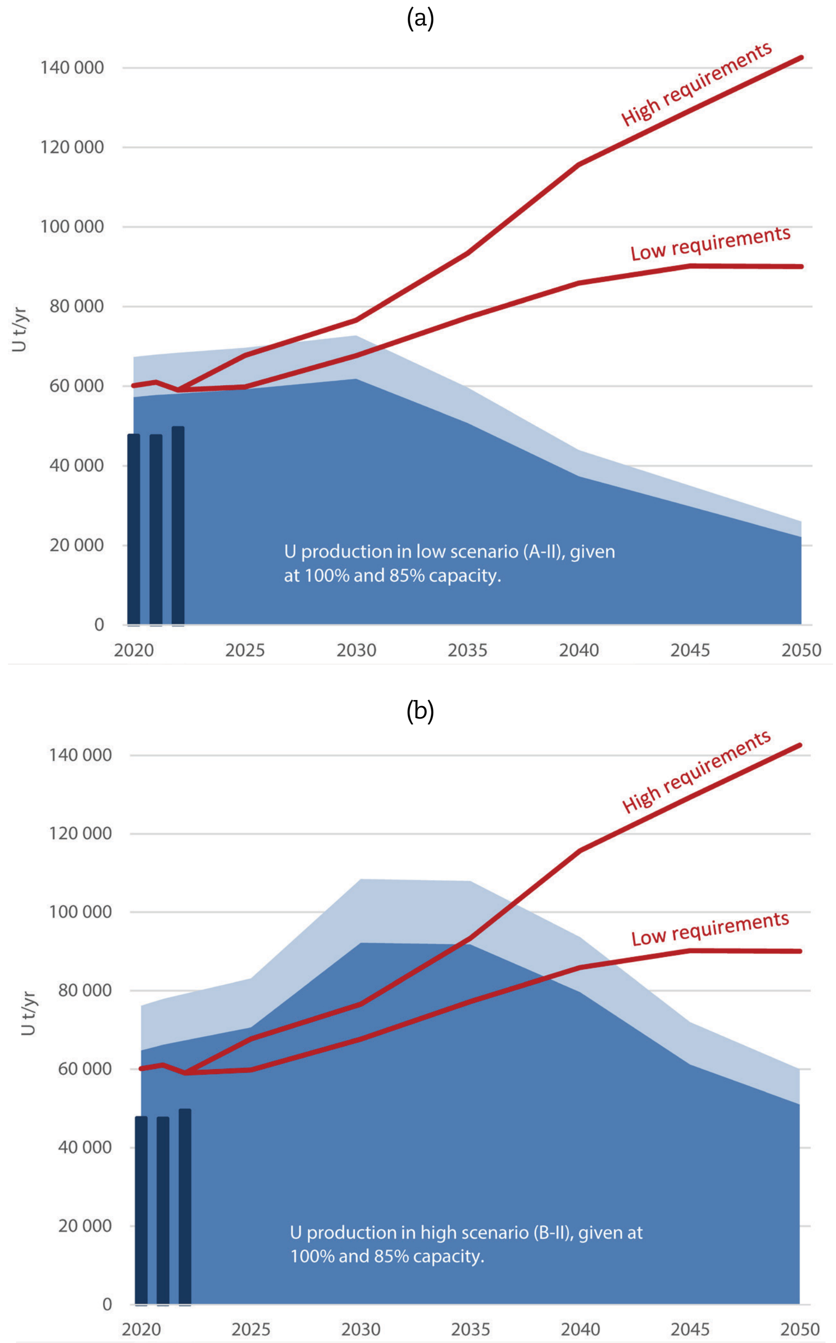
As expected, following a prolonged period of low market prices, production cuts at existing facilities, and the resulting excess production capability, there were limited new production plans unveiled and the list of committed new mines and expansions (Table 1.24) remains thin.

Figure 2.10 also provides an overview of long-term production and demand adequacy, assuming global mine production operates at 85% of capacity. For reference, actual production figures for recent years (2020-2022) are shown in bar form. Under the low production scenario (A-II), the existing gap is expected to persist in both the high and low demand cases. In the high production scenario (B-II), the gap is projected to appear around 2035 for high demand and around 2039 for low demand. These production and demand gaps will need to be addressed with secondary supplies in the short term, and by developing new projects in the medium to long term.

It should however be noted that prices are unlikely to remain constant across different demand scenarios. In a high-requirement scenario, increased demand would drive higher prices, encouraging greater production. Conversely, lower demand in a low-requirement scenario would likely lead to reduced prices and production levels. While detailed modelling of these dynamics is beyond the scope of this report and therefore not reflected in the comparisons of supply and demand scenarios presented here, which aim solely to assess the adequacy of supply relative to potential future demand, the authors acknowledge the interdependent relationships between prices, demand and production, as well as the influence of price elasticity.

4. As defined in Chapter 1, A-II production capabilities projected for 2030 to 2050 include *existing and committed production centres* in the <USD 130/kgU category.
5. As defined in Chapter 1, B-II production capabilities projected for 2030 to 2050 include *existing, committed, planned and prospective production centres* in the <USD 130/kgU category.

Figure 2.10. **Projected world uranium production capability to 2050 (supported by identified resources at a cost of <USD 130/kgU) compared with reactor requirements**



Source: Tables 1.23 and 2.5, NEA, 2023, NEA, 2018c.

Figure a) illustrates the A-II case (production capability of existing, idled and committed centres supported by RAR and inferred resources recoverable at <USD 130/kgU). Figure b) illustrates the B-II case (production capability of existing, idled, committed, planned and prospective centres supported by RAR and inferred resources recoverable at <USD 130/kgU). Both figures illustrate two production capacities per case: the light shaded area represents 100% of production capacity, the darker shade represents 85% of the production capacity. Dark blue bars show the production values for 2020-2022.

Note that figures do not include the secondary supply forecast, which has in the past filled the gap between primary production and demand.

Similarly, the resource base is influenced by market dynamics. Higher demand and prices typically incentivise increased exploration, leading to the identification of additional resources. Although these interactions are not explicitly modelled here, the authors recognise their significance and their potential to shape the resource base over time. The relationships between demand, prices, exploration efforts, and resource availability underscore the complex and dynamic nature of the supply-demand balance.

In-ground uranium resources will be brought into production when market conditions lend confidence that a given project will return value for investors and operators. Conversely, poor market conditions not only hold back new supply, but also slow investment in uranium exploration, which could affect the delineation of additional resources in the longer term. Historically, significant proportions of identified resources have never been extracted while, on average, the extraction of identified resources has taken one to two decades or more than originally planned (see, for example, IAEA 2020, Figure 2.75). In order to be able to meet future demand in the case of significant growth of nuclear energy, uranium prices will need to be sustained at a level that is adequate to justify the development of existing resources. Investment in exploration will also be necessary to identify additional resources, and funding for research and development to create innovative, cost-effective extraction techniques for unconventional, low-grade uranium deposits will be required.

Despite the reported additions to production capacity, both the low- and high-demand scenarios indicate it will be crucial to identify new resources, and to bring new facilities online in the coming years. Long lead times for establishing new production centres are expected, particularly in today's risk-averse investment market, and considering complex and lengthy regulatory processes in many uranium mining jurisdictions. Coupled with complex geopolitical challenges and prospective technical difficulties in the development of new mines and mill facilities, efforts must be made today to ensure an adequate supply of uranium is available in the medium term. Given that it can take several decades for a new discovery to reach production, the timely development of new projects is essential to prevent future supply disruptions.

Strong and sustained uranium demand market conditions are vital for attracting the necessary investment into the industry. As significant new nuclear generating capacity is added, additional resources of economic interest are likely to be identified with additional investment and exploration efforts.

Cumulative uranium consumption vs uranium resource base (all cost categories considered)

This section addresses whether the global uranium resource base is sufficient to meet the growing demands of nuclear power through 2050 and beyond, focusing on the fundamental question: Is there enough uranium to support future expansion of nuclear energy? This question assumes that most of the world will continue to use a once-through fuel cycle, which remains the dominant approach today.

To provide clarity, cumulative uranium requirements under a high-growth scenario are compared with the currently identified geological uranium resource base. This comparison considers both the period leading up to 2050 and the implications for the remainder of the century.

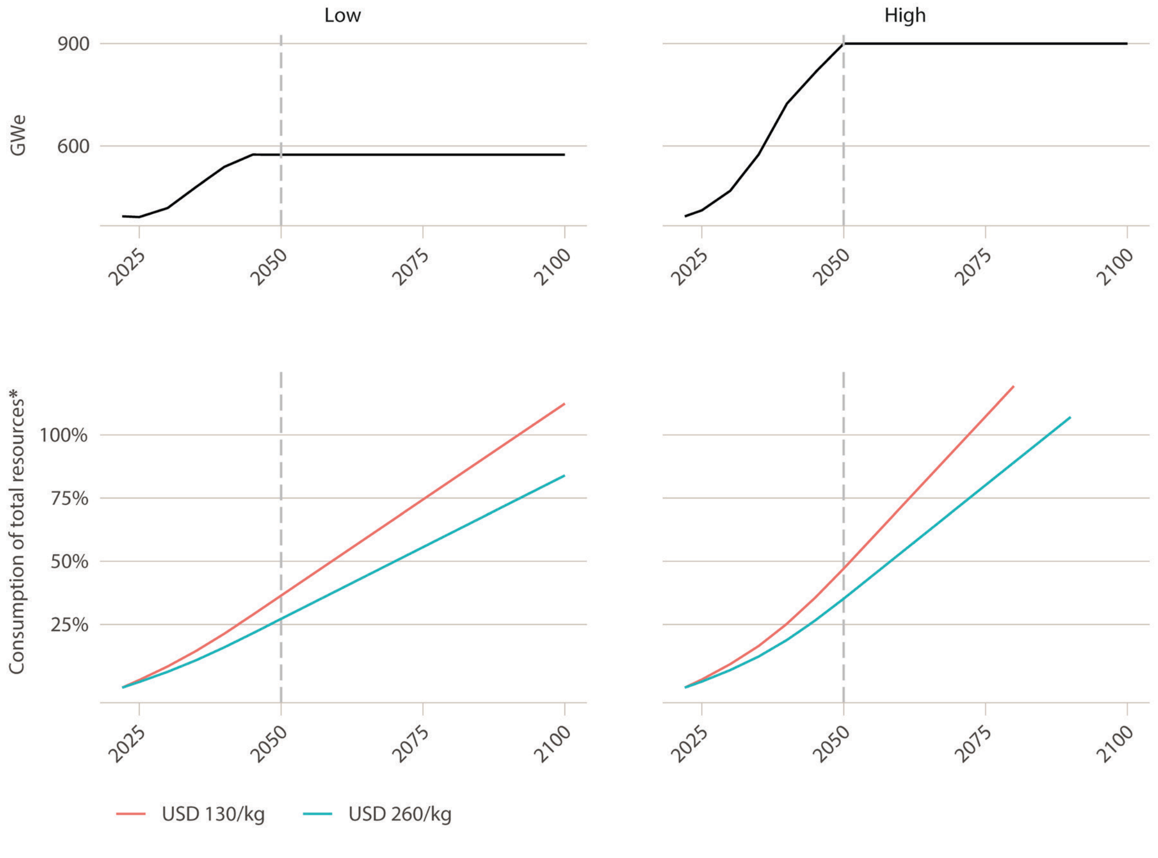
As of 2023 (see Table 1.1), the identified uranium resource base, approximately 8 million tonnes, is sufficient to meet the projected expansion of nuclear capacity through 2050, even under the high-growth scenario. However, achieving these high-demand projections would require about 2.8 million tonnes of natural uranium by 2050. To put this into perspective, this amount is roughly equivalent to the total quantity of uranium mined globally since the deployment of civilian nuclear power.

Looking beyond 2050, even if nuclear capacity is simply maintained at 2050 levels until the end of the century – an assumption consistent with the expected lifespan of newly built reactors – the quantity of natural uranium required for both low- and high-growth scenarios would likely exceed the entire currently identified uranium resource base of approximately

8 million tonnes. Figure 2.11 illustrates this, showing the progression of cumulative uranium requirements as a percentage of the total resource base. In the high-growth scenario, cumulative uranium requirements would reach 100% of the identified resource base at a cost of <USD 130/kgU by the 2070s, while in the low-growth scenario, this would occur by the 2090s.

In summary, while current uranium resources are sufficient to meet nuclear power demand through mid-century, sustaining or expanding capacity beyond 2050 would require mobilising uranium quantities comparable to today's entire known resource base, all before 2100s. These estimates are based on the currently known identified conventional recoverable resource base. Additional sources of uranium could come from undiscovered (around 8 million tonnes estimated in this edition) or unconventional resources, but significant time, effort and investment will be needed to access them and bring them into production. This highlights the urgent need for further exploration, resource development and reconsideration of the once-through fuel cycle as the default approach for a growing global nuclear fleet.

Figure 2.11. **Projected cumulative uranium requirements under low and high demand scenarios, assuming capacity is maintained from 2050 to 2100 (top), shown as a *percentage of total identified resources at costs below USD 130/kg U and USD 260/kgU (bottom)**



The long-term perspective

Global uranium demand is primarily driven by the number of operating nuclear reactors, historically tied to electricity demand. However, the future role of nuclear energy may increasingly need to consider both electricity production and non-electric applications, such as heat generation. The expansion of global nuclear capacity and the adoption of novel nuclear technologies – including SMRs and AMRs and their associated fuel cycles – will largely depend on government policies and the effective management of various factors. These include economics, safety, energy security, supply chain resilience, waste disposal, environmental concerns, and the technological readiness of these new applications. In this context, nuclear energy's role in future low-carbon energy mixes remains a central topic in global energy policy discussions.

All credible models show that nuclear energy has an essential role in decarbonisation and climate change mitigation as an established, large-scale, low-carbon energy source. Achieving net zero by 2050 is not possible without a significant contribution from nuclear power. However, the nuclear industry requires clear, consistent policy support for both existing and new capacity development, as well as the inclusion of nuclear in clean energy incentive schemes. Long-term assurances of uranium supply availability are equally essential. Nuclear energy is a reliable and dispatchable source of heat and electricity. For these reasons – and as concerns about energy security mount coupled with incentives for all types of low carbon power generation – demand for nuclear energy is expected to continue to grow and may, in fact, accelerate.

Beyond net zero ambitions, energy security concerns have come to the forefront due to the ongoing Russia-Ukraine conflict. This geopolitical situation has impacted the global nuclear fuel supply market, with many Western utilities looking to reduce reliance on Russian fuel and services.

Interest in SMRs is growing in both established nuclear countries and emerging nuclear markets globally. Numerous reports, and notably (NEA, 2024a), highlight the progress in SMR design, technology, technical feasibility, economic viability, and factors influencing their competitiveness. SMR designs are currently at various stages of development, from conceptual design to licensing and construction.

Technological advancements will significantly influence the long-term future of nuclear energy and uranium demand. These innovations aim to address economic, safety, security, non-proliferation, and waste management challenges while enhancing uranium resource efficiency. The introduction of advanced reactor designs, including Generation IV reactors, could enable the use of alternative nuclear fuels and more efficient consumption of fissile resources. Fast neutron reactors in particular hold the potential to maximise natural uranium utilisation.

Several national and international initiatives, such as the Generation IV International Forum and the IAEA's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), are actively working on the development of these advanced technologies. In the long term, new reactor designs, coupled with reprocessing and recycling infrastructures for used nuclear fuel, have the potential to transform the nuclear fuel landscape and significantly enhance overall nuclear fuel efficiency.

Conclusion

As reported in this edition, sufficient uranium resources exist to support the continued use of nuclear power and significant growth in nuclear capacity for electricity generation through 2050 and beyond. Uranium requirements from emerging nuclear applications, such as SMRs – including both electric and potentially non-electric uses such as industrial decarbonisation and district heating – will need to be considered once there is greater clarity on these novel applications.

Given the limited maturity and geographical reach of uranium exploration worldwide, there is considerable potential for discovering new resources of economic interest. Recent years have clearly demonstrated that, with appropriate market signals, new uranium resources can be readily identified, developed and mined. However, it is essential that consumers and producers ensure that the necessary framework conditions for uranium exploration, mining, processing and transportation are in place. This includes pricing mechanisms that provide sufficient market visibility to support the long-term investments required for these developments. A strong uranium market, characterised by sustained prices at an adequate level, will be crucial for developing resources in time to meet future uranium demand, which is projected to more than double by 2050 in the high scenario outlined in this edition.

When comparing projected annual uranium production to requirements, it appears likely that the existing demand-supply gap in the uranium market, which has persisted for three decades, will continue into the next decade if significant nuclear capacity growth occurs worldwide. Given the long lead times between resource discovery and production, identifying new projects in the near to medium term will be essential to prevent potential supply disruptions.

Considering both the low and high nuclear capacity scenarios to 2050 presented in this edition, and assuming their 2050 capacity is maintained for the rest of the century, the quantities of uranium required by the global fleet – based on the current once-through fuel cycle – would likely surpass the currently identified uranium resource base in the highest cost category before the 2110s.

Additionally, there are sizeable unconventional uranium resources, such as phosphate deposits and black schists/shales, that could extend the period during which the known uranium resource base could support global energy demand using current technologies. However, further research, innovation and investment are required to better define the scope of these unconventional resources and to develop cost-effective extraction methods.

The development and deployment of advanced reactor and fuel cycle technologies could also significantly enhance the efficiency of uranium use in the long term, in particular the adoption of advanced reactors and closed fuel cycles with fuel recycling could potentially extend the availability of nuclear energy from uranium fission for thousands of years.

In conclusion, while sufficient physical uranium resources exist to meet demand for nuclear power generation at both current and increased levels through 2050 and beyond, significant exploration and investment will be needed to identify and develop new mining projects in a timely manner. This will be necessary to ensure sufficient supply is available to meet demand at reasonable prices.

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Chapter 3. National reports on uranium exploration, resources, production, demand and the environment

Introduction

This chapter presents the national submissions on uranium exploration, resources and production. These reports have been provided by official government organisations (see Appendix 1) responsible for the control of nuclear raw materials in their respective countries, although the details are the responsibility of the individual organisations concerned. In countries where commercial companies are engaged in exploration, mining and production of uranium, the information is first submitted by these companies to the government of the host country and may then be transmitted to the NEA or the IAEA at the discretion of the government concerned. In certain cases, where an official national report was not submitted, and where it was deemed helpful for the reader, the NEA/IAEA has provided additional comments or estimates to complete this report. In such cases, "NEA/IAEA estimates" are clearly indicated. This chapter contains 62 country reports on uranium exploration, resources, production and reactor-related requirements, 48 of which were prepared from officially reported government data and narratives, and 14 that were prepared by the secretariats of the Nuclear Energy Agency (NEA) and International Atomic Energy Agency (IAEA).

It should be noted that exploration activities may be currently ongoing in a number of other countries that are not included in this report. In addition, uranium resources may have been identified in some of these countries. It is believed, however, that the total of these resources would not significantly affect the overall conclusions of this report. Nevertheless, the NEA and IAEA encourage the governments of these countries to submit an official response to the questionnaire for the next edition of the Red Book.

Additional information on the world's uranium deposits is available in the IAEA online database *World Distribution of Uranium Deposits – UDEPO*[1]. UDEPO contains information on location, ranges of uranium tonnage and average grade, geological type, status, operating organisations (in case the deposit is being mined), and other technical and geological details about the deposits.

1. See IAEA (n.d.), World Distribution of Uranium Deposits – UDEPO, www-nfcis.iaea.org.

Algeria

Uranium exploration and mine development

Historical review

For over fifty years, uranium prospecting in Algeria, which began with the launch of a mineral prospecting programme in the Hoggar region, underwent a first stage (1969-1973) marked by a significant investment effort that led to the discovery of the first uranium deposits in the Hoggar Precambrian crystalline basement (Timgaouine-Abankor-Tinef).

These results, obtained through ground radiometric surveys and geological mapping, quickly identified the uranium resource potential of the Hoggar region, which overall has favourable geological and metallogenic characteristics for mineral deposits.

An aeromagnetic-spectrometric survey of the entire country, carried out in 1971, provided the initial incentive and direction for uranium exploration. The processing of the data collected from this survey identified potential regions for further uranium prospecting, including the Eglab, Ouggarta, and Tin Seririne sedimentary basins (Southern Tassili where the Tahaggart deposit was discovered), as well as individual areas in Tamart-n-Iblis and Timouzeline.

While these developments were taking place, uranium prospecting entered a new phase (1973-1981) primarily aimed and focused on the assessment of uranium reserves and the development of previously discovered deposits.

Despite a pronounced slowdown in prospecting activities in the phase that followed (1984-1997), work undertaken in the immediate vicinity of previously discovered deposits and in other promising areas revealed indications of uranium mineralisation and radiometric anomalies in the Amel and Tesnou zones located to the northwest and north of the Timgaouine region respectively.

Surveys conducted in the Tin Seririne Basin (Tassili South Hoggar) provided a basis on which to undertake geologic mapping and revealed the distribution of uranium-bearing minerals in Palaeozoic sedimentary formations.

Recent and ongoing uranium exploration and mine development activities

In 2017 and 2018, the Agency of the Geological Service of Algeria in collaboration with the United States Geological Survey carried out preliminary prospecting work for undiscovered mineral resources (diamond, Au, PGE-Cr, Cu-Ni-PGE-Cr and Mo-Cu) in the Eglabs region, including uranium resources related to granites, calcretes, alkaline rocks and carbonatites.

No uranium prospecting or mine development work was carried out between January 2019 and January 2021. All prospecting programmes were placed on hold, largely due to the COVID-19 pandemic.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

There are two geological types of reasonably assured resources in Algeria: upper Proterozoic vein deposits in the western Hoggar, and a deposit linked to the Precambrian basement and its Palaeozoic sedimentary unconformity in the central Hoggar. The first type includes vein deposits linked to faults crossing the Pan-African batholith in the Timgaouine region, represented by the Timgaouine, Abankor and Tinef deposits in the southwestern Ahaggar.

The second type is unconformity-related, represented by the Tahaggart deposit. It is associated with a weathering profile (regolith) developed at the interface between the Precambrian basement and the Palaeozoic cover, and to conglomerates at the base of the Palaeozoic sedimentary sequence in the Tin Seririne Basin (south-east of Hoggar). It is worth noting that the uranium mineralisation discovered in the Ait Oklan-El Bema (north Hoggar) region has not been assessed in terms of uranium resources.

Undiscovered conventional resources (prognosticated and speculative resources)

Algeria does not report any resources in any category other than reasonably assured resources.

Uranium production

Historical review

Algeria does not produce uranium.

Regulatory regime

Mining activities related to raw materials for nuclear energy, and environmental protection aspects to be taken into account for such activities are governed, among others, by:

- Law No. 03-10 of 19 July 2003 on the protection of the environment for sustainable development.
- Law No. 14-05 of 24 February 2014 relating to mining activities.
- Law No. 19-05 of 17 July 2019 on nuclear activities.

Algeria decided to regulate activities related to the research, production and peaceful use of nuclear energy with the adoption of Law No. 19-05 of 17 July 2019 on nuclear activities.

The law sets objectives such as the protection of human health, the environment and future generations against potentially harmful effects related to the use of ionising radiation, while respecting the principles of radiological protection and nuclear safety and security, in compliance with Algeria's commitments under international treaties and conventions. It applies to activities related to nuclear materials and ionising radiation sources, nuclear and radiological installations, radioactive waste, and uranium and thorium ores.

The measures to be put in place by operators, importers, transporters, and holders of radioactive materials to achieve these objectives, including exposure limits, accident prevention measures, or systems to control access to facilities or to combat illicit trafficking in nuclear materials, will be set by regulation.

By application of this law, the National Authority for Nuclear Safety and Security (NNSSA) was created under the supervision of the Prime Minister by executive decree (No 21-148 of 20 April 2021) and is currently operational. The Atomic Energy Commission (COMENA) for its part will continue to provide aid and assistance to the NNSSA.

National policies related to uranium

From a mining perspective, in a world market dominated in the short- and medium-term by a small number of producers, it is currently not economically feasible to exploit uranium resources in Algeria.

Algeria's uranium resources can only be exploited in a sustainable manner within the framework of an integrated development of the nuclear sector and its main applications. The latter includes nuclear power generation and seawater desalination plants, together with applications in medicine, agriculture, water resources and industry.

Regarding the current situation in the global energy market, Algeria is working towards the integrated development of the uranium sector, ranging from exploration to production and encompassing research and development, training, and long-term nuclear power generation prospects.

The development of the uranium production cycle and its applications would require the acquisition of technical expertise, which can only be achieved through ambitious research, development and training programmes. Through its nuclear research centres, Algeria currently has the appropriate tools to undertake work in the future, either alone or through bilateral or multilateral co-operation. It is in a spirit of openness and transparency that Algeria applied itself to the task of putting in place the most favourable and appropriate institutional and regulatory framework with which to pursue the energy development of the country, including a Mining Act, Environmental Protection Act, an Oil and Gas Act and recently a Civil Nuclear Activities Act. The latter establishes the regulatory framework for mining activities relating to radioactive minerals, from exploration to mine rehabilitation, including the management of radioactive mining waste.

To improve the mining sector and boost research, exploration and development, the government amended Law 01-10 (of 3 July 2001) by promulgating Law 14-05 on 24 February 2014. This mining law aims to create better conditions for the revival of the sector through adequate funding for research and exploration of new economically viable mining deposits, including uranium.

Uranium stocks

None.

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Unspecified	0	0	0	26 000
Total	0	0	0	26 000

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Unspecified	0	0	0	26 000
Total	0	0	0	26 000

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Proterozoic unconformity	0			2 000
Granite-related				24 000
Total				26 000

Mid-term production projection

(tonnes U/year)

2025	2030	2035	2040	2045	2050
N/A	N/A	N/A	N/A	N/A	N/A

Installed nuclear generating capacity to 2050

(MWe net)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Argentina

Uranium exploration and mine development

Historical review

Uranium exploration in Argentina, and the subsequent development of uranium resources, was started in the 1950s by the National Atomic Energy Commission (CNEA). Since then, several areas of uranium mineralisation have been discovered, and resources evaluated. As of the beginning of the 2000s, in addition to CNEA, junior and provincial mining companies and senior industrial producers have been involved in uranium exploration projects that are at different stages of progress.

In the early 1950s, the exploration activities carried out by the CNEA led to the discovery of the Papagayos, Huemul, Don Otto and Los Berthos uranium deposits. During the late 1950s and the early 1960s, airborne surveys also led to the discovery of the Los Adobes sandstone-type deposits in Patagonia.

During the 1960s, the Schlagintweit and La Estela granite-related deposits were discovered and subsequently mined. During the 1970s, follow-up exploration near the previously discovered uranium occurrences in Patagonia led to the discovery of two new sandstone deposits: Cerro Condor and Cerro Solo. At the end of the 1980s, a nationwide exploration programme was undertaken to evaluate geological units with uranium potential.

From 1990 to 1997, exploration was conducted in the vicinity of the Cerro Solo deposit (Chubut Province), where more than 56 000 m were drilled to test the potential of favourable portions of the paleochannel structure. The results included the localisation and partial evaluation of specific mineralised bodies with 4 600 tU of reasonably assured and inferred resources.

These results allowed the CNEA to complete a preliminary economic assessment of the Cerro Solo U-Mo deposit in 1997, including a revised geological model and ore resource estimates, mining and milling methods and costs, cash flow and risk analysis, as well as the exploration and evaluation of the surrounding areas.

As a result of the national government’s policy announced in August 2006 to reactivate the nuclear programme, different areas of uranium interest have been explored and evaluated by the CNEA.

In the early 2000s, six private uranium exploration companies began work in Argentina as noted by the *Cámara Argentina de Empresas de Uranio* (CADEU – Argentine Chamber of Uranium Companies): U3O8 Corp. (Meseta Exploraciones S.A. - MEXSA; Calypso Uranium Corp. merged with U3O8 Corp.); Sophia Energy S.A.; Blue Sky Uranium Corp. (Minera Cielo Azul S.A.); Cauldron Minerals Ltd; Gaia Energy Argentina S.A. and UrAmerica Ltd. Of these private companies, U3O8 Corp., Sophia Energy S.A., UrAmerica Ltd. and Blue Sky Uranium Corp. continue with their work in Argentina.

For more detailed historical information, please refer to the 2022 edition of the Red Book.

Recent and ongoing uranium exploration and mine development activities

As of 2023, the CNEA owns approximately 50 exploration licences in Argentina, considering requested and conceded exploration permit areas, statements of discovery and ore deposits. They are located in the provinces of Salta, Catamarca, La Rioja, San Juan, Mendoza, La Pampa, Río Negro, Chubut and Santa Cruz.

In recent years, exploration activities carried out by the government have slowed down and from 2017 to 2021 no drilling has been carried out. The main areas that have been targeted by the CNEA for uranium exploration are located in Cañadón Asfalto Basin (Chubut Province), Neuquén Basin (Río Negro and La Pampa Provinces), Meseta Sirven (Santa Cruz Province), Velasco Range (La Rioja Province), Fiambalá Range (Catamarca Province) and Salta Group Basin (Salta Province). In general, the activities have been focused on field work for geological and radiometric reviews, geophysical surveys, radon emmanometry surveys, sampling for geochemical analysis and environmental studies.

Of those uranium deposits managed by the CNEA, the most relevant in the assessment/exploration stage is Cerro Solo, located in Chubut Province. Identified uranium resources of the Cerro Solo deposit total 9 230 tU. To define hydrometallurgical extraction of uranium and molybdenum minerals, laboratory-scale sample testing has been completed, but further up-scale testing was postponed. From 2012 to 2023, one of the main activities at the Cerro Solo deposit was related to environmental monitoring and baseline surveying in compliance with provincial regulations. In this regard, hydrological, palaeontological, socio-economic, air quality, flora and fauna, pedological and archaeological studies have been completed, while a radiometric/radiological baseline is underway and natural acidic drainage survey is planned to be carried out in 2023-2024.

Due to the COVID-19 pandemic, during 2020 and 2021, uranium exploration activities focused mainly on desktop work, consisting of: data collection, processing, and interpretation; writing of technical reports; dissemination, training and teaching activities. Limited laboratory activities were carried out, which included preparation, studies and analysis of geological samples. Field tasks were very limited and reduced to two geological commissions carried out in the Northwest of the country.

Government exploration activities increased in 2022 and included a programme of 1 197 metre drilling (6 drilled holes) in the Neuquén Basin (Río Negro Province). In 2023, 1 exploration hole of 171 m was drilled in this basin.

In 2021-2022 the CNEA formulated an investment project on comprehensive exploration and evaluation of uranium resources in the Cañadón Asfalto Basin (Chubut Province) and the Deseado Massif and their areas of influence (Santa Cruz Province). In 2022 a specific co-operation agreement was signed between the CNEA and FOMICRUZ S.E., aimed at co-ordinating actions and developing uranium favourability and exploration in the Santa Cruz Province. Within the framework of these two initiatives, during the first half of 2023, an exploration programme was carried out in the Meseta Sirven area (Santa Cruz Province) excavating 63 exploration trenches (approximately 220 m trenching). It was expected that this programme would resume in the final part of 2023 to complete the total of 200 trenches (700 m trenching) that had been planned for the whole year of 2020.

In 2022-2023, the CNEA formulated a new investment project on exploration of Neogene and Quaternary uranium deposits in the Puna and Pampean Ranges (Jujuy, Salta and Catamarca Provinces), whose activities are planned to begin in 2024.

Blue Sky Uranium Corp., U3O8 Corp., Consolidated Uranium Inc., UrAmerica Ltd. and Sophia Energy S.A. reported exploration-related activities during the 2019-2023 period.

In 2019, Blue Sky Uranium Corp. announced the first preliminary economic assessment for the Ivana deposit (Amarillo Grande project), as well as an updated resource estimate. The inferred in situ resource estimate includes 8 730 tU at 0.031% U and 2 920 tV at 0.011% V. Blue Sky Uranium Corp.'s exploration efforts from 2020 to 2022 achieved two goals. First, the exploration of the area located close to the Ivana deposit defined new targets based on mapping, surficial sampling (outcrops, soil, pits and/or auger holes), radiometric surveys (surficial and borehole) and geo-electrical or seismic geophysical surveys. A total of 4 214 metres of drilling in 83 holes was carried out on these new targets, including reverse circulation (RC), direct circulation (DC) and diamond drill holes (DDH). Second, the Ivana deposit was advanced with more drilling (3 346 m in 350 RC holes) and metallurgical tests (membrane filtration and liming, uranium-vanadium separation by solvent extraction, uranium and vanadium precipitation and uranium/vanadium calcining). The exploration plan for 2023 includes a continued drilling programme of 3 000 metres at new targets and completing metallurgical test-works, updated mineral resources, and a preliminary economic assessment for the Ivana deposit.

In June 2021, U3O8 Corp. announced that Consolidated Uranium Inc. (former International Consolidated Uranium Inc.) had been chosen to exercise its option to purchase the Laguna Salada project (Chubut Province) from U3O8 Corp. The terms of the option agreement were outlined in U3O8 Corp.'s press release dated 14 December 2020. In December 2021, Consolidated Uranium Inc. closed its option to acquire the Laguna Salada uranium and vanadium project. This project has been in care and maintenance since 2014. In 2022, Consolidated Uranium Inc. undertook mapping and surface sampling to further the geological understanding of the project. The company has no exploration plans for 2023 and the project will be put back into care and maintenance. In 2023 Consolidated Uranium Inc. also acquired the Huemul Project, which is an early-stage exploration project located in the southern part of Mendoza Province. Huemul consists of approximately 27 350 hectares of exploration claims centred around CNEA's historic Huemul-Agua Botada mine, Argentina's first producing uranium mine.

In 2020, the memorandum of understanding (MOU) signed in 2018 among UrAmerica Ltd, Uranium One Group from Russia, UrAmerica Argentina and the Government of Argentina expired. The main purpose of that MOU was to promote co-operation and the joint development of uranium exploration and production focused on ISL, with planned investment amounting to USD 250 million. UrAmerica Ltd plans to set up a subsidiary company based in the United States, which among other goals would provide uranium exploration investments for its Argentinian uranium projects. UrAmerica Ltd. is primarily focused on uranium but its prospective package of licences also contains critical metals such as lithium, rare earths, molybdenum and vanadium.

In recent years, Sophia Energy S.A. continued exploration of its mining properties at the Sirven deposit in Santa Cruz Province. Activities include processing satellite imagery, geological mapping, ground and airborne radiometric surveys, and geochemical and geobotanical sampling and analyses, a portion of which was carried out in co-operation with the University of Surrey (United Kingdom). These exploration efforts brought encouraging results. In December 2019, Sophia Energy S.A. received approval from the province of Santa Cruz Mining Authorities to perform an intensive two-year exploration programme focused on follow-up studies on targets identified by the airborne survey carried out in 2018. The COVID-19 pandemic caused exploration activities to be put on hold since early 2020. A trenching exploration and resource assessment programme has been formulated to start in 2023-2024.

The information about private exploration expenditures must be taken as only partially complete since the industry is not required to report these expenditures to the government.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

No new reasonably assured and inferred resources have been assessed since the 2022 edition of the Red Book.

As of 1 January 2023, the total identified recoverable resources of Argentina are 34 250 tU at the cost category <USD 130 /kgU, comprising the seven projects listed in the above table. At the highest production cost category of <USD 260/kgU, there is no substantial variation and total recoverable identified resources amount to 35 300 tU.

Identified recoverable uranium resources (RAR+IR) in Argentina

(as of 1 January 2023)

Deposit (ownership)	Province	Type	RAR tU <USD 130/kgU	Inferred tU <USD 130/kgU
Sierra Pintada (CNEA)	Mendoza	Volcanic-related	3 900	6 110
Cerro Solo (CNEA)	Chubut	Sandstone	4 420	3 760 (4 810)*
Don Otto (CNEA)	Salta	Sandstone	180	250
Laguna Colorada (CNEA)	Chubut	Volcanic-related	100	60
Laguna Salada (Consolidated Uranium Inc.)	Chubut	Surficial	1 860	1 120
Meseta Central (UrAmerica Ltd)	Chubut	Sandstone	-	5 290
Ivana/Amarillo Grande (Blue Sky Uranium Corp.)	Río Negro	Sandstone (surficial)	-	7 200
Subtotal			10 460 tU	23 790 tU (24 840 tU)*
Total Identified resources			34 250 tU (35 300 tU)*	

* tU for production cost category of <USD 260/kgU.

Undiscovered conventional resources (prognosticated and speculative resources)

No new prognosticated and speculative resources have been assessed since the 2022 edition of the Red Book.

There are 13 800 tU of prognosticated resources associated with five sandstone-type deposits in the Cerro Solo and Sierra Cuadrada uranium districts of Chubut Province (Cerro Solo, El Ganso, Puesto Alvear, El Molino, Sierra Cuadrada Norte and Arroyo Perdido). Additionally, 6 900 tU of prognosticated resources have been evaluated in other provinces at the Catriel (6 000 tU; sandstone type; Río Negro Province), El Gallo (600 tU; intrusive type; La Rioja Province) and Laguna Sirven (300 tU; surficial type; Santa Cruz Province) deposits. Therefore, total prognosticated in situ resources account for 20 700 tU in the <USD 260/kgU cost category.

To assess the uranium favourability and estimate the potential resources by the application of quantitative McCammon and Deposit Size Frequency (DSF) methods, also used in the US National Uranium Resource Evaluation (NURE) programme, the country was divided into 61 investigation units (IU). These units, which cover 1 450 000 km^2, were delineated on the basis of the geotectonic setting as well as petrological, mineralogical and geochemical characteristics. Speculative uranium in situ resources amount to 79 500 tU according to the resource assessment that has been completed in 5 IUs considered as the units with high uranium potential (i.e. Salta Group Basin, Pampean Ranges, Paganzo Basin, San Rafael Basin and Chubut Group Basin). Sandstone, volcanic-related and granite-related uranium deposit types have been taken into consideration in this approach.

In addition, qualitative methodologies based on spatial modelling and mineral system concepts have been applied to determine uranium exploration targets in several geological units (Salta Group Basin, Pipanaco Salt Flats/Aimogasta Basin, Paganzo Basin, Western Precordillera and Western Flank of the Pie de Palo Range, Pampean Ranges, Ambargasta Salt Flats, Sumampa Ranges, Deseado Massif and related areas). Other prospective studies have been conducted, notably related to uranium from phosphates (unconventional resources) and granite-related uranium deposits in the framework of IAEA Coordinated Research Projects. Preliminary studies have been carried out for the assessment of the uranium potential of phosphate rocks and testing uranium extraction from low-grade phosphate ores. Interpretation of new studies on uranium mineralisation from several uranium sites of interest has improved the metallogenetic understanding of the granite-related deposits and the exploration guidelines.

Uranium production

Historical review

From 1952 to 1997, Argentina produced 2 582 tU in the form of ammonium diuranate ("yellowcake"), intended to meet the domestic Argentinian demand. Seven production centres (not simultaneous) and a pilot plant processed the uranium ore from about 13 deposits, distributed throughout the country, where both open-pit and underground mining methods (82% and 18%, respectively) were used. Heap-leaching with ion-exchange resins extraction was the main processing technique applied for yellowcake production. Regarding the geological deposit types, 64% were volcanic-related, 26% sandstone, and the remaining 10% were granite-related deposits.

In the late 1990s, the decline in the price of uranium made domestic production no longer competitive and the decision was taken to shut down the last facility that was in operation, the San Rafael Mining-Milling Complex, which was placed on standby in 1997. No uranium has been produced since then, neither privately nor by the state.

Status of production facilities, production capability, recent and ongoing activities and other issues

Regarding the prospects of domestic production, it is considered that uranium projects with identified resources and a higher degree of maturity, such as Sierra Pintada, Cerro Solo, Laguna Salada, Meseta Central and Amarillo Grande, must complete the resource delineation and advance the technical studies for comprehensive recovery of uranium and other associated metals of economic interest, notably vanadium and molybdenum.

A large part of the identified uranium resources in Argentina are in the Chubut and Mendoza provinces, where uranium mining and processing is constrained by current legislation, and it will be necessary to interact adequately with society to generate a more positive perception towards mining activity in these provincial domains. Should legislation be amended in these regions, there is the potential to resume development and ultimately mining and processing of these identified uranium deposits. Production from these mines would positively contribute to clean energy initiatives and provide positive economic benefits to the National State.

To date, San Rafael, Cerro Solo, Amarillo Grande and Laguna Salada have been considered as prospective uranium production centres. San Rafael and Cerro Solo centres belong to the CNEA and technical details have been provided by internal and external reports. Amarillo Grande and Laguna Salada centres belong to Blue Sky and Consolidated Uranium, respectively, and their technical details have been provided in the NI 43-101 Preliminary Economic Assessment (PEA) reports filed to date.

The San Rafael Mining-Milling Complex (CMFSR) Remediation and Reactivation Project

In 2004, once the CNEA evaluated the possibility of reopening the production facilities of the San Rafael Mining-Milling Complex (Sierra Pintada mine), an environmental impact assessment (EIA-2004, according to provincial Act 5961) was presented to the authorities in the province of Mendoza and to the Nuclear Regulatory Authority. This study evaluated the potential impacts of uranium concentrate and dioxide production and the treatment of the former wastes simultaneously.

This EIA concluded that former operations had not affected the quality of underground and surface waters in the area, or any other environmental component in the surrounding area. Provincial authorities nonetheless rejected the reopening proposal, arguing that the CNEA must first remediate the open-pit water and the milling wastes stored in drums before restarting production. In response, the CNEA prepared and submitted a new EIA (2006) addressing only the treatment of wastes in temporary storage and pit water. This proposal received technical approval, but not final approval because it lacked the required statutory public hearing. A further complication that increased the difficulty of reopening the plant was the approval of Mendoza Provincial Act 7722 (2007), which prohibits the use of sulphuric acid, among other chemicals, in mining activities.

Currently, the CNEA is constructing evaporation ponds and defining the basic engineering for the simultaneous treatment of open-pit water and milling wastes stored at the San Rafael complex. To date, three effluent evaporation ponds have been finished and one more is under construction. In 2018, the update of the EIA 2006 (EIA, 2013) presented to the provincial control authorities reached a favourable technical opinion and a mandatory public hearing by law was held in 2019 with positive outcomes. Therefore, the provincial authorities granted approval of the environmental impact statement through Resolution N° 259/19.

The CNEA has set up public investment projects to secure sufficient funds for the remediation works of former uranium production facilities. Currently, efforts are being made to rehabilitate the old plant to manage mine water, solid waste and other environmental liabilities.

Before restarting uranium production in San Rafael, it is necessary to obtain both provincial approval and agreement to amend the provincial law that prevents the use of sulphuric acid, among other chemicals. Technical feasibility has been partially demonstrated by the fact that this deposit was previously in operation, using the acid heap-leach processing method. Other alternatives have been considered for possible future production, including the use of alkaline leaching, bioleaching and vat leaching. Also, given the possibility of reopening the mining-milling complex, all available data have been processed to redefine the geological model and formulate more suitable mining and processing designs.

The Cerro Solo Project

The CNEA carried out several laboratory-scale tests to determine the most economical milling process for the proposed mining of the Cerro Solo deposit and initiated pre-feasibility studies.

A conceptual study of the mining plans was advanced and improved using specific software for geological modelling. A pre-technical economic feasibility study was in development, beginning with validation of all prior information (tonnages, grade, geotechnical, geostructural and hydrogeological) and some surface works.

The conceptual engineering of the project has already been defined, but pre-feasibility study is in standby status awaiting a governmental decision to continue it.

Besides technical considerations, a Chubut provincial law 5001/03 that prevents open-pit mining remains in effect and mining projects need to wait for the Chubut provincial territory zoning provisions of the aforementioned law, as well as the introduction of a regulatory framework for mining in this jurisdiction.

Ownership structure of the uranium industry

In Argentina, the uranium industry is mainly owned by the government. Private sector participation exists only in the exploration phase, although legislation provides for the participation of both state and private sectors in uranium exploration and production activities.

Employment in the uranium industry

In connection with the uranium production industry, currently most of the employees are working on development, maintenance and remediation of the San Rafael Mining-Milling Complex.

Future production centres

To date, the reopening of the San Rafael complex (Mendoza Province) and the development of a new production centre in Chubut Province, near the Cerro Solo deposit, are acceptable options to the government for future production.

Production and/or use of mixed oxide fuels

Argentina neither produces nor uses MOX fuel in its nuclear power plants.

Production and/or use of re-enriched tails

In Argentina there is no production or use of re-enriched tails.

Uranium production centre technical details

(as of 1 January 2023)

	Centre #1	Centre #2
Name of production centre	San Rafael Mining-Milling Complex	Cerro Solo
Production centre classification	Prospective (reopening)	Prospective
Date of first production	NA	NA
Source of ore:		
Deposit name(s)	Sierra Pintada	Cerro Solo
Deposit type(s)	Volcanic-related (synsedimentary)	Sandstone (paleochannel)
Recoverable resources (tU)	6 000	4 500-5 000
Grade (% U)	0.107	0.15-0.20
Mining operation:		
Type (OP/UG/ISL)	OP	OP
Size (tonnes ore/day)	550	600
Average mining recovery (%)	90	85-90
Processing plant:		
Acid/alkaline	Acid	Acid
Type (IX/SX)	IX	SX
Average process recovery (%)	78	80-85
Nominal production capacity (tU/year)	150	250-300
Plans for expansion	Yes	NA
Other remarks	Production started in 1976 and ceased in 1997. Remediation activities are underway.	Pre-feasibility in standby stage

	Centre #3	Centre #4
Name of production centre	Amarillo Grande	Laguna Salada
Production centre classification	Prospective	Prospective
Date of first production	NA	NA
Source of ore:		
Deposit name(s)	Ivana	Guanaco, Lago Seco
Deposit type(s)	Sandstone (+/-Surficial)	Surficial
Recoverable resources (tU)	8 708	2 450
Grade (% U)	0.031	0.009
Mining operation:		
Type (OP/UG/ISL)	OP	OP
Size (tonnes ore/day)	6 500	12 000
Average mining recovery (%)	89	82
Processing plant:		
Acid/alkaline	Alkaline	Alkaline
Type (IX/SX)	SX	IX
Average process recovery (%)	95	94
Nominal production capacity (tU/year)	520	300
Plans for expansion	NA	NA
Other remarks	Preliminary Economic Assessment Stage	Preliminary Economic Assessment Stage

Environmental activities and socio-cultural issues

Environmental impact assessments

In Argentina, production permits are subject to both national and provincial legislation. Currently, environmental studies are being undertaken on three major uranium production projects.

The San Rafael Mining-Milling Complex Remediation Project (Mendoza Province)

An update of the 2006 EIA (MGIA-2013) was presented to the authorities of the Mendoza Province. This study addressed only the treatment of solid wastes (currently in temporary storage) and open-pit mine water. The proposal received technical approval (2013 EIA), which was endorsed after the implementation of the statutory public hearing in 2019. In the meantime, the CNEA has continued to evaluate technical options to minimise environmental impacts and established additional security measures.

Cerro Solo ore deposit (Chubut Province)

As requested by the provincial authorities, the CNEA is developing environmental baseline studies through contracts with universities and institutes, and parts of the studies (archaeological, palaeontological, and socio-economic impacts) have already been presented to provincial authorities. In addition, the CNEA continues with communication activities, offering information on mining practices to residents located near the proposed mining projects and areas of exploration.

The Los Gigantes former Mining-Milling Complex Remediation Project (Córdoba Province)

In November 2018, the detailed engineering of the environmental restitution project of the site was presented to provincial authorities and the CNEA is awaiting a response before conducting a public hearing and developing an environmental impact statement.

Monitoring

The San Rafael Mining-Milling Complex Remediation Project (Mendoza Province)

The CNEA currently has an intense monitoring programme, which includes:

- Surface water: surface water and run-off, both upstream and downstream of the facilities, is being sampled systematically to follow the evolution of possible pollutant concentrations (U, As, Ra, among others) inside and outside the CNEA's influence area.
- Groundwater: groundwater within a redesigned well network inside the complex is being sampled systematically.
- Air pollution: particulate matter and radon emissions are periodically sampled in key locations of the complex.
- Open-pit water: open-pit water is being sampled systematically in every pit.
- Sediments: sediments are being sampled systematically in the complex.

Cerro Solo deposit (Chubut Province)

The sampling work includes analysis of water samples from exploration wells, water samples from domestic wells (owned by inhabitants of the area), surface run-off and sediment from streams and springs in the watershed (analysing for U, Ra, As, F, among others). Analysis of air quality includes particulate matter and radon emission measurements.

Site rehabilitation

The San Rafael Mining-Milling Complex Remediation Project (Mendoza Province)

In general, the CNEA is submitting technical proposals to rehabilitate those areas of the complex that will not be used for uranium production in the future. Topics include rehabilitation of the former tailings dump, open-pits and waste rock management.

Uranium Mining Environmental Restoration Programme

The CNEA is undertaking the Uranium Mining Environmental Restoration Programme (PRAMU). The aim of this programme is to restore the environment as much as possible in every area where uranium mining and milling activities have taken place.

At the Malargüe site (Mendoza Province), the environmental restoration work was completed in June 2017, together with the construction of a recreation space for the community. From that date, a post-closure environmental and radiological monitoring programme was initiated.

The Córdoba and Los Gigantes sites (Córdoba Province) have advanced detailed engineering projects underway. The sites being studied are Huemul (Mendoza Province), Pichiñán (Chubut Province), Tonco (Salta Province), La Estela (San Luis Province), and Los Colorados (La Rioja Province), where environmental baseline studies are being developed. All these sites are the subject of periodic radiological and environmental monitoring. PRAMU seeks to improve the conditions of the tailing deposits and mines to ensure the long-term protection of people and the environment.

The CNEA is required to comply with all legislation that is in force and is under the control of various national, provincial and local state institutions.

Regulatory activities

Argentina's provinces have legislation limiting certain aspects of mining activities (e.g. use of certain substances, open-pit mining). The local regulations co-exist with national legislation related to mining activities and environmental protection.

National regulations

- Law No. 25 675: "General Environmental Law" establishes minimum standards for achieving sustainable management of the environment, the preservation and protection of biodiversity and the implementation of sustainable development.
- Law No. 1 919: "National Mining Code", which in Title Eleventh (Articles 205 to 212) refers to nuclear minerals (U and Th).
- Law No. 24 585: Requirement to submit an environmental impact assessment (EIA) prior to each stage of development of a mining project. It sets the maximum acceptable limits of various effluent parameters in water, air and soil.

Mendoza provincial regulations

- Law No. 3 790, created the Mining General Direction with specific functions related to the administration, control and promotion of the mining industry in all its phases throughout the province.
- Law No. 7 722 prohibits the use of chemicals such as cyanide, mercury, sulphuric acid, and other toxic substances typically used in metalliferous mining, including prospecting, exploration, exploitation and industrialisation of metal ores obtained by any extraction method in the province.
- Resolution No. 778/96 of the General Department of Irrigation (DGI) regulates all activities that potentially affect surface water and groundwater quality in the province.

Chubut provincial regulations

- Law XVII-No. 68 prohibits open-pit metal mining in the province, as well as the use of cyanide in mining production processes. It also specifies the need for zoning in the province for the exploitation of mineral resources with an approved production model required for each case.

Uranium requirements

As of 1 January 2023, the country has three heavy water reactors in commercial operation: Atucha I (Buenos Aires province), with an installed gross capacity of 362 MWe, which is fed with slightly enriched U (0.85% U-235), and Embalse (Córdoba province) and Atucha II (Buenos Aires province), both operated with natural uranium fuel and installed gross capacities of 656 MWe and 745 MWe, respectively. With a total installed capacity of 1 763 MWe, nuclear power has a 7-8% share in the national electricity matrix, with natural uranium requirements of approximately 200-220 tU per year.

The future uranium requirements correspond to an estimate made through the Guidelines and Scenarios for the Energy Transition to 2050 published by the National Energy Secretariat in May 2023, and the reactivation of the Argentine Nuclear Energy Plan launched in 2006. As of the end of 2022, the nuclear plan's status is as follows:

- finishing construction and commissioning of Atucha II (achieved);
- extending the licence of Embalse (achieved);
- extending the licence of Atucha I (committed);
- development and construction of a small modular nuclear power reactor (CAREM; in progress);
- expansion of nuclear power network (planned);
- reactivation of uranium enrichment (in progress);
- reactivation of uranium mining industry (in standby status).

The most important update in Argentina's nuclear production was the start-up of Atucha II, reaching first criticality at the end of 2014 and obtaining its commercial operating licence in 2016.

Between 2016 and 2018, Embalse was out of the electricity generation system for refurbishment tasks designed to extend its operating time frame by 30 years, which also increased its output by an additional 35 MWe. In January 2019, the refurbished unit successfully reached criticality and in August of the same year obtained a commercial operation licence for its second life cycle.

In the period 2024-2025, Atucha I will remain inoperative as it undergoes facility refurbishment for life extension through a financial and public infrastructure trust called NASA IV destined to finance works.

The expansion of the nuclear power network has also been proposed, which would be covered by the construction of a 700 MWe pressurised heavy water reactor by 2030 and a 1 150 MWe pressurised water reactor by 2032.

According to the National Energy Secretariat scenarios, the incorporation of three additional pressurised heavy water reactors of 700 MW each is also expected.

Additionally, the Argentine prototype small modular reactor CAREM (32 MWe gross) is under construction with perspectives to come into operation in 2027. There are plans to increase the scale of this unit to a higher capacity of approximately 120 MWe, which is expected to be marketed on a 480 MWe scale (4 units). The first 120 MWe unit would start operating in 2036.

A pilot plant for uranium enrichment located in the Pilcaniyeu Technological Complex (Bariloche) was operated in the 1980s and early 1990s before deactivation in 1995. A restart project was launched in 2006 and operations resumed in March 2014, enabling Argentina to produce enriched uranium by gaseous diffusion technology. The plant has a capacity of 20 000 SWU/year and in 2015 enriched about 600 kg of UF_6. The CNEA is currently engaged in the development of other enrichment technologies, such as ultra-centrifuges and lasers.

Supply and procurement strategy

In 1992, due to low prices in international markets, uranium concentrates began to be imported from South Africa, eventually leading to the closure of local production in 1997. Since then, there has been no production of uranium in Argentina and uranium requirements for operating nuclear power plants have been met with raw material imports from abroad (i.e. Uzbekistan, Czechia, Kazakhstan and Canada).

Nucleoelectrica Argentina S.A., operator of the domestic nuclear power plants, implements the uranium supply strategy and is responsible for guaranteeing a uranium fuel stock of at least two years for Argentina's operational nuclear power plants.

The uranium dioxide producing company (Dioxitek S.A.) acquires uranium oxide concentrates, which in recent years have come from Canada and Kazakhstan. On average, the country imports approximately 220 tU annually.

The last shipment from Kazakhstan (Kazatomprom, National Atomic Company) of 221 tU was received in April 2022 at a final cost of around USD 153/kg U. Likewise, for the 2023-2025 supply, Dioxitek signed a new contract with Kazatomprom for the supply of 175 tU per year, for which Argentina will pay the average spot price of the eight weeks prior to the date of each shipment.

In addition, the fuel fabrication company (Conuar S.A.) every year imports a few tonnes of low-enriched uranium (LEU), which is required for manufacturing slightly enriched uranium (SEU: 0.85% ^{235}U) fuel for Atucha I and low-enriched uranium (LEU: 1.8/3.1% ^{235}U) fuel for the CAREM SMR prototype.

At present, both government and industry are carrying out exploration projects with the intention of restarting domestic uranium production to achieve the goal of self-sufficiency in uranium supply in a foreseeable future.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

The Nuclear Activity Law of 1997 establishes the roles of the CNEA and the Nuclear Regulatory Authority. It also provides for the participation of the public and private sectors in uranium exploration and development activities.

The National Mining Code of 1994 states that nuclear minerals (uranium and thorium) can be explored and exploited by both the national government and the private sector with legal licences issued by a Competent Provincial Authority. The national government has the first option to purchase all uranium and thorium produced in Argentina and the export of nuclear minerals depends upon first guaranteeing domestic supply and control of the destination of any exports. The government also regulates development activities to ensure practices comply with international environmental standards.

Uranium stocks

Uranium stocks consist of 90 tU in the form of UOC and 20 tU contained in purified natural UO_2.

Uranium prices

Since 1997, uranium needs have been entirely met with purchases on the spot market through international tenders, without subscribing to medium- or long-term supply contracts.

In recent years, the average prices paid by the country have ranged from USD 125/kgU to USD 155/kgU, including transportation fares, taxes and insurance premiums.

Uranium exploration and development expenditures and drilling effort – domestic

(In USD)

	2020	2021	2022	2023 (expected)
Private* exploration expenditures	698 000	3 939 000	6 947 000	2 153 000
Government exploration expenditures	391 000	1 032 000	868 000	818 000
Private* development expenditures	0	0	0	0
Government development expenditures	0	0	0	0
Total expenditures	1 089 000	4 971 000	7 815 000	2 971 000
Private* exploration drilling (m)	385	1 493	5 683	3 000
Private* exploration holes drilled	8	38	387	80
Private* exploration trenches (metres)	0	0	0	0
Private* tranches (number)	0	0	0	0
Government exploration drilling (metres)	0	0	1 197	171
Government exploration holes drilled	0	0	6	1
Government exploration trenches (m)	0	0	0	700
Government trenches (number)	0	0	0	200
Private* development drilling (m)	0	0	0	0
Private* development holes drilled	0	0	0	0
Government development drilling (m)	0	0	0	0
Government development holes drilled	0	0	0	0
Subtotal exploration drilling (m)	385	1 493	6 880	3 171
Subtotal exploration holes drilled	8	38	393	81
Subtotal development drilling (m)	0	0	0	0
Subtotal development holes drilled	0	0	0	0
Total drilling (m)	385	1 493	6 880	3 171
Total number of holes drilled	8	38	393	81

* Expenditures made by private companies. Government expenditures refer to those corresponding to majority government funding.

Reasonably assured conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	0	180	180	72
Open-pit mining (OP)*	0	6 990	10 280	10 280*	70-76.7
Total	0	6 990	10 460	10 460	

* 82% of the total has an overall recovery factor of 72% and 18% of the total has an overall recovery factor of 76.7%.

Reasonably assured conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	0	1 860	1 860	1 860	76.7
Heap leaching* from UG	0	0	180	180	72.0
Heap leaching* from OP	0	5 130	8 420	8 420	72.0
Total		6 990	10 460	10 460	

* A subset of open-pit and underground mining, since it is used in conjunction with them.

Reasonably assured conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Sandstone	0	2 890	4 600	4 600	72.0
Volcanic-related	0	2 240	4 000	4 000	72.0
Surficial	0	1 860	1 860	1 860	76.7
Total		6 990	10 460	10 460	

Inferred conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	12 310	18 250	19 300*	72-76.7-82.5
Underground mining (UG)	0	0	250	250	72.0
Unspecified	0	0	5 290	5 290	72.0
Total	0	12 310	23 790	24 840	

* 57% of the total with an overall recovery factor of 72%, 37% of the total with a recovery factor of 82.5%, and 6% of the total with a recovery factor of 76.7%.

Inferred conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	0	12 310	18 250	19 300**	72-76.7-82.5
Heap leaching* from UG	0	0	250	250	72.0
Unspecified	0	0	5 290	5 290	72.0
Total	0	12 310	23 790	24 840	

* A subset of open-pit and underground mining, since it is used in conjunction with them.

** 57% of the total with an overall recovery factor of 72%, 37% of the total with a recovery factor of 82.5%, and 6% of the total with a recovery factor of 76.7%.

Inferred conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Sandstone	0	9 390	16 500	17 550*	72-82.5
Volcanic-related	0	1 800	6 170	6 170	72.0
Surficial	0	1 120	1 120	1 120	76.7
Total	0	12 310	23 790	24 840	

* 59% of the total has a recovery factor of 72% and 41% of the total with a recovery factor of 82.5%.

Prognosticated conventional resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	20 100	20 700

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	79 500	0

Historical uranium production by production method

(tonnes U in concentrate)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Open-pit mining[1]	1 859	0	0	1 859	0
Underground mining[1]	723	0	0	723	0
Total	2 582	0	0	2 582	0

1. Pre-2018 totals may include uranium recovered by heap and in-place leaching.

Historical uranium production by processing method

(tonnes U in concentrate)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Conventional	753	0	0	753	0
Heap leaching	1 829	0	0	1 829	0
Total	2 582	0	0	2 582	0

Historical uranium production by deposit type

(tonnes U in concentrate)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Volcanic-related	1 600	0	0	1 600	0
Sandstone	729	0	0	729	0
Granite-related	253	0	0	253	0
Total	2 582	0	0	2 582	0

Mid-term production projection

(tonnes U/year)

2025	2030	2035	2040	2045	2050
0	0	NA	NA	NA	NA

Mid-term production capability

(tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	0	0	0	0	0	0	0

2035				2040			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
NA	NA	NA	NA	NA	NA	NA	NA

2045				2050			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
NA	NA	NA	NA	NA	NA	NA	NA

Net nuclear electricity generation

	2021	2022
Nuclear electricity generated (TWh net)	6.86	4.58

Installed nuclear generating capacity to 2050

(MWe gross capacity)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
1 641	1 641	1 300	1 300	1 668	2 322	3 397	4 051	3 846	5 602	4 294	6 705	4 294	7 154

Annual reactor-related uranium requirements to 2050

(tonnes U)*

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
192	144	182	182	231	319	1 014	1 102	602	869	693	1 048	693	1 139

* First core loads for planned new reactors are included in the U requirements data. There are no plans to build an inventory (stockpile) of U.

Armenia

Uranium exploration

Historical review

On 23 April 2008, the Director-General of Rosatom (a state corporation of Russia) and the Armenian Minister of Ecology Protection signed a memorandum on the development of co-operation in the field of geological exploration, mining and processing of uranium ores. Based on this memorandum, an Armenian-Russian joint venture, CJ-SC Armenian-Russian Mining Company (ARMC), was established in September 2008 for the purpose of geological exploration, mining and processing of uranium. The founders of ARMC are the Armenian government and Atomredmetzoloto of Russia.

Within this framework, the collection and analysis of archival material relevant to uranium mining was completed, and a document, "Geologic Exploration Activity for 2009-2010", specifically regarding uranium ore exploration in Armenia, was published and approved. In the spring of 2009, fieldwork related to uranium exploration started in the province of Syunik. Geological prospecting carried out on the first Voghchi zone of the Pkhrut-Lernadzor licenced area in 2011 identified some anomalies. Exploration of the Voghchi zone of the Pkhrut deposit led to the identification of a very small occurrence, below 1 000 tU inferred resources (category C2 in Russian classification).

In 2015 the Armenian-Russian joint venture activities were suspended due to unfavourable uranium market prices.

Uranium production

Armenia does not produce uranium, so there is no associated infrastructure (legislation, regulatory authority, licensing/authorisation system, inspection, etc.).

Uranium requirements

Armenia's short-term needs in uranium have been calculated taking into account the extension of the life of one VVER-440 unit (Armenian-2) until 2036, as well as the possible transition to fuel assemblies with increased enrichment. A detailed estimation of uranium needs was performed in view of the extension of the lifetime of this reactor and the increase in installed power to 448 MW. Long-term uranium requirements depend on the country's policy in the nuclear energy sector.

On 14 January 2021, the Government of the Republic of Armenia approved the Strategic Programme of the Energy Sector Development of the Republic of Armenia until 2040 and the schedule ensuring its implementation. According to the Programme, the life extension of the existing nuclear power unit from 2026 to 2036 is one of the main priorities. After that period the main priority is to build a new nuclear power plant in Armenia.

Supply and procurement strategy

Nuclear fuel for the Armenian nuclear power plant is supplied by Russia. Armenia's nuclear fuel requirements have remained unchanged over the past two years. The fuel procurement strategy has also remained unchanged and continues to be based on fuel sourced from Russia. The requirements for the proposed new unit will depend on the reactor type.

In 2007, the Armenian government decided that it would enter an agreement with the governments of Kazakhstan and Russia to establish an international uranium enrichment centre (IUEC) at the Angarsk electrolytic chemical combine in Russia. Armenia completed the legal registration of accession and in 2010 joined the IUEC.

Net nuclear electricity generation

(TWh net)

	2021	2022
Nuclear electricity generation (TWh net)	2.0	2.85

Installed nuclear generating capacity to 2040

(MW(e) net)

2021	2022	2025		2030		2035		2040	
		Low	High	Low	High	Low	High	Low	High
407	448	407	448	407	448	407	448	NA	NA

Annual reactor-related uranium requirements to 2040 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040	
		Low	High	Low	High	Low	High	Low	High
64	64	60	70	60	70	60	70	NA	NA

Australia

Uranium exploration

Historical review

Australia has maintained involvement in the uranium industry since its inception and remains one of the world's largest producers and exporters of uranium. The majority of Australia's significant uranium deposits were discovered between 1969 and 1980 when exploration expenditures were relatively high. Since 1985, following the greenfield discovery of the Kintyre deposit in Western Australia by Conzinc Rio Tinto of Australia (CRA), exploration budgets for uranium have generally declined. However, despite the lack of major recent greenfield discoveries, Australia's uranium resource base has grown. This is due to significant brownfield extensions to known resources, and some new occurrences with similar geology delineated proximally to known deposits.

Discovered by Western Mining in 1975 and owned and operated by BHP since 2005, the Olympic Dam mine in South Australia is the world's largest single uranium resource, with continuous production since 1988. Australia's uranium has usually been produced from a small number of mines (often only three). In addition to Olympic Dam, mining has occurred at Mary Kathleen and Westmoreland in Queensland; Radium Hill, Mount Painter, Honeymoon, Four Mile and Beverley in South Australia; along with Ranger, Nabarlek and Rum Jungle in the Northern Territory.

Most of Australia's uranium resources occur in two main types of deposits: breccia complex deposits, such as Olympic Dam, or unconformity-related deposits, such as Ranger or Kintyre. Other categories include sandstone uranium deposits, such as Honeymoon; surficial (calcrete) deposits such as Yeelirrie or Centipede; and metasomatite, metamorphic, volcanic or intrusive deposits. Australia has no significant deposits of the quartz-pebble conglomerate-type, vein-type and collapse breccia-pipe type.

During the reporting period Australia had two operating mines that produce uranium, Olympic Dam and Four Mile, both in South Australia. Honeymoon mine (also in South Australia) recommenced production in early 2024.

Recent and ongoing uranium exploration and mine development activities

Mineral exploration in Australia is undertaken exclusively by commercial entities. However, quality geoscientific databases and information systems are maintained and made available by the Federal Government and relevant state or territory governments, augmenting Australia's favourable geological settings.

Exploration expenditure for uranium increased in 2022 to AUD 21.7 million from AUD 12.3 million in 2021 and AUD 6.7 million in 2020.

Western Australia

In 2017, the state government announced a ban on future uranium mining leases but noted that it would not prevent development of projects that had previously received State Ministerial approval. Prior to the decision to ban uranium mining, environmental approval for four uranium mining projects was obtained: Mulga Rock (Deep Yellow Ltd, formerly Vimy Resources Ltd), Wiluna (Toro Energy Ltd) and Yeelirrie and Kintyre (both Cameco Australia Pty Ltd). These projects are subject to legally binding State Ministerial approval conditions and were required to have been substantially commenced within five years from the date of the approval.

Cameco Australia's Yeelirrie and Kintyre projects as well as Toro Energy's Wiluna project did not meet the requirement of "substantial commencement" and their environmental approvals expired in January 2022.

Vimy Resources submitted a mining proposal for Mulga Rock under the Western Australian Mining Act 1978 in 2020. The Mining Proposal was approved in September 2021, consistent with conditions of the primary approval granted by the Minister for Environment. In November 2021, Vimy Resources formally notified the Western Australian government of "substantial commencement" of this project.

- Mulga Rock

The Mulga Rock resource is sandstone-type and is wholly owned by Deep Yellow Ltd, following a merger between Vimy Resources Ltd (the previous owner) and Deep Yellow in August 2022. The Mulga Rock Project is located 240 kilometres east of Kalgoorlie in Western Australia and consists of four deposits, Ambassador and Princess (Mulga Rock East), Emperor and Shogun (Mulga Rock West). The project will involve shallow open-pit mining of the four polymetallic deposits where commercial grades of uranium occur in sandstone-hosted carbonaceous material. It has a 15-year mine life and is anticipated to produce 1 346 tU annually.

In January 2018, Vimy Resources released a definitive feasibility study (DFS) for the Mulga Rock Project and, in September 2021, the Western Australian Department of Mines, Industry Regulation and Safety approved the Mulga Rock mining proposal and associated mine closure plan.

- Yeelirrie

The surficial calcrete-hosted Yeelirrie uranium deposit is wholly owned by Cameco Australia Pty Ltd and is located about 420 km north of Kalgoorlie and 70 km southwest of Wiluna in Western Australia. It is one of the world's largest surficial uranium deposits and is, therefore, suited to open-pit mining with minimal drilling or blasting required. Cameco acquired the Yeelirrie project from BHP Ltd in 2012.

It is estimated that average production from the Yeelirrie project would be nearly 3 300 tU per annum over 19 years, utilising open-pit mining and alkaline leach technology.

The Yeelirrie Uranium Project received environmental approval from the Commonwealth Government in April 2019. However, the environmental approval that was granted by the Western Australian government in January 2017 has since expired.

- Kintyre

The unconformity-related Kintyre uranium deposit is wholly owned by Cameco Australia Pty Ltd, which acquired the 30% interest that was held by Mitsubishi Development Pty Ltd in 2018. Kintyre is located in the East Pilbara region of Western Australia, approximately 260 km northeast of Newman at the western edge of the Great Sandy Desert. Although there is no outcrop, the Kintyre resource is suited to open-pit mining with the uppermost parts of the resource 50 m below surface. It is estimated that average production from the Kintyre project would be around 2 290 tU per annum, with an estimated mine life of 15 years.

Cameco Australia in 2015 secured a Commonwealth and state environmental approval for the Kintyre project that has since expired.

- Wiluna Uranium Project

Toro Energy Ltd is the single owner of the Wiluna Uranium Project, which is a surficial calcrete-hosted regional resource located 30 km from the town of Wiluna in central Western Australia. Wiluna comprises six deposits: Centipede, Lake Way, Millipede, Lake Maitland, Dawson Hinkler and Nowathanna. The first four deposits collectively make up the Wiluna Uranium Project, while the Dawson Hinkler and Nowathanna deposits are regarded as advanced exploration prospects.

Mining at Wiluna is planned as shallow strip excavation to a maximum depth of 15 metres. The project proposes to use alkaline agitated leaching in tanks at elevated temperatures to process the ore. Since 2022, Toro Energy has been investigating the potential of developing the Lake Maitland uranium deposit as a stand-alone mining and processing operation that would also produce vanadium as a by-product. It is estimated that average production from the Wiluna Uranium Project would be around 500 tU per annum and 0.7 Mlbs of vanadium pentoxide (V_2O_5), with an estimated mine life of 17 years.

Mining of the Centipede and Lake Way uranium deposits, including the construction of a processing facility at Centipede, received environmental approval from the Western Australian government in 2012 and the Commonwealth Government in 2013. Toro expanded the Wiluna project proposal, which encompasses the Lake Maitland and Millipede resources, and received Commonwealth and state environmental approval in 2017, with the state environmental approval now expired. Toro Energy recently reported that it intends to apply for an extension to the "substantial commencement" condition that would allow for the future development of the Wiluna Uranium Project (Toro Energy Ltd; ASX Release 28 April 2023; Quarterly Activities Report for period ending 31 March 2023).

South Australia

South Australia has five approved uranium mines: Olympic Dam, Honeymoon, Beverley, Beverley North and Four Mile. Only Olympic Dam and Four Mile produced uranium as of 2022. Mining at Beverley and Beverley North has ceased and the sites are working towards closure.

- Olympic Dam

BHP Ltd's breccia complex-hosted Olympic Dam is Australia's largest uranium mine. In 2022 it contributed around two-thirds of Australia's uranium production, as a by-product to primary copper production. Plans for a large expansion at Olympic Dam have been scaled back. BHP plans to instead steadily increase production capacity under its existing approvals, and in 2018, underground operations commenced in the "Southern Mining Area" of the resource.

While uranium production is planned to remain stable in the near term, it is anticipated that output will increase over time through incremental production efficiency gains and infrastructure investment.

- Four Mile

The Four Mile mine is located approximately 550 km north of Adelaide. It is operated by Quasar Resources Pty Ltd using in situ leaching (ISL or ISR) to extract uranium from sandstone deposits. Uranium is extracted at Four Mile West with other ore bodies identified and under continued delineation at Four Mile East, Four Mile North East and Four Mile North. Uranium-bearing resin from Four Mile is pumped to the Beverley processing plant for elution, precipitation and drying as uranium concentrate.

- Honeymoon

Operated by Boss Energy Ltd, the sandstone-type Honeymoon deposit, was in care and maintenance from 2013 until it recommenced production in early 2024. This re-start followed a positive Enhanced Feasibility Study released by Boss Energy Ltd in June 2021 and a 10-year period where the mine was in care and maintenance. Uranium extraction from the host sandstone units will be undertaken using in situ leaching (ISL or ISR). The Honeymoon project, comprising Honeymoon, Gould's Dam and Jason's, has identified recoverable resources of 23 306 tU.

- Samphire

The Samphire Project, comprising the Blackbush and Plumbush uranium deposits, is located 20 km south of Whyalla in regional South Australia, with Alligator Energy Ltd being the tenement holder. Uranium extraction through an ISR field recovery trial is planned in 2023/2024 at the Blackbush deposit. Outcomes of the trial and further exploration will determine if an application for mining will be sought by the company.

Northern Territory

- Ranger

After 40 years of uranium production, and a total of approximately 112 000 tU, mining operations at the Ranger mine ceased on 8 January 2021. The Ranger mine, operated by Energy Resources of Australia Ltd. (ERA; majority owner Rio Tinto with98.43%) is located in the Pine Creek Inlier and is classified as an unconformity-related deposit. In 2012, Pit 3 mining operations ceased, with production from 2013 being maintained through stockpiled ore material. Activities ceased at Ranger Pit 1 in 1994 and it has since been filled, capped and revegetated. Active rehabilitation of the mine area is expected to be completed in 2035 followed by approximately 25 years of monitoring.

Queensland

Queensland hosts more than 80 known sites that contain valuable amounts of uranium, mainly in the remote northwestern area of the state. In March 2015, the Queensland government announced that it intended to reinstate a ban on uranium mining, which was originally appealed in 2012. Currently, Queensland allows uranium exploration but not mining.

New South Wales

Uranium exploration was prohibited in New South Wales for 26 years until 2012, when the state government overturned the ban. However, while uranium exploration is currently permitted, the ban on uranium mining remains in place.

Victoria

Uranium exploration and uranium mining are prohibited in Victoria.

Tasmania

Uranium exploration and uranium mining are permitted in Tasmania but the state does not have significant resources.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

On 1 January 2023, Australia's total uranium reasonably assured conventional resources recoverable at a cost of <USD 130/kgU amounted to 1 236 161 tU (1 960 115 tU in situ) and inferred conventional resources totalled 435 035 tU (684 775 tU in situ).

Estimated mining and processing losses were deducted from commercial uranium resource reports for individual deposits submitted under the Australian Joint Ore Reserves Committee (JORC) Code. For deposits where this information is not available, an overall mining and milling recovery factor was applied as recommended in the 2023 Red Book Questionnaire. Overall recovery factors range from 58% to 95%.

The 2023 national total is substantially unchanged from Australia's previous 2022 country report. Although the closure of the Ranger Mine in January 2021 and the associated removal of its RAR resources resulted in a reduction of Australia's overall uranium inventory, this was more than offset by the delineation of new in situ resources at Olympic Dam.

Although there are more than 35 deposits with identified resources recoverable at costs of <USD 130/kgU, the vast majority of Australia's resources are within the following three individual deposits: Olympic Dam in South Australia, Jabiluka in the Alligator Rivers Region of the Northern Territory and Yeelirrie in Western Australia. At the Olympic Dam mine, uranium is a by-product of copper mining, with gold and silver also recovered.

Undiscovered conventional resources (prognosticated and speculative resources)

Geoscience Australia does not make estimates of Australia's undiscovered uranium resources.

Unconventional resources and other materials

Geoscience Australia does not make estimates of Australia's unconventional uranium resources.

Uranium production

Historical review

Uranium produced in Australia is exported to countries in North America, Asia and Europe and is used as fuel in nuclear power stations to generate electricity. The current phase of Australian uranium production commenced in 1976. Exports are approximately 6 400 (tU) per annum (averaged over ten years), or around 12% of the global market.

A review of the history of uranium exploration, development and production in Australia is provided in Australia's Uranium Resources, Geology and Development of Deposits, available at: www.ga.gov.au/webtemp/image_cache/GA9508.pdf.

Uranium production centre technical details

(as of 1 January 2023)

	Centre #1	Centre #2	Centre #3	Centre #4
Name of production centre	Olympic Dam	Four Mile[(a)]	Honeymoon	Mulga Rock
Production centre classification	Existing	Existing	Planned (reopening)	Planned
Date of first production (year)	1988	2014	2011	Not known
Source of ore				
Deposit name(s) or district name	Olympic Dam	Four Mile	Honeymoon, Gould's Dam, Jason's	Princess, Shogun, Ambassador, Emperor
Deposit type(s)	Polymetallic Fe-oxide breccia complex	Sandstone	Sandstone	Sandstone
Recoverable resources (tU)	1 340 950	14 680[(a)]	23 306	28 836
Grade (% U)	0.048	0.29	0.15	0.08
Mining operation				
Type (OP/UG/ISL)	UG	ISR	ISR	OP
Size (tonnes ore/day)	12	NA	NA	NA
Average mining recovery (%)	85	NA	NA	95
Processing plant				
Acid/alkaline	Acid	Acid	Acid	Acid
Type (IX/SX)	SX	IX	IX	
Size (tonnes ore/day)	12	NA	NA	NA
Average process recovery (%)	68	85	85	87
Nominal production capacity (tU/year)	3 250	1 700	769	1 346
Plans for expansion (yes/no)	yes	no	no	no

(a) The recoverable resources stated for the Four Mile mine are only current to December 2018. Subsequent production at Four Mile from 2019 to 2022 has been approximately 7 100 tU.

	Centre #5	Centre #6	Centre #7
Name of production centre	Yeelirrie	Wiluna	Kintyre
Production centre classification	Planned	Planned	Planned
Date of first production (year)	Not known	Not known	Not known
Source of ore			
Deposit name(s) or district name	Yeelirrie	Centipede, Lake Way, Millipede, Lake Maitland	Kintyre
Deposit type(s)	Surficial (Calcrete)	Surficial (Calcrete)	Proterozoic unconformity
Recoverable resources (tU)	39 409	19 344	18 253
Grade (% U)	0.13	0.09	0.53
Mining operation			
Type (OP/UG/ISL)	OP	OP	OP
Size (tonnes ore/day)	NA	NA	NA
Average mining recovery (%)	NA	NA	NA
Processing plant			
Acid/alkaline	Alkaline	Alkaline	Alkaline
Type (IX/SX)	IX	IX	NA
Size (tonnes ore/day)	NA	NA	1 700
Average process recovery (%)	80	80	80
Nominal production capacity (tU/year)	3 265	500	2 290
Plans for expansion (yes/no)	no	yes (vanadium)	no

Status of production capability and recent and ongoing activities

As of 1 January 2023, Australia had two operating uranium mines, Olympic Dam (BHP Ltd) and Four Mile (Quasar Resources Pty Ltd), both in South Australia. Total uranium production for 2022 from the two operating mines amounted to 4 555 tU.

Olympic Dam

Olympic Dam's production of payable metal in concentrate for 2022 was 2 813 tU, an increase of 891 tonnes from 2021. Olympic Dam contains well over one million tonnes of uranium resources, making it the largest single uranium deposit in the world. It is also the only known breccia complex deposit that has significant economic resources of uranium.

Olympic Dam produces copper cathode, refined gold and silver bullion, along with uranium oxide. The BHP-owned underground mine utilises long-hole open-stoping technology and cemented aggregate fill, with integrated metallurgical processing.

Beverley/Beverly North

The sandstone-type Beverley resources, located east of the Flinders Ranges in South Australia, began operations in 1990. Production from Beverley, operated by Heathgate Resources Pty Ltd, started in late 2000, making it Australia's first operating ISR mine.

The Beverley and Beverley North mines were in care and maintenance from early 2012 and 2018, respectively and in 2020, both moved to closure. Rehabilitation of old production wellfields will continue over the next decade.

Four Mile

The Four Mile resource, which is operated by Heathgate Resources on behalf of Quasar Resources Pty Ltd, comprises two significant sandstone uranium deposits, Four Mile East and Four Mile West. The initial phase of operations consisted of pumping uranium-bearing solutions to the nearby satellite ion-exchange plant at the Pannikan deposit. The resin produced was initially trucked to the Beverley processing plant for elution, but as of October 2019 it is pumped via trunk lines for precipitation and drying of the uranium concentrates.

Honeymoon

Boss Energy Ltd's, Honeymoon uranium ISR mine, began production in 2011 but ceased operations in 2013 due to low uranium prices. Originally owned by Uranium One, it was acquired by Boss Resources in 2015 (now Boss Energy Ltd). Honeymoon recommenced mining in early 2024.

Ownership of uranium production

Australia's uranium mines are owned and operated by a range of domestic and international companies:

- The Olympic Dam mine is fully owned by BHP Ltd, listed on the Australian Stock Exchange (ASX: BHP).
- The Four Mile mine is fully owned by Quasar Resources Pty Ltd, but operated by sister company Heathgate Resources Pty Ltd. Both Quasar Resources and Heathgate Resources are owned by General Atomics (United States).
- The Honeymoon mine is fully owned and operated by Boss Energy, listed on the Australian Stock Exchange (ASX:BOE)

Secondary sources of uranium

Australia does not produce or use mixed oxide fuels, re-enriched tails or reprocessed uranium.

Environmental activities and socio-cultural issues

Environmental approvals

Australia's Commonwealth and relevant state or territory legislative framework require proponents of uranium mines to undertake rigorous and comprehensive environmental impact assessment processes that incorporate public comments on the proposal. A Commonwealth assessment is conducted under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). An EPBC Act assessment is usually undertaken bilaterally with relevant state and territory authorities. An environmental assessment is required for modifications to existing projects along with new proposals, ensuring that strict requirements for environmental, heritage and nuclear safeguards are maintained.

Social factors are also considered in the approvals processes. In particular, Aboriginal Land Rights and Native Title legislation seeks to ensure that the concerns and cultural needs of Aboriginal people are respected.

Recent environmental assessments include:

- Alligator Energy's Samphire Project, where a field recovery trial will be assessed by the South Australian government in 2023.

Site rehabilitation

The Ranger mine, operated by Energy Resources Australia, ceased uranium production on 8 January 2021. The Ranger project area will now undergo extensive rehabilitation work that is expected to be completed in 2035. An updated Ranger mine closure plan was released by ERA in October 2024, with the objective to rehabilitate the disturbed regions of the project area to a condition similar to the environment of the surrounding Kakadu National Park. The closure plan also includes a monitoring programme for 25 years after the rehabilitation programme is completed. The total cost of rehabilitation, is predicted to be AUD 2.4 billion.

Regulatory activities

Radiological protection matters arising from uranium mining in Australia are principally the responsibility of the states and territories where mining occurs. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) is responsible for developing Australia's national radiological protection framework as laid out in the Radiation Protection Series (RPS), which are implemented through jurisdictional legislation and licence conditions.

ARPANSA's RPS includes a pivotal background document, RPS F-1 *Fundamentals for Protection Against Ionising Radiation* (2014), and several codes and guides relating to uranium mining and associated processes:

- *RPS 9 Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005); RPS 15 Safety Guide for the Management of Naturally Occurring Radioactive Material (NORM) (2008);*
- *RPS 16 Safety Guide for the Predisposal Management of Radioactive Waste (2008);*
- *RPS 20 Safety Guide for Classification of Radioactive Waste (2010);*
- *RPS 9.1 Safety Guide for Monitoring, Assessing and Recording Occupational Radiation Doses in Mining and Mineral Processing (2011);*
- *RPS C-2 Code for the Safe Transport of Radioactive Material (2014);*
- *RPS G-1 Guide for Radiation Protection of the Environment (2015);*
- *RPS C-1 Code for Radiation Protection in Planned Exposure Situations (2016)*.

ARPANSA continues to develop frameworks that guide radiological protection best practice and works closely with industry representative bodies through relevant consultative processes. ARPANSA also administers the Australian National Radiation Dose Register (ANRDR) for the storage and maintenance of dose records of workers occupationally exposed to ionising radiation. Since 2013, ANRDR has complete coverage of the uranium mining and milling industry in Australia with all operations submitting relevant dose records.

A Radon Progeny Technical Coordination Group was established with representation from the uranium mining industry, state regulators, and ARPANSA to develop a national approach to radon progeny dose assessment to address proposed changes in international recommendations. This included a programme of measurements in Australian uranium mines. This work has been published as an Advisory Note on the ARPANSA website: *New dose coefficients for radon progeny: Impact on workers and the public*, and is available at: www.arpansa.gov.au/understanding-radiation/sources-radiation/radon/new-dose-coefficients-radon-progeny-impact-workers.

The Australian government released the 2016 edition of the *Leading Practice Sustainable Development Program for the Mining Industry (LPSDP)* of that year. The latest edition consists of a 17-book series with several updated handbooks and two new handbooks – *Community Health and Safety and Energy Management in Mining*. Further information on the Leading Practice handbooks can be found at www.industry.gov.au/data-and-publications/leading-practice-handbooks-for-sustainable-mining.

Uranium requirements

Australia has no commercial nuclear power plants and has very limited domestic uranium requirements. An Open Pool Australian Lightwater (OPAL) research reactor is operated by the Australian Nuclear Science and Technology Organisation (ANSTO) at Lucas Heights, south of Sydney, New South Wales. The OPAL reactor was opened in 2007, with the capacity to produce commercial quantities of radioisotopes utilising low-enriched uranium (LEU) fuel.

Uranium policies, uranium stocks and uranium prices

National policies

Australian policy states Australian uranium can only be exported to countries with which Australia has a nuclear co-operation agreement, to be used for peaceful purposes. They must also have safeguards agreements with the International Atomic Energy Agency (IAEA), including an Additional Protocol. Australia's network of safeguards agreements now totals 25.

The Australian government supports the development of a sustainable Australian uranium mining sector in line with the world's best practice environmental and safety standards.

The regulatory framework governing uranium mining and exploration in Australia varies between Commonwealth, state, and territory jurisdictions. Uranium exploration and mining are permissible in South Australia and the Northern Territory. In Western Australia, uranium exploration is permissible, but uranium mining is prohibited except, for projects that were approved prior to 2017 and have since demonstrated "substantial commencement". In New South Wales and Queensland, uranium mining is prohibited but exploration is permissible. Victoria prohibits uranium exploration and mining.

Australia's moratorium on nuclear power has been in effect since 1998. The Australian Government is supporting Australia's energy transformation through its Powering Australia plan, focused on firmed renewables. Further processing of uranium is prohibited in Australia, under two Commonwealth laws (noting State and Territory laws also apply to these activities)

- The Australian Radiation Protection and Nuclear Safety Act 1998 prohibits enrichment of uranium, reprocessing spent fuel, and construction of nuclear power plants.
- The Environment Protection and Biodiversity Conservation Act 1999 requires the Minister for the Environment's approval to undertake uranium mining and milling activities, and bans enrichment of uranium and reprocessing of fuel.

Previously, at the state level, the South Australian Nuclear Fuel Cycle Royal Commission was held in 2015 and, in 2019, the inquiry regarding New South Wales Uranium Mining and Nuclear Facilities (Prohibitions) Repeal Bill 2019 and the Victorian Inquiry into Nuclear Energy Prohibition. At the Commonwealth level, the House of Representatives Standing Committee on the Environment and Energy undertook an inquiry into the Prerequisites for Nuclear Energy in Australia, also in 2019. These have not resulted in a change of policy position.

Regulation 9 of *Australia's Customs (Prohibited Exports) Regulations 1958*, provides that the export of goods listed in Schedule 7 of the Regulations is prohibited unless permission is obtained from the Commonwealth Minister administering the *National Radioactive Waste Management Act 2012* or their authorised person. Goods listed in Schedule 7 include minerals, ores and concentrates containing more than 500 parts per million of uranium and thorium combined.

Uranium stocks

For reasons of confidentiality, information on producer stocks is not available.

Uranium prices

The average price of uranium exported from Australia in 2022 was USD 41.22/lb U_3O_8 with exports governed by a combination of contract specifications. Average export prices for the last five years are listed in the table below.

Average export prices for Australian uranium oxide 2017–2022

Average export value	2017	2018	2019	2020	2021	2022
AUD/lb U_3O_8	35.90	39.58	42.81	48.47	43.63	59.33
USD/lb U_3O_8	27.53	29.60	30.05.	33.48	32.79	41.22

Uranium exploration and development expenditures and drilling effort – domestic

(AUD millions)

	2020	2021	2022	2023 (expected)
Private* exploration expenditures	6.7	12.3	21.7	25
Government exploration expenditures	0	0	0	0
Private* development expenditures	NA	NA	NA	NA
Government development expenditures	0	0	0	0
Total expenditures	6.7	12.3	21.7	25
Private* exploration drilling and trenches	NA	NA	NA	NA
Government exploration drilling and trenches	0	0	0	0
Private* development drilling	NA	NA	NA	NA
Government development drilling	0	0	0	0
Subtotal exploration drilling (metres)	NA	NA	NA	NA
Subtotal development drilling (metres)	NA	NA	NA	NA
Total drilling (metres)	NA	NA	NA	NA
Total number of holes drilled	NA	NA	NA	NA

* Non-government.

Conventional reasonably assured resources by production method

(recoverable, tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Underground mining (UG)	NA	NA	88 706	96 479
Open-pit mining (OP)	NA	NA	120 590	144 903
In situ recovery (ISR)	NA	NA	32 155	40 737
Co-product and by-product	NA	NA	994 710	1 034 860
Total	NA	NA	1 236 161	1 316 979

Conventional reasonably assured resources by processing method

(recoverable, tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional from UG	NA	NA	1 083 416	1 131 339
Conventional from OP	NA	NA	120 590	144 903
In situ recovery (ISR)	NA	NA	32 155	40 737
Total	NA	NA	1 236 161	1 316 979

Conventional reasonably assured resources by deposit type

(recoverable, tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Proterozoic unconformity	NA	NA	78 151	80 990
Sandstone	NA	NA	64 360	74 247
Polymetallic Fe-oxide breccia complex	NA	NA	994 710	1 035 206
Granite-related	NA	NA	322	322
Intrusive	NA	NA	0	15 672
Volcanic-related	NA	NA	2 433	4 826
Metasomatite	NA	NA	29 281	29 699
Metamorphic	Na	NA	0	4 894
Surficial	NA	NA	66 904	71 123
Total	NA	NA	1 236 161	1 316 979

Conventional inferred resources by production method

(recoverable, tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Underground mining (UG)	NA	NA	44 056	48 216
Open-pit mining (OP)	NA	NA	19 163	107 953
In situ recovery (ISR)	NA	NA	18 757	40 014
Co-product and by-product	NA	NA	353 059	422 072
Total	NA	NA	435 035	618 255

Conventional inferred resources by processing method

(recoverable, tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional from UG	NA	NA	397 115	470 288
Conventional from OP	NA	NA	19 163	107 953
In situ recovery (ISR)	NA	NA	18 757	40 014
Total	NA	NA	435 035	618 255

Conventional inferred resources by deposit type

(recoverable, tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Proterozoic unconformity	NA	NA	37 491	52 424
Sandstone	NA	NA	35 361	70 436
Polymetallic Fe-oxide breccia complex	NA	NA	353 059	422 072
Granite-related	NA	NA	0	28
Intrusive	NA	NA	0	8 965
Volcanic-related	NA	NA	0	1 089
Metasomatite	NA	NA	8 424	11 902
Metamorphic	NA	NA	0	14
Surficial	NA	NA	700	51 325
Total	NA	NA	435 035	618 255

Prognosticated conventional resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
NA	NA	NA

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
NA	NA	NA

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Open-pit mining	132 504	29	0	132 533	0
Underground mining	838	0	0	838	0
In situ recovery (ISR)	16 899	1 847	1 742	20 488	1 858
Co-product/by-product	81 595	1 922	2 813	86 330	2 800
Total	231 836	3 798	4 555	240 189	4 658

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Conventional	214 937	1 951	2 813	219 701	2 800
In situ recovery (ISR)	16 899	1 847	1 742	20 488	1 858
Total	231 836	3 798	4 555	240 189	4 658

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Proterozoic unconformity	125 090	29	0	125 119	0
Sandstone	16 899	1 847	1 742	20 488	1 858
Polymetallic Fe-oxide breccia complex	81 595	1 922	2 813	86 330	2 800
Metasomatite	7 531	0	0	7 531	0
Intrusive	721	0	0	721	0
Total	231 836	3 798	4 555	240 189	4 658

Ownership of uranium production in 2022*

Domestic		Foreign		Totals	
private		Government/private			
(tU)	(%)	(tU)	(%)	(tU)	(%)
2 813	62	1 742	38	4 555	100

* These figures are estimated based on public ownership information. For reasons of confidentiality, government vs private ownership information is not available; there is no Australian government production ownership. Estimated by proportioning domestic private ownership and foreign private ownership for each uranium mining company by its production for 2022.

Uranium industry employment at existing production centres

(person-years)

	2020	2021	2022	2023 (expected)
Total employment related to existing production centres	4 600	4 300	4 300	4 500
Employment directly related to uranium production	2 440	2 170	2 170	2 350

Mid-term production projection (tonnes U/year)

(tonnes U/year)

2025	2030	2035	2040	2045	2050
5 700	4 020	4 020	4 020	4 020	4 020

Mid-term production capability (tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
NA	NA	5 700	13 200	NA	NA	4 020	11 500

2035				2040			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
NA	NA	5 700	10 000	NA	NA	4 000	13 000

2045				2050			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
NA	NA	4 020	4 600	NA	NA	4 020	4 020

Bangladesh

Uranium exploration and mine development

Historical review

The vision of the Bangladesh Atomic Energy Commission (BAEC) is to contribute to the country's socio-economic development through the peaceful application of nuclear science and technology. To implement that vision, the BAEC initiated a number of exploration programmes for atomic minerals in favourable geological areas in Bangladesh.

Four regions in Bangladesh are considered to be interesting for uranium exploration: the Eastern Mobile Belt, the Stable Platform, the Dauki Fault Belt and the Dinajpur Slope. The northeastern border of Bangladesh, located near the Meghalaya uranium province of India, is also potentially promising. Targets include sandstone and basement hosted deposits (U, U-Th-REE) and placer deposits (Th, U, REE).

The presence of radioactivity in U and Th bearing zircon- and monazite-rich beach and river sand deposits in Bangladesh was reported in the early 1960s. BAEC has been studying placer minerals along the coastal belts of Bangladesh since its independence and a programme of systematic exploration of heavy minerals was initiated in 1968. The entire southeastern and southern coastal areas along with their offshore islands were explored from 1968 to 1986. This detailed survey estimated a total of 1.76 million tonnes of economic heavy minerals, among which uranium and thorium bearing zircon and monazite were estimated at 1 158 117 tonnes and 17 352 tonnes, respectively. The findings include:

- Testing of bulk sand samples by BAEC indicate that radioactive heavy minerals can be concentrated in specific fractions.
- In separated zircon fractions, uranium and thorium values of up to 140 ppm U (0.014% U), and 526 ppm Th were identified by neutron activation analysis.
- In radioactive sample concentrates, uranium, and thorium were measured as high as 1 400 (0.14% U) and 700 ppm, respectively. Values from mineral grain concentrates were recorded as high as 5 120 ppm U (0.512% U) and 37 600 ppm Th using high-resolution gamma-ray spectroscopy.

In 1976, with assistance from the International Atomic Energy Agency and through the United Nations Development Programme, a reconnaissance radiometric survey was conducted through the Exploration of Uranium and Thorium in Bangladesh project. Some of the highlights of the project are listed below:

- A regional reconnaissance survey was completed over a 2 000 km^2 area of the greater Chittagong and Chittagong Hill Tracts and Sylhet districts. More than 150 surface radiometric anomalies were identified.
- An aerial survey was completed over the Jaldi anticline, and a detailed survey was completed over a 450 km^2 area including the Sylhet, Jaintia and Harargaj geological structures.
- Radon surveys were carried out in a 35 km^2 area over the Sylhet anticline and the Jaintia Structure.

- About 27 shallow boreholes were drilled in the Sylhet region resulting in the identification of more than 85 anomalies.
- Uranium indicators were identified in the Harargaj anticline, Moulavibazar District, Eastern Mobile Belt. Most of the samples collected from anomalous beds contain uranium and thorium ranging from 10 to 300 ppm (0.001-0.03% U) and 100 to 1 000 ppm, respectively. The highest radiometric counts occurred in the Phooltala Reserve Forest, at 6 000 counts per second (60 times the background count). Chemical analysis of this sample indicated the presence of 1 020 ppm of total uranium (0.102% U). Uranothorite and thorianite were identified in the rock samples.

The project was suspended in 1985 before the follow-up exploration of prospective areas. BAEC reinitiated its uranium and thorium exploration activity in 1993 through the Exploration and Exploitation of Atomic Minerals: Joypurhat – Sylhet Area in the Dauki Fault project. Project outcomes include:

- In 1995, a radiometric survey was conducted over various locations along the Dauki Fault, Jaintiapur. Radioactivity in some locations was found to be 5-6 times above background levels. Also, radioactive counts were found to be 4 to 6 times the background level in the Jadukata valley and 3.5 times the background level near the Rangpani River, with a maximum of up to 10 times the background level at one location.
- Gamma logging was completed in a 300 m deep drill hole (EDH-52, drilled by the Geological Survey of Bangladesh at Madarpur, Mithapukur, Rangpur). Total gamma count anomalies of 20-25 times the background level were identified at various depths in the crystalline basement rocks. Larger-scale follow-up surveys have not yet been carried out in prospective regions due to limited budgets and technical know-how. However, BAEC continues to conduct small-scale exploration research.

Recent and ongoing uranium exploration activities

During the last five years, (from 2018 to 2022), BAEC conducted uranium and thorium exploration along the transboundary rivers over the northeastern part of Bangladesh. The areas included the Sari and Dauki Rivers in the Jaintiapur and adjacent areas of Sylhet, Zadukata and the Chalti Rivers of Sunmaganj, and the Shomeswari River of Netrokona District. The recent depositions of the transported sediments of these rivers covers an area of approximately 50 square kilometres. Exploration activities were also conducted over the exposed Tertiary sediments of the Juri and Fultola region of the Moulovibazar district where previously uranium mineralised zones were reported. This exploration was carried out through the Institute of Nuclear Minerals of the Atomic Energy Research Establishment, Bangladesh Atomic Energy Commission. Notable findings from the exploration include:

- Naturally occurring radioactive materials (NORMs) were found as 611±10, 45±13 and 83±12 Bq/Kg, respectively for ^{40}K, ^{226}Ra, ^{232}Th. The highest value of ^{40}K was 1 040 Bq/Kg, whereas that of ^{226}Ra and ^{232}Th was measured as 86 and 179 Bq/Kg, respectively in Jaintiapur region.
- Recent depositions in both sands and soils at the Zadukata and Chalti Rivers have 6-8 ppm U-238 and 11 to 16 ppm Th-232. Radon concentration in river water of the survey area was found to vary from 4 to 10 kBq/l whereas in floodplain sand, it ranges from 24 to 1 270 kBq/m^3.
- In situ measurement of radioactivity at the Shomswary River showed the presence of 2 to 29 ppm of ^{238}U and 4 to 52 ppm of Th-232.
- Tertiary sediments at the Juri anticline and Fultola regions average 4 to 7 ppm of U-238 and 7 to 14 ppm of Th-232.

Uranium exploration and development expenditures and drilling effort – Government domestic

(BDT)*

	2021	2022	2023	2024 (expected)
Government exploration expenditures	450 000	500 000	700 000	700 000
Total expenditures	450 000	500 000	700 000	700 000
Total drilling (metres)	NA	NA	NA	NA
Total number of holes drilled	NA	NA	NA	NA

* Bangladeshi Taka.

Recent mine development activities

Bangladesh has no current or planned mine development activities.

Uranium resources and production

Bangladesh has no current uranium resources or production.

Uranium requirements

Bangladesh began construction of its first nuclear power reactor (Rooppur 1) in November 2017 with scheduled commissioning in 2023 and commercial production in 2023 or 2024. Construction of the second unit at Rooppur commenced in July 2018, with scheduled completion in 2024 and commercial production in 2024 or 2025. The country has a rapidly increasing power demand and is aiming to reduce its dependence on natural gas. All fuel for Rooppur will be provided by Rosatom and used fuel will be repatriated to Russia.

Bolivia

Uranium exploration and mine development

Historical review

The Bolivian Nuclear Energy Commission (COBOEN), created by the Law N° 16045 on 29 December 1978, has the responsibility for all the activities of research and application of nuclear energy for peaceful purposes in the fields of geology, mining, metallurgy, research, industry, energy, agriculture, medicine, hydrology, and others.

On 3 June 1983, COBOEN was restructured and changed its name to The Bolivian Institute of Science and Technology (IBTEN), embracing the activities of research and the application of nuclear techniques, planning and supervision of the development of nuclear technology.

Uranium and thorium prospecting and exploration activities are conducted by the Geological Mining Survey of Bolivia (GEOBOL), with the specific function of evaluating the potential of such resources. In addition, the Uranium Metallurgy project of the Institute of Mining and Metallurgical Research has the specific function of completing studies on the extraction of uranium concentrates and the optimisation of production costs based on new techniques within the framework of the national nuclear policy.

The main uranium exploration activities occurred in three stages.

First stage

In 1953, at the request of the Bolivian government, the United States Atomic Energy Commission (USAEC) sent a geological reconnaissance mission to the country to investigate the uranium exploration potential.

The mission detected heightened radioactivity in some areas of Bolivia (Potosí and Cochabamba Departments) related to old mines where uranium minerals associated with copper, cobalt and nickel minerals in the Santa Cruz Department. During this campaign, radioactive anomalies were also identified in the eastern highlands of Santa Cruz, as a result of the aerial reconnaissance.

In 1954-55, the USAEC and the former National Department of Geology of Bolivia (DENAGEO) carried out a new exploration campaign, which despite many difficulties encountered in the field, yielded interesting results, which were reflected in the report by Henderson and others1. Among numerous mines investigated in the Cordillera and Altiplano regions, based on the measurements made on mineral samples, the tin porphyry mine Siglo XX (also known as Siglo Veinte, Llallagua, and Catavi), located close to the city of Llallagua in Bustillos province (Potosí), appeared to have good potential for uranium resources. In addition, other uranium indicators were found in the areas of Sorata, in La Paz and Tasna, in Potosí.

1 Henderson, J., Honea, M. and Donoso, G. (1955), “Appraisal of uranium possibilities in Bolivia”, United States Atomic Energy Commission Unpublished Report 4060.

Second stage

In 1963, on behalf of the DENAGEO and the United Nations Development Program (UNDP), a Swedish Consulting Company carried out an aerial prospecting campaign, covering the Cordillera and the Altiplano regions.

The reports indicated that there were several radioactive anomalies of variable dimensions, detected mainly in "La Meseta de Los Frailes" in an area of around 15 000 km^2. Despite the uncertainties, it was concluded that there were enough indicators to guide the future exploration by COBOEN.

COBOEN paid close attention to the western part of the "Los Frailes" volcanic plateau with the central Altiplano-Cordillera boundary. In 1968 the first exploratory work was planned in this volcanic area.

In 1970, the regional prospecting project began in the "Los Frailes" region, covering the adjacent altiplanic portion, located between Salinas, Sevaruyo and Río Mulato. During this campaign, the Cotaje deposit (the only Bolivian deposit at that time) was discovered in July 1970. In addition, regional prospecting work was carried out that year in the areas of Tupiza, Camargo and Uyuni.

After a technical evaluation of the economic possibilities of the uranium deposits, Homestake Mining Co., in co-ordination with COBOEN, in 1973 recommended that the evaluation of the prospects in the Sevaruyo area and prospecting in the Chacarilla area with ground and aerial methods should continue and that anomalies found in the Tupiza area should be investigated.

In December 1974, COBOEN authorities delivered two kilograms of uranium concentrates (yellowcake), recovered in its laboratories from Cotaje uranium deposit ore (Potosí), to the national government. This work was carried out in co-operation with the Nuclear Operations and Processes Division and marked a technological milestone in Latin America and for the Bolivian nuclear metallurgy in particular.

Third stage

From 1975, prospecting and exploration were consolidated across Bolivia, though the rate of anomaly discovery was reduced. Activities at Cotaje deposit were maintained to evaluate the feasibility of the metallurgical mining project and to quantify the economic potential of existing resources, using exploration equipment donated by the UNDP.

In 1977, the first uranium ore concentration pilot plant was inaugurated in Cotaje (the second in Latin America). Its design, installation and start-up were undertaken exclusively by COBOEN personnel.

Exploration of the Cotaje metallurgical mining complex was intensified in 1979 employing an electrical resistivity geophysical survey. The geological evaluation found that the estimated resource base did not justify the construction of an industrial plant for uranium processing. It was instead decided to expand the Cotaje pilot plant to a semi-industrial scale with a declared rated annual production capacity of 4 tonnes of U_3O_8 in the form of commercial concentrates. In September 1980, the plant was officially inaugurated, but due to the limited budget and lack of prospecting equipment it was not possible to continue with the discovery of additional resources in the country.

In 2002, the IBTEN and IAEA authorities visited the SERGEOMIN uranium facility located around Chiripuyo (Oruro), where about 300 kg of yellowcake was in a plastic container, which in turn was in another external metal container. Currently, this container is stored in a concrete pool.

Mining exploration work was resumed in 2008 when the Prefecture of the Department of Potosí contracted the services of the National Geological and Technical Mining Survey (SERGEOTECMIN; now SERGEOMIN) to carry out a prospecting and exploration programme in the Cotaje district and adjacent areas.

Results from the Cotaje deposit indicated that mineralisation was low-grade and not commercially exploitable. In addition, the uranium grade was less than what was estimated by COBOEN in the 1970s.

The prospecting and exploration of radioactive minerals continued to be very active and with strong state support until the cessation of COBOEN and the creation of the Bolivian Institute of Nuclear Sciences and Technology (IBTEN) in June 1983.

During the 2009-2010 period, SERGEOTECMIN conducted a prospecting radiometric survey in the sectors previously investigated by COBOEN, defining Tholapalca, Asunción and Coroma Este as the areas of greatest interest due to heightened uranium anomalies.

Between 2009 and 2011, SERGEOTECMIN signed a contract with the Prefecture of Potosí and subsequently with the Departmental Autonomous Government to conduct exploration. In 2011, more detailed geological exploration was carried out, including a diamond drilling programme at the Tholapalca and Coroma Este sites. However, due to a lack of funding, project activities were suspended.

Recent and ongoing uranium exploration and mine development activities

The Bolivian Nuclear Energy Agency (ABEN) is the nation's nuclear operator, and is responsible for overseeing the development of research, production, commercialisation, and provision of goods and services related to nuclear technology. Based on its mandate and alignment with Bolivia's national development plan, ABEN began in the latter half of 2022 to collect and analyse geological samples for the presence of radioactive elements (U and Th). These activities, which have continued into 2024, aim to assess the country's potential in terms of radioactive resources, contributing to the strategic exploration and development of Bolivia's nuclear capabilities.

Identified conventional resources (reasonably assured resources and inferred resources)

According to the December 2011 SERGEOMIN report, there are 1 720 tU of in situ inferred resources related to the volcanic type Cotaje deposit. There have been no changes since Red Book 2022.

Inferred conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining	0	0	0	1 720	NA
Total	0	0	0	1 720	NA

Inferred conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	0	1 720	NA
Total	0	0	0	1 720	NA

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Volcanic-related	0	0	0	1 720
Total	0	0	0	1 720

Botswana*

Uranium exploration and mine development

Historical review

A surge in uranium prices in the 1970s led to exploration activities in Botswana by various foreign and local companies. Large airborne radiometric surveys were followed by ground surveys, soil sampling, trenching and drilling. However, the thick sand cover in many parts of the country hindered exploration activities. Exploration effectively ceased in the early 1980s with the slump in uranium prices. No deposits of economic interest were discovered in this early phase of exploration, but significant mineralisation was identified in the Karoo sandstones and surficial calcretes, particularly in the east-central part of the country.

Rising uranium prices in 2005 renewed interest in uranium exploration by junior Australian companies, and by 2011, there were 168 uranium prospecting licences registered in Botswana.

A-Cap Energy Ltd (formerly known as A-Cap Resources) has been exploring in Botswana since 2004, following up on mineralisation discovered by Falconbridge in the 1970s in the Serowe area and further discovering significant mineralisation at the Letlhakane project. Intensive drilling resulted in A-Cap reporting Botswana's first JORC compliant uranium resource in 2008 of just over 100 000 tU at an average grade of 129 ppm U (0.0129% U).

Impact Minerals Ltd, another Australian junior company, acquired permits around A-Cap's areas in early 2008. Exploration activities in 2009 began with airborne radiometric surveys, followed by field reconnaissance, mapping and drilling, leading to the discovery of four prospects in Karoo siltstones and sandstones. In addition to sandstone-hosted mineralisation, there were discoveries of uranium-bearing alaskitic rocks, similar to those found at Rössing in Namibia, and mineralisation related to Proterozoic sedimentary and basement rocks with similarities to the unconformity-related deposits in Australia and Canada. Impact Minerals was also exploring prospective deposits in eastern Botswana, including Lekobolo, with uranium mineralisation down to 45 m. Further south, it had the Shoshong and Ikongwe prospects in calcrete.

At the end of 2012, A-Cap's prospecting licences for uranium covered 5 000 km^2, while Impact Minerals Ltd controlled 26 000 km^2. The two companies drilled a total of 12 462 m in 95 reverse circulation holes during 2011 but no drilling was reported in 2012. Both companies completed regional ground gravity surveys and Impact Minerals Ltd completed a soil geochemical survey over an area of 250 km^2 at the Ikongwe prospect.

In May 2013, Impact Minerals Ltd announced the sale of four prospecting licences to a local company, Sechaba Natural Resources, but this was not completed due to licensing delays. In 2014 Impact Minerals Ltd put its uranium exploration on hold and the majority of their prospecting licences within the Botswana uranium project licences were not renewed.

The Letlhakane uranium deposit has been the focus of detailed technical work for A-Cap since 2010, resulting in the February 2013 release of a positive scoping study. A thorough examination of all aspects of the resource has led to a greater understanding of the framework and grade distribution of uranium mineralisation and the use of appropriate mining techniques to maximise the economics of the deposit.

* Report prepared by the NEA/IAEA, based on previous Red Books and A-Cap Energy Ltd reports.

The uranium mineralisation, hosted predominantly in carbonaceous mudstones and siltstones, occurs in relatively thin (0.5-5 m), laterally extensive lenses with lower-grade material separating higher-grade ore horizons. The nature of the ore combined with shallow, flat-lying and soft strata lends itself well to open-pit extraction methods. This information has resulted in a resource estimation that is smaller than previously reported, but with higher grades.

A drilling programme was completed in September 2014 focusing on shallow high-grade zones where initial optimisation runs delineated possible early pits. The drilling programme was designed to test the continuity and mine scale variability of mineralisation in three main project areas (Kraken, Gorgon and Serule West), and to provide data for further resource modelling and mine planning. This drilling yielded excellent results and confirmed the presence and continuity of high-grade mineralisation within these areas.

A drill optimisation study has also been completed, focused on the Kraken area where infill drilling had previously been completed. Holes were then excluded to define pre-infill drilling grids at 400 m spacing, 200 m spacing, as well as patterns of 100 x 100 m and 50 x 100 m. The results from the Kraken area concluded that the drilling defines the resource at 200 m spacing and only small variations in grade and contained metal occur when infill drilling is subsequently conducted. This gives A-Cap an excellent guide to defining mineralisation for the project.

A follow-up infill drilling programme to further define potential early pilot pits was successfully completed in November 2014. Resource evaluation, using uniform conditioning (UC) and localised uniform conditioning (LUC) techniques, were conducted. In September 2015, A-Cap announced an upgrade of Letlhakane resources utilising the LUC method. The JORC compliant resources for all deposits are presented in the table below.

Resources reported by A-Cap Energy Ltd, compliant with the JORC 2012 code (September 2015)

Cut-off (U ppm)	Total indicated			Total inferred			Total		
	Mt	U (ppm)	Contained U (tU)	Mt	U (ppm)	Contained (tU)	Mt	U (ppm)	Contained U (tU)
85	197.1	167	32 890	625.0	172	107 740	822.1	171	140 630
170	59.2	274	16 230	209.7	272	57 010	268.9	272	73 240
255	22.2	393	8 730	81.6	378	30 890	103.8	382	39 620

In August 2015, a mining licence application was submitted to the Botswana Department of Mines. The application was based on the results of a technical study and financial modelling, assuming open-pit mining and heap leaching processing, to produce 1 440 tU/yr over a mine life of 18 years. A detailed programme of process test work including acid column leaching, solvent extraction and ion exchange was completed. Uranium recoveries varied from 60.5% to 77.7% depending on the mineralisation type.

Recent and ongoing uranium exploration and mine development activities

In 2017, A-Cap completed in-house processing studies with the objective of reducing acid consumption and increasing recovery. Acid soluble uranium analysis was performed on 296 samples. Results showed spatial and mineralogical relationships with high acid consumption in the Kraken and Gorgon South areas, exhibiting an increase in acid consumption with depth. Optimisation studies identified savings of up to 26% of acid consumption.

Exploration activities were suspended in 2018 due to an unfavourable uranium price outlook. In 2018-2019 A-Cap continued to attend to the requirements of the Letlhakane Uranium Project's mining licence, including meeting reporting requirements, maintenance of the mining licence boundary, radiation inspectorate compliance, and engaging with the community to update them on the project's status. The Department of Mines confirmed that the mining licence and all prospecting licences continue to be in good standing.

In mid-2022, A-Cap commenced a comprehensive programme of development activities aimed at restarting exploration and advancing Letlhakane. A-Cap planned to start with a 1 500 m drill programme to collect up to 2 t of ore for additional beneficiation tests. Later in 2023, it was announced that Lotus Resources will acquire the Letlhakane project.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

In September 2015, A-Cap Energy upgraded the global JORC Resource of the Letlhakane Uranium Project. Letlhakane hosts a global resource of 822.1 million tonnes at 171 ppm U (0.017% U) for an in situ resource totalling 140 630 tU, based on an 85 ppm U cut-off grade. Within this resource, 32 890 tU belong to the RAR category and 107 740 tU to Inferred. Using a total recovery factor of 62% (mining and processing), the total identified recoverable resource amounts to 87 190 tU in the <USD 130/kg U category.

A-Cap has also defined a higher-grade resource of 73 240 tU, based on the 170 ppm U cut-off grade, or 39 620 tU, based on the 255 ppm U cut-off grade.

A-Cap continues to assess the Letlhakane resource in terms of mining optimisations, including different mining techniques, and to determine the optimal areas for conversion from inferred to indicated resources.

Undiscovered conventional resources (prognosticated and speculative resources)

The key feature for uranium mineralisation in Botswana is the presence of highly radiogenic granitoid suites, most relating to the Pan-African (~500 Ma) magmatic event, which introduced uranium-rich source material into the upper crust. The uranium mineralisation is highly mobile, and, through leaching, uranium-bearing solutions became concentrated in reduced environments in sandstones, mudstones and carbonaceous materials in the overlying lower Karoo system.

Most calcareous sediments in the Gojwane and the Foley area, which lies on the Karoo and the Karoo-aged sediments, are presumed to host widespread and continuous uranium mineralisation. These areas are considered to have the same geology as the Letlhakane area, which hosts one of the biggest undeveloped uranium deposits in Botswana.

Impact Minerals Ltd reports "target conceptual" undiscovered resources of less than 2 000 tU; however, the uncertainty of this term, and the small amount reported, do not warrant inclusion as undiscovered resources at this time. Although undiscovered resources no doubt exist, further work is required to develop the estimates.

Uranium production

From 2013-2015, A-Cap conducted feasibility studies required for the application of a mining licence for the Letlhakane Uranium Project.

Physical test work on expected lithology mixes was done to evaluate productivity and mining costs using surface mining methods. Metallurgical test work was completed to optimise the process design and provide geotechnical, geochemical, and hydrological data for studies on heaps and waste products. Process test work was based on heap leach processing using acid leaching for the primary oxide and secondary mudstone ore, and alkaline leaching for the secondary calcrete ore. The uranium recoveries varied from 60.5% to 77.7% depending on mineralisation type.

On completion of the feasibility study, a mining licence application was submitted to the Botswana Department of Mines in August 2015. The mining licence was granted by the Minister of Minerals, Energy and Water Resources on 12 September 2016, and is valid for 22 years.

A-Cap Resources anticipated starting production at its uranium mine by 2018, with a production capacity of 1 440 tU/yr, at an average operating cost of USD 34.90/lb U_3O_8 (USD 90.70/kgU) in the first five years and USD 40.70/lb U_3O_8 (USD 105.80/kgU) during the life of the mine.

On 23 April 2019, A-Cap met with the Botswana Department of Mines and submitted a letter requesting an amendment to extend by two years the commencement of the pre-construction and construction period for the Letlhakane Uranium Project. On 20 August 2019, A-Cap received confirmation from the Botswana Minister of Mineral Resources, Green Technology and Energy Security, that the amendment was approved. The amended date for the commencement of the pre-construction and construction period was changed to 30 October 2021. In September 2021, the Minister extended the start of construction to 30 September 2024, amending a condition of the mining licence.

Uranium production centre technical details

(as of 1 January 2021)

	Centre #1
Name of production centre	Letlhakane
Production centre classification	Prospective
Date of first production	NA
Source of ore:	
Deposit name(s)	Gojwane/Serule
Deposit type(s)	Secondary/calcrete
Recoverable resources (tU)	87 190
Grade (% U)	0.017
Mining operation:	
Type (OP/UG/ISR)	OP
Size (Mt ore/year)	24 000
Average mining recovery (%)	90
Processing plant:	
Acid/alkaline	Acid
Type (IX/SX)	Heap leaching
Size (Mt ore/year); for ISR (litre/hour)	
Average process recovery (%)	69
Overall recovery factor (%)	62
Nominal production capacity (tU/year)	1 440

Environmental activities and socio-cultural issues

A-Cap Resources has established a Safety, Health, Radiation, Environment and Community Group aimed at informing, educating and involving local communities with regard to their activities. Meetings are held on a regular basis. The company submitted an initial environmental and social impact assessment study of the Letlhakane project to the Botswana government in 2011. The scoping study indicates potential for a mine life of more than 20 years, subject to world market prices for uranium.

A detailed water exploration programme by A-Cap has confirmed that a well field located 30 km west of Letlhakane could supply water of sufficient quality and quantity to meet the project's requirements. A-Cap submitted water rights applications which were subsequently granted by Botswana's Water Apportionment Board in 2012.

An environmental and social impact assessment (ESIA) consistent with the Botswana government's requirements was completed in 2014 and submitted in May 2015 to the Department of Environmental Affairs (DEA). Studies determined that with appropriate mitigation all environmental and social aspects during the construction and planned operations could be addressed. The ESIA findings were presented to the Serule and Gojwane Kgoltas, the Mmadindare and Paje subland Boards, and the Tonata council.

Following a comprehensive review by the DEA, A-Cap was advised in March 2016 that it had adequately identified and assessed impacts associated with the project. A four-week public review was completed, following which the environmental and social impact assessment was approved on 13 May 2016.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

National policies regarding uranium exploitation and production are under development and no regulations for uranium mining and milling are currently in place. However, the government is committed to encouraging private investment in exploration and new mine development. The fiscal, legal and policy framework for mineral exploration, mining and mineral processing in Botswana is continuously being reviewed to make it more competitive. Amendments made to the Mines and Minerals Act in 1999 and the Income Tax Act in 2006 streamlined licensing, enhanced security of tenure and reduced royalty payments and tax rates.

Reasonably assured conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	20 390	20 390	62
Total	0	0	20 390	20 390	62

Reasonably assured conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Heap leaching* from OP	0	0	20 390	20 390	62
Total	0	0	20 390	20 390	62

* A subset of open-pit and underground mining, since it is used in conjunction with them.

Reasonably assured conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	20 390	20 390
Total	0	0	20 390	20 390

Inferred conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	66 800	66 800	62
Total	0	0	66 800	66 800	62

Inferred conventional resources by processing method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Heap leaching* from OP	0	0	66 800	66 800	62
Total	0	0	66 800	66 800	62

* A subset of open-pit and underground mining, since it is used in conjunction with them.

Inferred conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	66 800	66 800
Total	0	0	66 800	66 800

Brazil

Uranium exploration and mine development

Historical review

The Brazilian National Research Council began systematic prospecting for radioactive minerals in 1952. These efforts led to the discovery of the first uranium occurrences at Poços de Caldas (State of Minas Gerais) and Jacobina (State of Bahia). In 1955, a technical co-operation agreement was signed with the United States to assess the uranium potential of Brazil. After the creation of the National Nuclear Energy Commission (CNEN), a mineral exploration department was organised with the support of the French Alternative Energies and Atomic Energy Commission (CEA) in 1962.

In the 1970s, CNEN exploration for radioactive minerals accelerated with the addition of financial resources. Further incentive for exploration was provided in 1974 when the government opened NUCLEBRAS, an organisation with the exclusive purpose of uranium exploration and production. One of the early achievements of the government organisations was the discovery and development of the Osamu Utsumi deposit on the Poços de Caldas Plateau.

In late 1975, Brazil and Germany signed a co-operation agreement for the peaceful use of nuclear energy. It was the beginning of an ambitious nuclear development programme that required NUCLEBRAS to increase its exploration activities. This led to the discovery of eight areas hosting uranium resources, including the Poços de Caldas Plateau, Figueira, the Quadrilátero Ferrífero, Amorinópolis, Rio Preto/Campos Belos, Itataia, Lagoa Real and Espinharas (discovered and evaluated by Nuclam, a Brazilian-German joint venture).

As a result of the Brazilian nuclear development programme reorganisation of 1988, Indústrias Nucleares do Brasil S.A. (INB) discontinued uranium exploration activities in 1991. Since then, limited exploration work has been done to further define resources in Lagoa Real Province.

Recent and ongoing uranium exploration and mine development activities

During the 2012-2017 period, exploration efforts focused on favourable areas related to albitic metasomatites of LR 09, LR 35 and LR 36 deposits in the north part of the Lagoa Real Province. No exploration work was done during the 2018-2020 period. In late 2020, the INB started the reassessment of resources in six deposits in the provinces of Lagoa Real (Engenho Mine, LR-03, LR-06, LR-08, LR-35 and LR-36). No additional exploration work was done during the 2020-2022 period. For 2024 a 6 000 m drilling programme is scheduled to close the grid and upgrade the resource category of the LR-08 deposit.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Brazil's conventional identified uranium resources are hosted in the following deposits:

- Lagoa Real (Caetité), in Bahia state, with the following 15 deposits (belonging to the Lagoa Real Province): Engenho Mine, Cachoeira Mine, LR-01, LR-02/12, LR-03, LR-04, LR-05, LR-06, LR-07, LR-08/11, LR-31, LR-33, LR-34, LR-35 and LR-36. All these deposits are classified as metasomatite type, but different production/processing methods are considered for the evaluated recoverable resources: open-pit mine with heap leaching for Engenho Mine, underground mine with conventional milling for Cachoeira Mine, and open-pit mine with conventional milling for the other deposits.

- Santa Quitéria, in Ceará state, with the Itataia, Alcantil and Serrotes Baixos deposits. These deposits are classified as metamorphite type, where phosphate is the primary product and uranium is considered an important by-product for the evaluated recoverable resources.
- Poços de Caldas Plateau, in Minas Gerais state, with the Osamu Utsumi Mine (Cercado deposit) and Agostinho deposits. These deposits are classified as intrusive type, and the assessment of recoverable resources considers the production/processing through open-pit mine with conventional milling.
- Quadrilátero Ferrífero, in Minas Gerais state, with the Gandarela and Serra das Gaivotas deposits. These deposits are classified as paleo-quartz-pebble conglomerate type, with Au as the main mineral product, while uranium is considered as by-product for the evaluated recoverable resources.
- Amorinópolis, in Goiás state, with the Amorinópolis deposit. This deposit is classified as sandstone type, and the assessment of recoverable resources considers the production/processing through open-pit mine with conventional milling.
- Rio Preto/Campos Belos, in Goiás state, with the Rio Preto and Campos Belos deposits. These deposits are classified as metamorphite type, and the production/processing methods considered for the evaluated recoverable resources are unspecified.
- Figueira, in Paraná state, with the Figueira deposit. This deposit is classified as sandstone type, and the assessment of recoverable resources considers the production/processing through underground mine with conventional milling.
- Espinharas, in Paraiba state, with the Espinharas deposit. This deposit is classified as metasomatite type, and the production/processing methods considered for the evaluated recoverable resources are unspecified.

No additional resources were identified during the 2020-2022 period.

Previously it was considered that the Pitinga Site contributed with reasonably assured resources (50 800 tU) and inferred resources (67 700 tU). However, after a careful review of all available information, it was found that the existing documentation was not appropriate to support these resource statements. Pitinga's resources were then reclassified as speculative, and the removal of these values from identified resources resulted in a significant reduction (around 31% of Brazil's total identified resources).

The mining depletion of Cachoeira Mine, operated until 2014 as an open-pit mine, resulted in the decrease of the resources related to Lagoa Real Province (around 3% of Brazil's total resources).

The deposit-type classification related to deposits associated with the Santa Quitéria, Poços de Caldas Plateau, Rio Cristalino and Pitinga exploration projects were reclassified, ensuring a better geological representation and consistency with other IAEA documents.

Undiscovered conventional resources (prognosticated and speculative resources)

A review of estimates for the undiscovered resources resulted in a decrease of 300 000 tU in the prognosticated resources and of 245 606 tU in the speculative resources.

Currently, there are no prognosticated resources.

Brazil's speculative uranium resources are related to the following prospects:

- Rio Cristalino exploration project, in Pará state, with the Rio Cristalino deposit, classified as sandstone type.
- Pitinga Site (mine, stockpiles, and tailings), at Amazonas state, classified as intrusive type. This is not an exploration project, but a mine operated by a private company, with Sn, Nb and Ta as the main mineral products.

Uranium production

Historical review

The Poços de Caldas uranium production facility, which started production in 1982 with a design capacity of 425 tU/year, was operated by the state-owned company NUCLEBRAS until 1988. At that time, Brazil's nuclear activities were restructured. NUCLEBRAS was succeeded by the INB and its mineral assets transferred to Urânio do Brasil S.A. With the dissolution of Urânio do Brasil in 1994, ownership of uranium production is 100% controlled by the INB, a state-owned company.

Between 1990 and 1992, the production centre at Poços de Caldas was on standby because of increasing production costs and reduced demand. Production was restarted in late 1993 and continued until October 1995. After two years on standby, the Poços de Caldas production centre was shut down in 1997 and a decommissioning programme started in 1998. This industrial facility was used to produce rare earth compounds from monazite treatment until 2006, but closed the next year for market reasons.

The Caetité Unit (Lagoa Real Province), operated by INB, is currently the only uranium production facility in operation in Brazil. This unit started its production in 1999 and operated until 2015 with a design capacity of 340 tU/year, through the heap leaching process from the ore of the Cachoeira Mine (open-pit). The open-pit part of the Cachoeira deposit was entirely mined out in 2014, therefore any future exploitation of this deposit can only operate as an underground mine.

Status of production facilities, production capability, recent and ongoing activities and other issues

The Caetité Unit restarted operating in 2020, and it currently operates with a design capacity of 220 tU/year, through the heap leaching process from the ore of Engenho Mine (also open-pit).

The expansion of Caetité Unit to 678 tU/year is progressing and production is expected to start in 2027. Planning for expansion includes production of Engenho Mine and other deposits of Lagoa Real Province (all by open-pit mine), and involves replacement of the current heap leaching (HL) process by conventional milling (agitated leaching). The overall investment in this expansion is estimated to amount to USD 120 million.

Ownership structure of the uranium industry

The Brazilian uranium industry is 100% state-owned through the INB.

Employment in the uranium industry

Employment at existing production centre (Caetité Unit) slightly increased in 2022 from 2021 (see table below).

Future production centres

The Santa Quitéria Project, a partnership between the INB and a Brazilian fertiliser producer, is progressing and the operation is scheduled to begin in 2027. This phosphate/uranium project has a design capacity of 1 950 tU/year.

The licensing of this project involves the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) and the National Commission of Nuclear Energy (CNEN). In the case of IBAMA, the preliminary environmental licensing decision is expected at the end of 2024. In the case of CNEN, the licensing is split into a non-nuclear part, involving milling and phosphate production, and a nuclear part, involving uranium concentrate production.

Uranium production centre technical details

(as of 1 January 2023)

	Centre #1	Centre #2	Centre #3
Name of production centre	Caetité	Caetité Expansion	Santa Quitéria
Production centre classification	Existing	Prospective	Planned
Date of first production	2000	2030	2027
Source of ore:			
Deposit name(s)	Lagoa Real – Engenho	Lagoa Real – Others	Santa Quitéria – Itataia
Deposit type(s)	Metasomatite	Metasomatite	Metamorphite
Recoverable resources (tU)	9 927	41 978	43 888
Grade (% U)	0.152	0.170	0.075
Mining operation:			
Type (OP/UG/ISL)	OP	OP	OP
Size (tonnes ore/year)	216 000	435 000	3 866 000
Average mining recovery (%)	100	100	100
Processing plant:			
Acid/alkaline	Acid	Acid	Acid
Type (IX/SX)	SX	SX	SX
Size (tonnes ore/year)	216 000	435 000	3 866 000
Average process recovery (%)	67	92	68
Nominal production capacity (tU/year)	220	678	1 950
Plans for expansion (yes/no)	Yes	No	No
Other remarks	[1][2]	[2][3]	[4]

[1] Caetité refers to the existing centre named Uranium Concentration Unit (URA), located in Bahia state (BA).

[2] Currently, Caetité Unit operates through the heap leaching process from the ore of Engenho Mine (open pit). With the expansion of its processing plant, scheduled to 2027, Caetité Unit will operate through the conventional milling process from the ore of other deposits of Lagoa Real Province (also open pit).

[3] Lagoa Real – Others refers to the following 13 deposits of Lagoa Real Province (Cachoeira Mine is not included): LR-01, LR-02/12, LR-03, LR-04, LR-05, LR-06, LR-07, LR-08/11, LR-31, LR-33, LR-34, LR-35, LR-36.

[4] Santa Quitéria refers to the prospective centre named Santa Quitéria Project (PSQ), which will be located in Ceará state (CE), with uranium as a by-product from phosphate rock (open pit).

Environmental activities and socio-cultural issues

Licences in Brazil are issued by the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) and the National Commission of Nuclear Energy (CNEN).

The closure of Poços de Caldas in 1997 ended the exploitation of this low-grade ore deposit that produced vast amounts of waste rock. Several studies have been carried out to characterise geochemical and hydrochemical aspects of the waste rock and tailings dam to better establish the impact they may have had on the environment and to develop the necessary mitigation measures. A remediation/restoration plan, considering several alternatives, was submitted to the regulatory body at the end of 2012. Depending on the option adopted, the costs of implementing the remediation/restoration plan could reach USD 85 million. The INB, regulators and central government are involved in the consolidation of a work plan for the remediation.

Regulatory regime

Licences are issued by the IBAMA, according to Brazilian environment law and CNEN regulations.

Government policies and regulations established by the CNEN include basic radiological protection directives (NE-3.01 – *Diretrizes Básicas de Radioproteção*), standards for licensing of uranium mines and mills (NE-1.13 – *Licenciamento de Minas e Usinas de Beneficiamento de Minérios de Urânio ou Tório*) and decommissioning of tailing ponds (NE-1.10 – *Segurança de Sistema de Barragem de Rejeito Contendo Radionuclídeos*), as well as standards for conventional U and Th mining and milling (NORM and TENORM NM 4.01 – *Requisitos de Segurança e Proteção Radiológica para Instalações Mínero-Industriais*). In the absence of specific norms, the recommendations of the International Commission on Radiological Protection and the International Atomic Energy Agency are used.

Due to the potential future growth of the Brazilian nuclear programme, a new law, published in 2021, created an independent nuclear regulatory agency, named National Nuclear Safety Agency (ANSN). The ANSN will take the responsibility from CNEN related to standards, licensing, authorisation and supervision of nuclear safety and radiological protection of nuclear ore mining activities, in addition to tailings deposits and sites of waste storage, including the supervision of research and mining of these ores.

In 2022, a new law was sanctioned, bringing the possibility of new models of association with private companies in the activities developed by INB. With this new flexibility, it will be possible to seek partners, aiming at the development of research, mining and commercialisation of nuclear ores, their concentrates and derivatives, and nuclear materials. It was already possible for a private company to participate in a situation where uranium appears as a co-product. This is the case of the Santa Quitéria Project, where phosphate is the main product and uranium is the co-product.

This new law also makes possible an association between INB and private partners for the exploration of mineral deposits that have nuclear ores, whether or not technical and economic feasibility studies indicate that the quantity of nuclear materials present is of greater or lesser economic value than other mineral materials delineated or mined in the deposit.

Uranium requirements

Brazil’s present uranium requirements for the Angra 1 Nuclear Power Plant, a 609 MWe net pressurised water reactor (PWR), are about 140 tU/yr. The Angra 2 Nuclear Power Plant, a 1 280 MWe net PWR, requires 246 tU/yr. The start-up of the Angra 3 Nuclear Power Plant (a similar design to Angra 2) was scheduled initially for 2016, but construction was stopped in 2015. With the resumption of construction, Angra 3 is scheduled to be operating in 2028. Once in operation, it will add 256 tU/yr to annual domestic demand.

The national energy plan, Plano Nacional de Energia 2050 (PNE 2050), issued in 2020, is a fundamental study of long-term planning for the country’s energy sector. It assesses trends in production and use of energy and evaluates alternative strategies for expanding energy supply in the coming decades. The PNE 2050 also establishes guidelines for the role of nuclear power in the national strategy, including post-Fukushima risk perception and increasing costs, mastery of the complete nuclear fuel production cycle, and the possibility of exporting such products, taking into consideration the scale of production and competitiveness. Depending on different scenarios, nuclear generation could reach 10 GWe net in 2050.

In the table below, the low case considers a scenario with no additional reactors after Angra 3, while the high case considers a scenario with four additional reactors until 2050.

Supply and procurement strategy

All domestic production is designated for domestic requirements. The shortfall between demand and domestic production is met through market purchases. In the 2020-2022 period, the INB acquired a total of 501 tU.

The planned uranium production increases are designed to supply all reactor requirements, including the Angra 3 unit and all units foreseen in the planned long-term expansion of nuclear energy for electricity generation.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

The INB, a 100% government-owned company, oversees fuel cycle activities that are conducted under state monopoly. The INB is currently working on increasing uranium concentrate production and towards the full implementation of fuel cycle activities required to meet domestic demand.

Uranium stocks

The Brazilian government does not maintain stocks of uranium concentrate or enriched uranium product.

Uranium exploration and development expenditures and drilling effort – domestic

(in BRL)

	2020	2021	2022	2023 (expected)
Industry* exploration expenditures	0	0	0	0
Government exploration expenditures	0	0	0	6 000 000
Total expenditures	0	0	0	6 000 000
Industry* exploration drilling (m)	0	0	0	0
Government exploration drilling (m)	0	0	0	6 000
Total drilling (m)	0	0	0	6 000

* Non-government.

Reasonably assured conventional resources by production method

(in situ tonnes U)*

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	53 118	60 828	70-80
Underground mining (UG)	0	0	7 452	7 452	75
Co-product and by-product	81 576	81 576	81 576	81 576	65
Unspecified	0	0	4 664	4 664	75
Total	81 576	81 576	146 810	154 520	-

* Resource values may not sum to the totals due to rounding errors.

Reasonably assured conventional resources by processing method

(in situ tonnes U)*

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	77 336	77 336	130 453	130 453	65-80
Conventional from UG	4 240	4 240	11 691	11 691	65-75
Heap leaching** from OP	0	0	0	7 710***	70
Unspecified	0	0	4 664	4 664	75
Total	81 576	81 576	146 810	154 520	-

* Resource values may not sum to the totals due to rounding errors.

** A subset of open-pit and underground mining since it is used in conjunction with them.

*** Expected to be produced at Engenho Mine.

Reasonably assured conventional resources by deposit type

(in situ tonnes U)*

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	7 632	7 632
Intrusive	0	0	16 960	16 960
Paleo-quartz-pebble conglomerate	4 240	4 240	4 240	4 240
Metamorphite**	77 336	77 336	77 760	77 760
Metasomatite***	o	0	40 218	47 928
Total	81 576	81 576	146 810	154 520

* Resource values may not sum to the totals due to rounding errors.

** Associated with the Santa Quitéria site. Operating expenditures for uranium recovery are considered (incremental cost for uranium extraction).

*** Associated with the Lagoa Real site.

Inferred conventional resources by production method

(in situ tonnes U)*

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	26 321	32 793	70-80
Underground mining (UG)	0	0	6 527	6 527	75
Co-product and by-product	51 981	51 981	51 981	51 981	65
Unspecified	0	0	4 664	4 664	75
Total	51 981	51 981	89 494	95 965	-

* Resource values may not sum to the totals due to rounding errors.

Inferred conventional resources by processing method

(in situ tonnes U)*

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	43 501	43 501	69 823	69 823	65-80
Conventional from UG	8 480	8 480	15 007	15 007	65-75
Heap leaching from OP	0	0	0	6 471	70
Unspecified	0	0	4 664	4 664	75
Total	51 981	51 981	89 494	95 965	-

* Resource values may not sum to the totals due to rounding errors.

Inferred conventional resources by deposit type

(in situ tonnes U)*

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	3 392	3 392
Intrusive	0	0	5 766	5 766
Paleo-quartz-pebble conglomerate	8 480	8 480	8 480	8 480
Metamorphite	43 501	43 501	43 925	43 925
Metasomatite	0	o	27 930	34 402
Total	51 981	51 981	89 494	95 965

* Resource values may not sum to the totals due to rounding errors.

Prognosticated conventional resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	0	0

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	0	254 394

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020*	2021	2022	Total through end of 2022	2023 (expected)
Open-pit mining	4 257	29	43	4 329	171
Total	4 257	29	43	4 329	171

* Updated with respect to the Red Book 2022 according to a new review of historical records.

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020*	2021	2022	Total through end of 2022	2023 (expected)
Conventional	1 053	0	0	1 053	0
Heap leaching	3 204	29	43	3 276	171
Total	4 257	29	43	4 329	171

* Updated with respect to the Red Book 2022 according to a new review of historical records.

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020*	2021	2022	Total through end of 2022	2023 (expected)
Intrusive	1 053	0	0	1 053	0
Metasomatite	3 204	29	43	3 276	171
Total	4 257	29	43	4 329	171

* Updated with respect to the Red Book 2022 according to a new review of historical records.

Uranium industry employment at existing production centres

(person-years)

	2021	2022	2023 (expected)
Total employment related to existing production centres	532	537	570
Employment directly related to uranium production	184	197	200

Mid-term production projection (tonnes U/year)

2025	2030	2035	2040	2045	2050
170	2 630	2 630	2 630	2 630	680

Mid-term production capability (tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	0	0	0	0	1950	0	2 630

2035				2040			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	1950	0	2 630	0	1950	0	2 630

2045				2050			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	1950	0	2 630	0	0	0	680

Net nuclear electricity generation

	2021	2022
Nuclear electricity generated (TWh net)	13.46	13.33

Installed nuclear generating capacity to 2050

(MWe net)

2023	2024	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
1 817	1 817	1 817	1 817	3 074	3 074	3 074	4 864	3 074	6 653	3 074	8 443	3 074	10 233

Annual reactor-related uranium requirements* to 2050 (excluding MOX)

(tonnes U)

2023	2024	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
386	386	386	386	642	642	642	1 006	642	1 371	642	1 735	642	2 099

* First core loads for planned new reactors not included.

Bulgaria

Uranium exploration and mine development

Historical review

The presence of uranium mineralisation in Bulgaria, in the Buhovo ore deposit 25 km from Sofia, has been known since 1920. The first exploration activities were undertaken in 1935. More serious exploration activities using technological research methods and economic calculations were carried out between 1938 and 1939 with the co-operation of German specialists. The first 300 tonnes of uranium ore were mined in 1939.

During 1946-1947, Soviet geologists performed intensive geological investigations of the Buhovo ore deposit. In the spring of 1946, a joint Soviet-Bulgarian enterprise was established, but its activity ceased in 1956. The Rare Metals Bureau of the Council of Ministers was established and existed until 1992, when the government decided to cease all uranium production activities.

A large number of exploration methods were applied: geological, geophysical, technological and combined methods. Aero-gamma-ray-spectrometry, hydro-radio-geochemical and water-helium photography were used for exploration.

In total, 39 ore deposits were discovered, dozens of mines were developed across the country, and two facilities for the processing of uranium ore and production of uranium concentrate (U_3O_8) were built in Buhovo and Eleshnitsa.

Bulgarian uranium deposits are small to medium in size (up to 10 000 tU), with ore grades of about 0.1% U. They have complex morphologies and irregular mineralisation. Deposits exploited via classical mining methods have complex geological structures and are situated mainly in mountain regions (Stara Planina, Rhodope massif, East Sredna Gora). The areas of the ore beds range between 250 m^2 to 20 000 m^2, with an occurrence depth of about 500 m and low metal concentration. Technical mining conditions and geological parameters resulted in a high prime cost and lower efficiency of uranium production.

The main ore deposits for underground mining are: Buhovo near Sofia; Eleshnitsa, Senokos and Simitli in south-west Bulgaria; Vinishte and Smolyanovtsi in north-west Bulgaria; Sliven in central Bulgaria; Smolyan, Dospat and Selishte in the Rhodopa Mountains.

When sediment-hosted mineralisation was found, the acid in situ leaching (ISL) mining method was adopted[1]. It was first used in 1969 and applied mainly (90% of the time) to sandstone-hosted deposits (roll-front) using drilling systems (wellfields) for leaching, and occasionally (10% of the time) to hardrock deposits using underground systems.

Deposits of this type were found first in regions of the Upper Thracian Valley, then also in the Struma river valley and in the Dospat river valley. Uranium-bearing horizons occur at 30 to 250 m below the surface. Their thickness varies from 10-12 m to 60-80 m. Uranium mineralisation is hosted by Pliocene sandstone with a thickness varying from 0.4 m to 7-8 m. Uranium grades are variable, within large limits, but with an average value of 300 ppm U (0.03% U).

1 International Atomic Energy Agency (2016), "In Situ Leach Uranium Mining: An Overview of Operations", IAEA Nuclear Energy Series NF-T-1.4 report STI/PUB/1741.

In the case of hardrock deposits, the dimensions of ore bodies vary by height from 50-70 m to 500-600 m and by thickness from 2-4 m to 80-100 m. Uranium grades are between 0.03% U to 0.2-0.3% U.

Recent and ongoing uranium exploration and mine development activities

Uranium exploration and mine development activities were terminated in 1990. No exploration was conducted in recent years and no new exploration is expected to be conducted as of 2023.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 1991, identified conventional resources amounted to 20 565 tU in situ, which at the time were determined to be subeconomic based upon prevailing market conditions and processing technology.

A revised resource estimate was made based on a select subset of deposits using data from a Redki Metali State Company report (a final report coinciding with the termination of uranium, exploration, and mining activities in 1990) and from subsequent reports submitted to the Specialised Expert Committee on Reserves and Resources (SEC), within the Ministry of Environment and Waters.

As of 1 January 2009, the remaining identified conventional uranium resources were estimated to be 19 809 tU in situ in cost category <USD 260/kgU, of which 11 908 tU were determined to be amenable to underground mining methods, and 7 901 tU amenable to ISL methods.

The 11 908 tU of in situ resources amenable to underground methods are associated with 67 different sites (locations) where *insignificant* quantities of uranium were detected. These deposits and their resources were considered subeconomic with little or no production potential.

The 7 901 tU of in situ resources amenable to ISL mining methods were considered potentially economic. During production in 1991, an average recovery factor of 65% was achieved based on ISL operations at 16 sites.

To date, no official estimates of the cost of production have been performed. The stated evaluation of the identified conventional uranium resources is unchanged as of 1 January 2023. No determinations of the identified conventional resources per cost category are available.

Undiscovered conventional resources (prognosticated and speculative resources)

Prognosticated conventional resources are estimated to amount to about 25 000 in situ tU in cost category <USD 260/kgU.

Unconventional Resources and other materials

No unconventional resources have been identified.

Uranium production

Historical review

Up to 1990, about 16 500 tU were produced. Production grew from 150-200 tU/y in the 1950s to 430 tU in 1975. The adoption of the ISL mining method for uranium production from Upper Thracian uranium deposits raised the production to 660 tU in 1989, when 70% of the uranium was ISL extracted. Ores were processed in the two hydrometallurgical plants. Uranium extraction from ISL sorbent resins and their processing was done at the Zvezda plant near Eleshnitsa. U_3O_8 was produced with 80-82% of concentration (68-70% U).

Status of production facilities, production capability, recent and ongoing activities and other issues

At present no production centres exist that could be operated for uranium extraction. If plans for the renewal of uranium production were considered, independent of who operates these facilities, the entire process would need to be built from the beginning.

At the former uranium ore processing plant Zvezda, an installation for ion-exchange resins is operational. This facility serves for the purification of uranium-contaminated mine waters. It is a small capacity installation of some 742 m^3 of resins per year.

Since 1992 the only activities have been the dismantling of facilities, closing of mining works, re-cultivation of contaminated areas, purification of uranium-contaminated mine waters, and environmental monitoring.

Ownership structure of the uranium industry

All uranium production was carried out by the state.

Employment in the uranium industry

There is currently no uranium production and no exploration or production-related employment.

Environmental activities and socio-cultural issues

Uranium production and processing ceased by Government Decree No 163 of 20 August 1992.

Remediation activities from uranium production and processing include: technical liquidation, technical and biological re-cultivation, purification of uranium-contaminated mine waters, and environmental monitoring of the areas affected by the uranium mining.

Presently the main part of the environment re-cultivation from the uranium mining impact is considered completed.

Uranium requirements

The Bulgarian nuclear power programme was launched in 1974 with the commissioning of the first nuclear power unit of the Kozloduy Nuclear Power Plant. The nuclear facilities are concentrated at the Kozloduy site, where six units were built (units 5 and 6 are in operation and units 1-4 are in the process of decommissioning). In 2022, nuclear power comprised about 32.7% of total electricity production in Bulgaria. With an operable nuclear power capacity of 2 160 MWe (2 VVER V-320 units at Kozloduy), uranium requirements are estimated at 370 tU/year.

The lifetime extension of units 5 and 6 is a priority. From 2014 to 2018, the Plant Lifetime Extension (PLEX) project was completed. The project results demonstrated the units' technical capabilities for long-term operation – until 2047 for unit 5 and 2051 for unit 6. The Nuclear Regulatory Agency (NRA) Chairman issued operating licences for unit 5 in 2017 and for unit 6 in 2019.

Pursuant to the decisions taken by both the National Assembly 2018 and the Council of Ministers in June 2018, a call for selecting a strategic investor to construct the Belene Nuclear Power Plant was launched. Currently, the procedure to select a strategic investor is "on hold".

The Kozloduy Nuclear Power Plant-New Build project was established in May 2012. In August 2013, the NRA Chairman issued a Permit for determining the location (site selection). In February 2020, the Chairman of the NRA issued an Order, which approved the selected site ("Site No. 2") for the deployment of a new nuclear power plant at the Kozloduy site. According to the January 2021 decision of the Council of Ministers, the Minister of Energy is assigned to take the necessary actions for full use of the capacity of the approved Site No. 2 at Kozloduy, for construction of a new nuclear power plant, including the rational use of equipment supplied for the "on hold" Belene Nuclear Power Plant. An environmental monitoring network and database have been developed in accordance with the requirements of the project's EIA.

Detailed information about the Kozloduy Nuclear Power Plant, new build management, staffing as well as the activities carried out by the company are available on the website (npp-nb.bg).

Supply and procurement strategy

The Kozloduy Nuclear Power Plant fuel cycle does not include the purchase of uranium, its conversion or enrichment, but only the purchase of fuel assemblies from the supplier, their interim storage at the plant site after being removed from reactor cores, spent fuel transport for reprocessing, and further disposal of high-level waste. Those activities are based on an agreement between Bulgaria and Russia, as well as on commercial contracts for the supply of nuclear fuel and reprocessing of spent nuclear fuel.

In accordance with the European Energy Security Strategy, a study was conducted to explore options on diverse enriched uranium supplies for the manufacture of fuel assemblies, as well as for the identification of an alternative supplier of fuel assemblies.

Actions to ensure the diversification of supplies of nuclear fuel were launched in 2019. In the fourth quarter of 2022, Bulgaria took a major step forward in meeting the targets of the nuclear fuel diversification programme. On 22 December 2022, Kozloduy Nuclear Power Plant signed a 10-year contract with Westinghouse Electric Sweden AB to supply unit 5 with fresh nuclear fuel. The first delivery is planned for 2024. On 30 December 2022, Kozloduy Nuclear Power Plant signed an agreement with French company Framatome GmbH for supplies of nuclear fuel for unit 6. The contract is expected to be signed in the first quarter of 2023, with the first delivery of the fuel assemblies in 2025.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

There have been no changes to the legal basis related to uranium. At present, Bulgaria does not intend to renew uranium mining activities.

Uranium stocks

There have been no changes in the uranium stock levels.

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Open-pit mining*	90	0	0	90	0
Underground mining*	11 985	0	0	11 985	0
In situ leaching	4 272	0	0	4 272	0
Total	16 347	0	0	16 347	0

* Pre-2020 totals may include uranium recovered by heap and in-place leaching.

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Conventional	11 526	0	0	11 526	0
In-place leaching*	549	0	0	549	0
In situ leaching	4 272	0	0	4 272	0
Total	16 347	0	0	16 347	0

* Also known as stope leaching or block leaching.

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Sandstone	8 700	0	0	8 700	0
Polymetallic Fe-oxide breccia complex	4 640	0	0	4 640	0
Granite-related	1 497	0	0	1 497	0
Metamorphite	366	0	0	366	0
Volcanic-related	1 144	0	0	1 144	0
Total	16 347	0	0	16 347	0

Net nuclear electricity generation (TWh net)

	2021	2022
Nuclear electricity generated (TWh net)	15.615	15.615

Installed nuclear generating capacity to 2050

(MWe net)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
2 000	2 000	2 000	2 000	2 000	2 000	2 000	3 000	2 000	3 000	2 000	4 000	2 000	3 000

Annual reactor-related uranium requirements to 2050 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
343	343	370	370	370	370	370	560	370	560	370	740	370	560

Cameroon

Uranium exploration and development

Historical review

Uranium exploration in Cameroon from 1950 to 1988 saw the discovery of several indices, including two main deposits. Since then, exploration of this commodity in the country has mainly targeted the anomalies previously identified.

In Northern Cameroon, the Kitongo deposit was discovered in 1958 through spectrometric surveys and drilling. Based on these discoveries, a general geophysical reconnaissance campaign and strategic prospection for uranium were carried out in 1978, revealing the presence of radiometric anomalies in the granitic rocks and within nepheline syenites in southern Cameroon.

During the 1980s, the focus of research was wide in order to determine the overall uranium potential of the country. In 1980, limited drilling intersected significant uranium mineralisation in small portions of the Kitongo (Northern Cameroon) and Lolodorf (Southern Cameroon) deposits. Follow-up exploration was conducted between 1985 and 1986 on the identified deposits, with some field investigations in 1987 under a new co-operation agreement. This effort mainly focused on underground exploration and radiometric mapping of the Kogué-Mango batholiths in central Cameroon. In 2007, Mega Uranium Corporation Cameroon PLC began systematic exploration on the Kitongo, Lolodorf and Teubang deposits.

In southwestern Cameroon, preliminary exploration works within the Ekomédion deposit targeted molybdenum after its discovery in 1942. Due to the failure to identify an economically viable deposit, the exploration for molybdenum was abandoned in 1955. In 2008, Ridgeway Energy Ltd acquired exploration licences on the Ekomédion deposit for both molybdenum and uranium exploration. The current status of the exploration of this deposit is unreported.

Prior to 2009, more than eight companies were involved in uranium exploration in Cameroon. These included African Aura Resources, CAMINEX, East Mining Corporation (EMCO) S.A, Fer du Cameroun, Mega Uranium Corporation Cameroon PLC, Ridgeway Energy Ltd, URANEX S.A (Resource Generated Ltd) and Xplor-Tech. Thereafter, most of these companies either suspended their exploration activities or requested renewal of their expired licences.

Based on the 2009 annual reports from Mega Uranium Corporation Cameroon PLC, the preliminary evaluation of the Kitongo (Poli, Salaki, Voko and Gouna) and Lolodorf deposits showed an estimated resource of 13 125 tU and 11 000 tU, respectively, with a minimum grade of 0.1% U. However, by 2013, further evaluation of the Kitongo deposit within the Poli concession gave an estimated resource of 17 000 tU, calculated on 65% of the area cover of the concession. A drilling programme that was launched at the Kitongo deposit did not give encouraging results, and thus Mega Uranium Corporation Cameroon PLC activities were suspended in January 2010. The reason for this suspension was to reassess the drilling targets and to carry out a re-evaluation according to the international policy on mining by the technical department of the Ministry of Mines, Industry and Technological Development (MINMIDT) in collaboration with the concerned company (Mega Uranium Corporation PLC) for possible exploitation of the resources. However, in 2014, Mega Uranium Corporation PLC suspended all exploration activities on the Kitongo and Lolodorf deposits. By this time, only 35% of each Mega Uranium Corporation PLC concession had been covered, except for the Poli concession, which was 65% covered. The suspension of exploration coincided with the expiration of the exploration licences.

A suspension of uranium exploration in Cameroon was observed in response to the fall in the price of uranium on the world market. The fall in the price of uranium has affected uranium exploration in Cameroon so much that between 2014 and 2020 only four exploration permits were issued to companies for uranium exploration (two in 2014, one in 2017 and one in 2018).

Recent and ongoing uranium exploration activities

Presently, there are no ongoing exploration activities on the Kitongo, Lolodorf, Ekomédion and Teubang deposits. The reasons are as follows:

- the decline in the price of uranium in the world market;
- the expiration of the exploration licences in 2014 for the Kitongo (Poli; Salaki and Gouna) and Lolodorf deposits;
- country boundary disputes and the low economic viability of the Teubang deposit.

In 2012 MINMIDT initiated a project known as the *Projet de Renforcement des Capacités dans le Secteur Minier* (PRECASEM, project for strengthening capacity in the mining sector), which was completed in 2020. This project was financed by the World Bank and the goal was to produce a new geological map of the country at a scale of 1:200 000. One of the main objectives of the project was to re-evaluate the mineral potential of the country. The used methods involved airborne geophysics (magnetic and spectrometric), ground geological mapping and stream sediment prospection. From the results presented in 2021, significant uranium anomalies from the spectrometric survey occur within the central regions, which are closely associated with structures and intrusions within the central Cameroon shear zone (CCSZ). Geochemical results from rocks and stream sediments also show several uranium indices in the southern regions. Since the completion of the project in 2020, MINMIDT is yet to issue new exploration licences to companies for uranium prospection. Some exploration activities are ongoing in the northern and southern regions involving Borel Mining for the Lolo concession acquired in 2018, the Njoum III and Ntem concessions acquired by CAMINEX in 2017, the Essong concession acquired by Ridgeway Energy Ltd in 2012, and the Boude concession acquired by AUCAM in 2017.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Currently Cameroon hosts two identified uranium deposits, one in the north (Kitongo deposit) and another in the south (Lolodorf deposit). These deposits were estimated to contain 17 000 tU and 11 000 tU respectively, with an average grade of about 0.1% U based on MINMIDT 2017 report. As these projects are still in the exploration phase, the economic viability of extraction is yet to be determined due to insufficient information. Preliminary evaluation has been performed but the feasibility of extraction cannot be determined due to limited technical data. The estimated quantities associated with the deposits are based primarily on indirect evidence.

The Ekomédion, Teubang and Essong deposits have also identified resources since they occur as in situ in uraninite ores hosted within defined geological structures. However, as the deposits are still under early-stage exploration, drilling programmes and resource estimation have not been carried out.

Undiscovered conventional resources (prognosticated and speculative resources)

Central Cameroon shows great potential for prognosticated resources (PR) given that the recent geophysical survey conducted under the PRECASEM project show strong uranium anomalies that are controlled by the central Cameroon shear zone (CCSZ) and associated intrusions. The anomalies are stronger and larger than those that are associated with the Kitongo and Lolodorf deposits. Given that previous reports on the known deposits in the country generally point to the formation of these deposits through magmatic and hydrothermal activities, this shear zone might have enhanced magmatic activities and the concentration of uranium in the structures and associated formations, giving rise to the strong anomalies.

Uranium production

No uranium has been produced in Cameroon.

Conventional Inferred Resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Other or unspecified	0	0	0	28 000	NA
Total	0	0	0	28 000	NA

Conventional Inferred Resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Other or unspecified	0	0	0	28 000	NA
Total	0	0	0	28 000	NA

Conventional Inferred Resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Intrusive	0	0	0	11 000
Metasomatite	0	0	0	17 000
Total	0	0	0	28 000

Canada

Uranium exploration

Historical review

Uranium exploration in Canada began in 1942, with the focus of activity first in the Northwest Territories, where pitchblende ore had been mined since the 1930s to extract radium. Exploration soon expanded to other areas of Canada, resulting in the development of mines in northern Saskatchewan and in the Elliot Lake and Bancroft regions of Ontario during the 1950s. In the late 1960s, exploration returned to northern Saskatchewan, where large high-grade unconformity deposits were discovered in the Athabasca Basin and later developed (the first was the Rabbit Lake deposit, discovered in 1968 and brought into production in 1975). Saskatchewan is now the sole producer of uranium in Canada.

Recent and ongoing uranium exploration and mine development activities

During 2021 and 2022, exploration efforts continued to focus on areas favourable for the occurrence of deposits associated with the Proterozoic unconformity in the Athabasca Basin of Saskatchewan. Of the 120 uranium exploration projects being carried out in 2022, only 15 were located outside of Saskatchewan.

While uranium deposits in the Athabasca Basin tend to have high grades (i.e. 15% U) they can be difficult to locate because they are relatively small and often occur at great depths, with little, if any, surface expression. Airborne electromagnetic (EM) techniques are used to detect graphitic zones which are often associated with uranium mineralisation. High-resolution gravity and magnetic surveys are other methods used to define underlying structure and geology. More recently, resistivity and seismic reflection surveys have been used to further define drilling targets. Drilling results are evaluated for uranium content and mineralogy, which are used as inputs into geological and geochemical modelling software to inform the next stage of exploration.

Exploration activity has led to new uranium discoveries in the Athabasca Basin. Notable recently discovered large high-grade uranium deposits include Shea Creek, Phoenix/Gryphon, Triple R, Arrow, Hurricane, Millennium Tamarack and Fox Lake.

Domestic uranium exploration expenditures amounted to CAD 122 million in 2021, an increase of 79% from CAD 68 million in 2020, which had been severely affected by the COVID-19 pandemic. Domestic exploration expenditures increased further in 2022, to CAD 238 million, and are expected to amount to CAD 300 million in 2023. Overall Canadian uranium exploration and development expenditures amounted to CAD 204 million and CAD 332 million in 2021 and 2022, respectively, and are expected to amount to CAD 397 million in 2023.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2023, Canada's total identified conventional uranium resources recoverable at a cost of <USD 80/kgU amounted to 288 000 tU, a decrease of 1.5% from the 2021 estimate of 292 400 tU. Canada's total identified uranium resources recoverable at a cost of <USD 130/kgU

were 581 000 tU as of 1 January 2023, a decrease of 1.3% compared to the 2021 estimate of 588 500 tU. These decreases are due to mining depletion exceeding new resources. Canada no longer reports uranium resources in the <USD 40/kgU cost category. Companies that previously reported deposits with resources in the <USD 40/kgU cost category have reassessed these deposits using a cut-off grade that reflects a price of <USD 80/kgU. The <USD 80/kgU category more closely reflects recent uranium prices as well as increased costs of production. Most of Canada's identified uranium resources are re-evaluated annually by the uranium mining companies.

The bulk of Canada's identified conventional uranium resources occur in Proterozoic unconformity-related deposits in the Athabasca Basin of Saskatchewan and the Thelon Basin of Nunavut. These deposits host their mineralisation near the unconformity boundary (below, above and across) in either monometallic or polymetallic mineral assemblages. Pitchblende prevails in the monometallic deposits, whereas uranium-nickel-cobalt assemblages prevail in the polymetallic assemblages. The average grade varies from 1% U to over 15% U. None of the uranium resources referred to or quantified herein are a co-product or by-product output of any other mineral of economic importance. Mining losses (~10%) and ore processing losses (~3%) were used to calculate known conventional resources if not provided by the company.

The percentage of identified conventional uranium resources in existing or committed production centres that are recoverable at <USD 80/kgU, <USD 130/kgU and <USD 260/kgU are 100%, 63.4% and 53.2%, respectively. All the resources in existing or committed production centres are updated annually by the mining companies.

Undiscovered conventional resources (prognosticated and speculated resources)

Prognosticated and speculated resources have not been a part of recent resource assessments; hence there have been no changes to report in these categories since 1 January 2001.

Uranium production

Historical review

Canada's uranium industry began in the Northwest Territories with the 1930 discovery of the Port Radium pitchblende deposit. Exploited from 1933 to 1940 for radium, the mine was reopened in 1942 in response to uranium demand for the Manhattan Project. Provincial and Territorial bans on private exploration and development were lifted in 1947 and 1948, and by the late 1950s, some 20 uranium production centres had started up in Ontario, Saskatchewan and the Northwest Territories. Production peaked in 1959 at 12 200 tU. No further defence contracts were signed after 1959 and production began to decline. Despite government stockpiling programmes, output fell rapidly to less than 3 000 tU in 1966, by which time only four producers remained. While the first commercial sales to electric utilities were signed in 1966, it was not until the mid-1970s that prices and demand increased sufficiently to promote expansions in exploration and development activity. By the late 1970s, with the industry firmly re-established, several new facilities were under development in Saskatchewan and Ontario. Annual output grew steadily throughout the 1980s, as Canada's focus on uranium production shifted increasingly to Saskatchewan. The last remaining Ontario uranium mine closed in mid-1996. Uranium production peaked at 14 039 tU in 2016 when the Cigar Lake mine reached full output, but production had declined since 2016 due to the suspension of operations at Rabbit Lake and McArthur River/Key Lake in response to low uranium prices. Production from Cigar Lake was impacted by the COVID-19 pandemic in 2020 and 2021; however, with the resumption of operations at McArthur River/Key Lake in November 2022, Canada's uranium production is expected to return to near record levels.

Status of production capability and recent and ongoing activities

All active uranium production centres are in northern Saskatchewan and are operated by Cameco Corp. (Cameco) and Orano Canada Ltd (Orano). Current Canadian uranium production is well below the full licensed production capacity of the uranium mills. Production in 2022 was 7 380 tU, 55% above the 2021 production level of 4 747 tU, as operations at the Cigar Lake mine returned to full production after being affected by the COVID-19 pandemic and the McArthur River mine and Key Lake mill, which had been shut down since 2018, resumed production in November 2022. Canadian uranium output is expected to increase as operations at McArthur River and Key Lake ramp up to full production.

Cameco is the operator of the McArthur River mine, a Cameco (70%) and Orano (30%) joint venture which is the world's largest high-grade uranium deposit. Production was idled indefinitely in January 2018 in response to low uranium demand; however, the mine resumed operations in 2022. At the mine, ground freezing is used to reduce water inflow from the overlying rock formation and the high-grade ore (>5% U) is extracted using raise bore mining with concrete used as a backfill. A high-grade ore slurry is produced by underground crushing, grinding and mixing, which is then pumped to the surface and loaded on specially designed containers that are shipped 80 km southward by road to the Key Lake mill. The remaining identified resources for the McArthur River mine are currently 153 000 tU with an average grade of 5.4% U.

The Key Lake mill is a Cameco (83%) and Orano (17%) joint venture operated by Cameco. The mill had been in care and maintenance since January 2018 due to low uranium prices; however, production resumed in November 2022, with 442 tU being produced from McArthur River ore during the year.

The McClean Lake production centre, operated by Orano, is a joint venture between Orano (77.5%) and Denison Mines Corp. (22.5%). Production from Cigar Lake ore was 6 938 tU in 2022, an increase of 48% from 2021 production of 4 679 tU. The McClean Lake mill produced an additional 68 tU in 2021 from McClean Lake ore that was mined using Surface Access Borehole Resource Extraction (SABRE) technology.

Production from the Rabbit Lake production centre, wholly owned and operated by Cameco, has been idled since mid-2016 due to low uranium prices. Production could resume when uranium prices recover. Exploratory drilling at the Eagle Point mine before operations were suspended identified resources of 27 000 tU with an average grade of 0.63% U.

Cigar Lake, with identified resources of 107 200 tU at an average grade of 11.5% U, is the world's third-largest high-grade uranium deposit. The mine began operation in March 2014 and is a Cameco (54.547%), Orano (40.453%) and Tokyo Electric Power Company (5%) joint venture operated by Cameco. Cigar Lake was the world's largest producing uranium mine in 2021 and 2022 as operations returned to full production after being closed for several months in 2020 and 2021 due to the COVID-19 pandemic. Ground freezing is used to reduce groundwater inflow and ore is extracted using an innovative jet bore mining method with concrete used as backfill. The high-grade ore slurry is then shipped by road to the McClean Lake (JEB) mill for processing. The McClean Lake mill produced 4 679 tU and 6 938 tU from Cigar Lake ore in 2021 and 2022, respectively.

Ownership structure of the uranium industry

Cameco Corp. (Cameco) and Orano Canada Ltd. (Orano) are the operators of the current uranium production centres in Canada. Cameco is the owner and operator of the Rabbit Lake production centre, which includes the Eagle Point mine and the Rabbit Lake mill. Cameco is also the operator of the McArthur River mine and the Key Lake mill, which are joint ventures with Orano. Cameco is the majority owner and operator of the Cigar Lake mine, in which Orano and the Tokyo Electric Power Co. (TEPCO) have minority ownership. Orano is the majority owner and operator of the McClean Lake production centre in which Denison Mines Corp. has minority ownership.

Uranium production centre technical details

(as of 1 January 2023)

	Centre #1	Centre #2	Centre #3	Centre #4	Centre #5
Name of production centre	McArthur River /Key Lake	McClean Lake	Rabbit Lake	Cigar Lake	Midwest
Production centre classification	Existing	Idled	Idled	Existing	Planned
Date of first production	1999/1983	1999	1975	2014	NA
Source of ore:					
Deposit name(s)	P2N et al.	JEB, McClean, Sue A-E, Caribou	Eagle Point	Cigar Lake	Midwest
Deposit type(s)	Unconformity	Unconformity	Unconformity	Unconformity	Unconformity
Recoverable resources (tU)	153 000 tU	12 100 tU	27 000 tU	107 200 tU	19 000 tU
Grade (% U)	5.4	1.1	0.63	11.5	1.52
Mining operation:					
Type (OP/UG/ISR)	UG	UG/OP	UG	UG	OP
Size (tonnes ore/day)	~200	NA	NA	~200	NA
Average mining recovery (%)	NA	NA	NA	NA	NA
Processing plant:					
Acid/alkaline	Acid	Acid	Acid	Processed at McClean Lake	To be processed at McClean Lake
Type (IX/SX)	SX	SX	SX		
Size (tonnes ore/day)	864	300	2 880		
Average process recovery (%)	98	97	97		
Nominal production capacity (tU/year)	9 600	9 200	6 500	6 900	2 300
Plans for expansion		Expansion of tailings capacity	Expansion of tailings capacity		

Employment in the uranium industry

Employment in Canada's uranium production industry (including head office employees) totalled 1 842 in 2021, and 2 381 in 2022. Employment directly related to uranium production, including contract workers, was 1 787 in 2021 and 1 930 in 2022. The increase in employment at the mine and mill sites in 2022 is primarily the result of the Cigar Lake mine reaching full production and the McArthur River mine/Key Lake mill resuming operations in 2022, after being suspended since 2018

Future production centres

Two uranium mining projects in Saskatchewan that would feed existing mills could enter production within the next decade should uranium prices increase. Ore from Orano's proposed Midwest mine, which has received environmental approval, would provide additional feed for the McClean Lake mill. Ore from Cameco's proposed Millennium mine would be processed at the Key Lake mill. Cameco has also identified other deposits (Fox Lake, Tamarack) that could feed existing mills.

Several other exploration projects in the Athabasca Basin have recently identified large high-grade uranium deposits that have the potential for development. In the western Athabasca Basin, the Arrow deposit (NexGen Energy Ltd.) is the world's second-largest high-grade uranium deposit (130 000 tU) and a project to develop an underground mine and a mill is currently undergoing an environmental assessment. The nearby Triple R deposit (Fission Uranium Corp.)

is a high-grade uranium deposit (52 000 tU) which also has indicated and inferred gold resources totalling 67 000 ounces and is also undergoing an impact assessment for the development of an underground mine. In the eastern Athabasca Basin, Denison Mines Corp.'s Phoenix deposit (26 900 tU) is undergoing an environmental assessment process for a proposal to develop an ISL mining operation. The Phoenix deposit is located in permeable sandstone above the unconformity and ground freezing is proposed in the sandstone overlying the deposit to create the confining conditions required for ISL operations. Denison Mines Corp.'s nearby Gryphon deposit (24 000 tU) has the potential to be mined by conventional underground methods. In 2020, Denison conducted a Preliminary Economic Assessment for mining the Heldeth Túé deposit (former name: J-Zone deposit) at Waterbury Lake using ISL methods.

There is also a possibility of mines being developed outside of Saskatchewan; however, uranium prices would have to increase substantially. Orano has proposed developing the Kiggavik and Sissons deposits in Nunavut, should market conditions improve and mining become economic.

Secondary sources of uranium

Canada does not use secondary sources of uranium. Canada does not produce or use mixed oxide fuels nor use re-enriched tails.

Environmental activities and socio-cultural issues

Environmental impact assessments

As indicated above, environmental assessments are currently underway for proposals to develop the Arrow deposit and the Triple R deposit in the western Athabasca Basin and the Phoenix deposit in the eastern Athabasca Basin.

Effluent management

Water treatment and minor engineering works continued to be the main activities at the closed Elliot Lake area uranium mine and mill sites in 2021 and 2022. Water quality within the Serpent River Watershed has improved since the closure and decommissioning of the mines and currently meets Ontario Drinking Water Standards.

Site rehabilitation

The Cluff Lake mine, located in the western Athabasca Basin of Saskatchewan, ceased mining and milling operations in May 2002. A two-year decommissioning programme was initiated in 2004, following a five-year comprehensive environmental assessment study. Decommissioning was essentially completed by 2006, followed by revegetation. The remaining buildings were demolished in 2013 and access to the site is no longer restricted. The decommissioning objectives and criteria established have been met and in May 2023 the mining licence was revoked. This allows Orano to transfer the site to Saskatchewan's Institutional Control Program (ICP), which was set up by the province in 2007 as part of its institutional control framework for the long-term management of decommissioned and reclaimed mine and mill sites on provincial Crown lands.

In northern Saskatchewan, several mines (principally the Gunnar and Lorado mines) were operated from the late 1950s to early 1960s by private sector companies that no longer exist. When the sites were closed, there were no regulatory requirements in place to appropriately contain and treat the waste, which has led to environmental impacts on local soils and lakes. The responsibility for these sites is now held by the government of Saskatchewan and a project is currently underway to remediate these sites.

Uranium requirements

In 2022, nuclear energy provided 14% of Canada's total electricity needs and is expected to continue to play an important role in supplying Canada with electricity in the future. Uranium requirements are currently driven by the existing CANDU fleet, most of which is being refurbished. Of the 23 CANDU pressurised heavy water reactors built in Canada, 19 power reactors currently operate, with 18 reactors supplying about 51% of Ontario's electricity and one reactor supplying about 30% of New Brunswick's electricity demand. In the future, requirements for uranium will be driven by the long-term operations of refurbished units (past 2050) and may be amplified based on other CANDU units that are now being considered for life extension and on proposed SMR projects to be deployed in Ontario, Saskatchewan, New Brunswick and Alberta.

Canada's CANDU nuclear reactors are designed to provide electricity generation for 25-30 years. Through "refurbishment" (replacement of key reactor and station components), continued operation of the reactors can be extended for approximately 30 additional years. Refurbishment projects in New Brunswick (Point Lepreau) and Ontario (Bruce A units 1 and 2) have been completed and the reactors returned to service in the fall of 2012. More recently, as laid out in Ontario's 2013 Long-term Energy Plan, refurbishment of the first Darlington unit began in October 2016 and was completed on schedule in June 2020. Refurbishment of the second Darlington unit 3 began in September 2020 and came back online ahead of schedule in July 2023, with all four Darlington units expected to be refurbished by 2026 as planned and within budget. Similarly, the first Bruce unit 6 refurbishment began in January 2020 and reached its first criticality in August 2023, with all six Bruce units expected to be refurbished by 2033.

In June 2023, Ontario Power Generation (OPG) applied to the CNSC to extend operations at the Pickering nuclear generating station until September 2026. The Government of Ontario has requested that OPG conduct a feasibility assessment on the potential for refurbishing some units at Pickering. OPG is currently conducting a comprehensive technical examination and aims to submit a final recommendation to the province by the end of 2023.

In Canada, the responsibility for deciding on the energy supply mix and investments in electricity generation capacity, including the planning, construction and operation of nuclear power plants, resides with the provinces and their provincial power utilities. The Provinces of Alberta, Ontario, Saskatchewan, and New Brunswick signed a memorandum of understanding in 2019 to advance the demonstration and deployment of SMRs in Canada, to which the Province of Alberta formally became a signatory in April 2021. These provinces have agreed to collaborate on the advancement of SMRs as a clean energy option to address climate change and regional energy demands, while simultaneously supporting economic growth and innovation. In March 2022 the provinces released a joint strategic plan that outlines a path forward on SMRs. The plan highlights how SMRs can provide safe, reliable, and zero-emission energy to the benefit of the Canadian economy and population while creating new opportunities to export Canadian knowledge and expertise around the world.

In December 2021, OPG announced the selection of the GE-Hitachi BWRX-300 for the Darlington new nuclear site. This was further supported in October 2022 by a commitment from the Canada Infrastructure Bank (CIB) of CAD 970 million to OPG, and site preparation activities are now underway for Canada's first SMR. Canada's nuclear regulator, the Canadian Nuclear Safety Commission (CNSC), had previously granted a site preparation licence in 2012 for a nuclear new build at Darlington following approval of the environmental assessment. The licence was valid for ten years and was successfully renewed in October 2021 until October 2031, with the intention that the site be prepared for use as a demonstration of SMR technology. An SMR demonstration is also being considered at a second site in Chalk River, Ontario, located at Canada's nuclear laboratories, pending the licence to prepare the site.

In June 2023, NB Power, in partnership with ARC Clean Technology Canada, Inc. (ARC), submitted an Environmental Impact Assessment registration document to the Department of Environment and Local Government, as well as a site preparation licence application to the CNSC, for the advancement of New Brunswick's first SMR project.

In July 2023, the Ontario government announced that OPG would begin planning and licensing for three additional small modular reactors (SMRs), for a total of four SMRs at the Darlington nuclear site. Once deployed, these four units would produce a total 1 200 megawatts (MW) of electricity. Additionally, the Ontario government announced its intent to add a third nuclear generating station to Bruce Power of up to 4 800 MW. Bruce Power is already the largest generating station globally, and this would be the first new large-scale nuclear plant construction in Canada in three decades.

In August 2023, the federal government approved up to CAD 74 million in federal funding for SMR development in Saskatchewan, led by SaskPower. This funding will support pre-engineering work and technical studies, environmental assessments, regulatory studies and community and Indigenous engagement. SaskPower selected the GE-Hitachi BWRX-300 in June 2022 for potential deployment in Saskatchewan in the mid-2030s, subject to a decision to build that is expected in 2029.

Supply and procurement strategy

Approximately 1 700 tU of Canada's uranium production is used domestically to generate nuclear power. The nuclear utilities fill uranium requirements through long-term contracts and periodic spot market purchases.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

The Nuclear Fuel Waste Act (NFWA), which came into force on 15 November 2002, required nuclear energy corporations to establish a Nuclear Waste Management Organization (NWMO) to manage nuclear fuel waste safely and securely over the long term.

Adaptive Phased Management (APM) was chosen as Canada's plan for the safe, long-term management of used nuclear fuel. APM involves the containment and isolation of used nuclear fuel in a deep geological repository. The APM approach recognises that people benefiting from nuclear energy produced today must take steps to ensure that the wastes are dealt with responsibly and without unduly burdening future generations. At the same time, it is sufficiently flexible to adapt to changing social and technological developments. APM is implemented by the NWMO, using funds provided by the owners of nuclear fuel waste.

The NWMO has developed a siting process to identify informed and willing host communities with a safe, secure and suitable site for a deep geological repository. This nine-step siting process was collaboratively designed, refined and finalised through an iterative two-year public engagement and consultation process. In May 2010, the NWMO initiated the siting process with an invitation to communities to learn more about the APM project and the plan to safely manage used nuclear fuel. Initially, 22 communities expressed interest in learning more. Nineteen of these communities were located in the province of Ontario and three were located in the province of Saskatchewan. Over the last decade, through extensive technical and social assessments, the NWMO has narrowed its focus to two remaining siting areas: the Wabigoon Lake Ojibway Nation-Ignace area in northwestern Ontario and the Saugeen Ojibway Nation-South Bruce area in southern Ontario. The project will only proceed in an area with informed and willing hosts. The NWMO continues to work with communities in these two siting areas. As the site selection date nears, the NWMO has begun discussions with the potential host communities on partnership agreements. The communities have also defined their own willingness processes that they will follow to make their decisions in 2024. The NWMO has completed initial geoscientific evaluations of the two siting areas through borehole drilling and other testing and issued Confidence in Safety reports for each of the two siting areas. The NWMO remains on track to select a siting area in 2024.

On 31 March 2023, Natural Resources Canada released the modernised Policy for Radioactive Waste and Decommissioning for Canada, which ensures the safe management of radioactive waste in Canada continues to align with international standards and best practices that reflect the values and principles of Canadians and Indigenous Peoples. The Policy includes measures that support an integrated strategy for Canada's radioactive waste and the importance of considering future generations when making decisions related to the management of radioactive waste and the decommissioning of nuclear energy and technology installations. It also highlights the importance of recognising Indigenous rights and knowledge, engaging early and continuously, building capacity, and working together in partnership on radioactive waste management and decommissioning projects. The federal government ensures that radioactive waste management and disposal is carried out in a safe, environmentally sound, comprehensive and integrated manner. To enable the achievement of this, the Government of Canada has established four priorities that form the basis of Canada's Policy for Radioactive Waste Management and Decommissioning:

1. Protection of health, safety, and security of people and the environment, and ensuring nuclear non-proliferation;
2. Inclusive engagement, openness, and transparency on radioactive waste management and decommissioning matters;
3. Recognition of Canada's deep commitment to building partnerships and advancing reconciliation with Indigenous Peoples related to the management of radioactive waste and decommissioning, based on the recognition of rights, respect, collaboration and partnership; and
4. Global excellence in the fields of radioactive waste management and decommissioning.

This Policy builds on the views and perspectives heard from a variety of interested groups and individuals, including Indigenous peoples, interested Canadians, experts, waste producers and owners, and other levels of government. It significantly expands upon the 1996 Radioactive Waste Policy Framework and sets a strong foundation for the management and oversight of radioactive waste and decommissioning now and into the future.

The Nuclear Liability and Compensation Act (NLCA), which entered into force on 1 January 2017, replacing the Nuclear Liability Act of 1976, strengthened Canada's nuclear liability regime. It establishes the compensation and civil liability regime to address damages in the extremely unlikely event of a nuclear incident at a Canadian nuclear installation. It also enabled Canada's accession to, and implementation of, the IAEA Convention on Supplementary Compensation for Nuclear Damage. By being a member of the Convention, Canada commits to harmonising its nuclear liability principles with those of other member countries and provides compensation for civil damages in other member countries resulting from a nuclear accident in Canada. Reciprocally, another member country would provide compensation for civil damages resulting from a nuclear accident in that country. The Convention also provides for the establishment of a pool of funds that would be available in the event of an accident, should it be required, to compensate for damage in countries that are members of the Convention.

The NLCA embodies the principles of absolute and exclusive liability of the operator, mandatory insurance, and limitations on the operator's liability in both time and amount. Under the NLCA, the operator of a nuclear power plant is responsible for paying up to CAD 1 billion for civil damages resulting from an accident at that installation. The Act also established that the existing CAD 1 billion liability limit for nuclear installations must be reassessed at least once every five years and based on the assessment, the Government of Canada may increase the amount by regulation. The first review of the NLCA liability limit was undertaken in 2021, and following its conclusion, the government initiated an analysis to ensure financial security requirements for low-risk installations are proportional to the risks they pose. This will ensure Canada is prepared for the eventual deployment of SMRs and Canada's deep geological repository.

Uranium stocks

The Canadian government does not maintain any stocks of natural uranium and data for producers and utilities are not available. Since Canada has no enrichment or reprocessing facilities, there are no stocks of enriched or reprocessed material in Canada. Although Canadian reactors use natural uranium fuel, small amounts of enriched uranium are used for experimental purposes and in booster rods in certain CANDU reactors.

Uranium prices

In 2002, Natural Resources Canada suspended the publication of the average price of deliveries under export contracts for uranium.

Uranium exploration and development expenditures and drilling effort – domestic

(CAD millions)

	2020	2021	2022	2023 (p)
Industry* exploration expenditures	68	122	238	300
Industry* development expenditures	86	81	91	97
Total expenditures	154	203	329	397
Industry* exploration drilling (m)	109 232	156 615	200 127	281 583
Industry* exploration holes drilled	NA	NA	NA	NA
Industry* development drilling (m)	39 821	43 506	64 230	34 855
Industry* development holes drilled	NA	NA	NA	NA
Subtotal exploration drilling (m)	109 232	155 615	200 127	281 583
Subtotal exploration holes drilled	NA	NA	NA	NA
Subtotal development drilling (m)	39 821	43 506	64 230	34 855
Subtotal development holes drilled	NA	NA	NA	NA
Total drilling (m)	149 053	199 121	264 357	316 438
Total number of holes drilled	NA	NA	NA	NA

* Non-government.

Conventional reasonably assured resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	251 450	442 503	573 951	87*
Open-pit mining (OP)	0	260	18 980	62 214	87*
In situ leaching acid	0	26 487	31 213	31 213	87*
Total	0	278 197	492 696	667 378	87*

* Mining losses (~10%) and ore processing losses (~3%) were used to calculate recoverable resources if recovery factors were not provided by companies.

Conventional reasonably assured resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional from UG	0	251 450	442 503	573 951
Conventional from OP	0	260	18 980	62 214
In situ leaching acid	0	26 487	31 213	31 213
Total	0	278 197	492 696	667 378

Conventional reasonably assured resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Proterozoic unconformity	0	278 197	488 049	632 748
Sandstone	0	0	4 647	4 647
Metasomatite	0	0	0	29 983
Total	0	278 197	492 696	667 378

Conventional inferred resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	9 330	79 312	155 294	87*
Open-pit mining (OP)	0	0	9 560	29 085	87*
In situ leaching acid	0	415	415	415	87*
Total	0	9 745	89 287	184 794	

* Mining losses (~10%) and ore processing losses (~3%) were used to calculate recoverable resources if recovery factors were not provided by companies.

Conventional inferred resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional from UG	0	9 330	79 312	155 294
Conventional from OP	0	-	9 560	29 085
In situ leaching acid	0	415	415	415
Total	0	9 745	89 287	184 794

* Also known as stope leaching or block leaching.

** A subset of open-pit and underground mining, since it is used in conjunction with them.

Conventional inferred resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Proterozoic unconformity	0	9 745	86 447	158 047
Sandstone	0	0	2 840	18 828
Metasomatite	0	0	0	7 919
Total	0	9 745	89 287	184 794

Conventional prognosticated resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
50 000	150 000	150 000

Conventional speculative resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
700 000	700 000	0

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023
Open-pit mining*	119 566	0	0	119 566	0
Underground mining*	423 181	4 747	7 380	435 308	10 986
Total	542 747	4 747	7 380	554 874	10 986

* Pre-2020 totals include ~1 000 tU recovered by in-place leaching. 2014-2017 underground mining totals include 61 tU recovered at the Key Lake mill from recycling uranium refinery wastes.

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023
Conventional	541 747	4 747	7 380	553 874	10 986
In-place leaching*	1 000	0	0	1 000	0
Total	542 747	4 747	7 380	554 874	10 986

* Also known as stope leaching or block leaching.

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023
Proterozoic unconformity	366 840	4 747	7 380	378 967	10 986
Paleo-quartz-pebble conglomerate	144 182	0	0	144 182	0
Granite-related	7 539	0	0	7 539	0
Intrusive	5 636	0	0	5 636	0
Metasomatite	18 489	0	0	18 489	0
Other/unspecified*	61	0	0	61	0
Total	542 747	4 747	7 380	554 874	10 986

* Uranium recovered at Key Lake mill from recycling uranium refinery wastes.

Ownership of uranium production in 2022

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
0	0	4 093	55	2 939	40	347	5	7 380	100

Uranium industry employment at existing production centres

(person-years)

	2020	2021	2022	2023 (expected)
Total employment related to existing production centres	1 934	1 842	2 381	N/A
Employment directly related to uranium production	746	1 787	1 930	N/A

Mid-term production projection (tonnes U/year)

2023	2024	2025	2030	2035
10 986	13 000	15 000	15 000	15 000

2040	2045	2050
13 000	13 000	15 000

Mid-term production capability

(tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
12 330	18 850	12 330	18 850	12 330	22 000	15 000	30 000
2035				**2040**			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
12 330	18 850	15 000	30 000	12 330	18 850	15 000	30 000
2045				**2050**			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
12 330	18 850	15 000	30 000	12 330	18 850	15 000	30 000

Net nuclear electricity generation

	2021	2022
Nuclear electricity generated (TWh net)	95.5	92.7

Installed nuclear generating capacity to 2050

(MWe net)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
12 700	11 900	8 500	8 500	10 200	10 200	11 100	11 100						

Annual reactor-related uranium requirements to 2050 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
1 770	1 715	1 160	1 210	1 395	1 430	1 525	1 650	1 525	1 630				

* Uranium requirements calculated assuming 18.5 tU per TWh (net) electrical generation.

Total uranium stocks

(tonnes natural U-equivalent)

Holder	Natural uranium stocks in concentrates	Enriched uranium stocks	Enrichment tails	LWR reprocessed uranium stocks	Total
Government	0	0	0	0	0
Producer	NA	0	0	0	NA
Utility	NA	0	0	0	NA
Total	NA	0	0	0	NA

Central African Republic*

Uranium exploration and mine development

Historical review

France's Alternative Energies and Atomic Energy Commission (CEA) was the first organisation to prospect for uranium in the Central African Republic. Initial reconnaissance work commenced in 1947 and exploration of the extensive zones of crystalline formations which border the west and occupy the centre of the country was conducted without success. In 1956, prospecting using improved techniques and benefiting from improved knowledge of uranium metallogeny was extended to the detrital siliceous series of the Middle Precambrian-Upper Precambrian (Nbafkl and Fouroumbala Series). A major radiometric anomaly was discovered in the N'zako laterites, but importantly, a significant geological similarity was noted between the Fouroumbala Series and Franceville in Gabon, where a uranium deposit had been discovered. Encouraged by this similarity, the CEA intensified its exploration in 1959 with a systematic programme of aerial prospecting, covering the entire eastern region of the country, an area of around 50 000 km². This work led to the discovery in 1961 of the country's first uranium deposit near the town of Bakouma, where three deposits were discovered. Geologically, the host is a uranium-bearing phosphatic formation of the Eocene age. The notable feature is the exceptionally high uranium content for a formation of this type. In 1963, the CEA and the Compagnie Française des Minéraux d'Uranium (CFMU) formed a syndicate to continue exploration and to study the feasibility of mining the deposit. A jointly owned mining company, the Bakouma Uranium Mining Company (URBA), was set up in 1969 between the state and the CEA and CFMU partnership. However, the result of the feasibility study on the mining of the deposit was unfavourable, as the phosphatic nature of the ore made it difficult to develop a suitable processing method, and activities by URBA ceased in 1971.

After the oil crisis in the winter of 1973-1974, numerous foreign companies showed interest in the Bakouma deposit, and Aluminium Suisse S.A. of Zurich resumed studies on the mining of the deposit. In February 1975, a new mining company (URCA, Central African Uranium Company) was set up between Aluminium Suisse and the three original partners of URBA. Prospecting conducted by the Atomic Energy Commission, URBA, and URCA used the following methods: (a) geological investigation and cartography; (b) airborne radiometric surveys; (c) ground radiometric surveys; (d) ground verification of selected anomalous zones; (e) drilling of boreholes at different spacing intervals; (f) geochemical analysis of soil, water and alluvial sediments. However, subsequent technical, metallurgical, and economic studies indicated that the deposits were not economically viable at the then-prevailing price of uranium, and in 1978 the project was terminated.

In May 2006, UraMin Inc. was granted one mining permit and two research permits for the exploration of uranium mineralisation in the Bakouma region. Reverse circulation percussion drilling commenced at the Patricia deposit in August 2006 to confirm the presence of uranium mineralisation and to increase the known resource. Initial drilling of 66 holes on a 100 m × 50 m grid spacing delineated the extent of the Patricia deposit. Data from these holes were used as the basis for the resource estimate. Reverse circulation infill drilling on a 50 m × 50 m grid spacing commenced and a diamond drilling campaign to acquire additional geological and geotechnical information was also planned. Further reverse circulation and diamond drilling were planned at the other deposits that comprise the Bakouma project.

* Report prepared by the NEA/IAEA, based on previous Red Books and company reports.

On 30 July 2007, UraMin Inc., the owner of Bakouma and other African uranium deposits, was acquired by Areva (now Orano) for USD 2.5 billion. This transaction gave Areva a 90% interest in the project, with a 10% carried interest retained by the state. The start-up of the Bakouma pilot project was planned for 2010. In June 2012, gunmen attacked the Bakouma project site and since then all activities have been suspended.

Recent and ongoing uranium exploration and mine development activities

There has been no recent exploration and mining development for uranium in the Central African Republic.

Uranium resources

The uranium mineralisation of the Bakouma Basin is associated with phosphate lenses intercalated with silts and siliceous horizons. It is these lenses that have the highest concentrations of uranium mineralisation, and they are grouped into several deposits: Palmyre, Pama, Pamela, Pâquerette, Patou and Patricia, which make up the greater Bakouma deposit.

Identified conventional resources

In its 2022 annual report, Orano reports inferred in situ resources amounting to 36 475 tU at an average grade of 0.20% U (resource evaluation completed in 2020)

In previous Red Book editions, the Central African Republic reported 42 200 tU as RAR in situ resources, in the <USD 260 cost category.

Unconventional resources

The Central African Republic does not report unconventional resources. While the Bakouma uranium deposit is associated with phosphates, it is classified as a conventional deposit because of the relatively high (0.15-0.30% U) uranium grade.

Uranium production

The start-up of the Bakouma pilot project was planned for 2010. It aimed to start open-pit mining at 1 200 tU/yr. At full capacity, the mine would have produced 2 000 tU per year. The Areva group suspended the uranium mining project at the end of 2011 for one to two years due to low uranium prices and the need for further research on the metallurgy. In June 2012, gunmen attacked the Bakouma uranium mine project site, and since then all activities have been suspended.

Inferred conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open pit	0	0	0	36 475	NA
Total	0	0	0	36 475	NA

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Phosphate	0	0	0	36 475
Total	0	0	0	36 475

Chile*

Uranium exploration and mine development

Historical review

Uranium exploration was initiated in the 1950s with a review of uranium potential in mining districts with Cu, Co, Mo, Ag mineralisation conducted by the US Atomic Energy Commission. Following a delay of about ten years, activities were renewed in 1970 by the Spanish Nuclear Energy Organisation, focusing for four years on Region IV of the Tambillos mining district.

Between 1976 and 1990, regional prospecting encompassing an area of 150 000 km^2 was conducted in co-operation with the IAEA using geochemical drainage surveys, aerial radiometry, and ground-based geology and radiometry. This work led to the detection of 1 800 aerial anomalies, 2 000 geochemical and radiometric anomalies, and the definition of 120 sectors of interest. Subsequent investigation of 84 of these sectors of interest led to the identification of 80 uranium occurrences, prompting further study of the 12 most promising prospects, preliminary exploration of these prospects, and eventually the evaluation of uranium resources as a by-product of copper and phosphate mining.

From 1980 to 1984, Cía Minera Pudahuel (the Pudahuel Mining Company), in co-operation with the Chilean Nuclear Energy Commission (CCHEN), conducted drilling of the Sagasca Cu-U deposit, Region I (Tarapacá), leading to a technical and economic evaluation of the Huinquintipa copper deposit, Region I. The Production Development Corporation (Corporación de Fomento de la Producción – CORFO) and CCHEN conducted exploration and a technical economic evaluation of the Bahía Inglesa phosphorite deposit, Region III (Atacama) in 1986 and 1987.

Between 1990 and 1996, CCHEN undertook geological and metallogenic uranium research, mainly in the north of the country. From 1996 to 1999, CCHEN and the National Mining Company of Chile (ENAMI) investigated REE in relation to radioactive minerals in the Atacama and Coquimbo regions. Dozens of primary occurrences were studied, with the "Diego de Almagro" Anomaly-2 chosen as a priority. The study of this 180 km^2 sector found disseminations and veins of davidite, ilmenite, magnetite, sphene, rutile and anatase, with 3.5 to 4.0 kg/t of REE oxides (REO), 0.3 to 0.4 kg/t of U and 20 to 80 kg/t of Ti. The geological resources of the ore contained in this prospect were estimated at 12 000 000 t. The metallurgical recovery of REO from these minerals was also investigated with a purpose of investigating mining resources with economic potential in the medium term.

In 1998 and 1999, CCHEN created the National Uranium Potential Evaluation Project, encompassing the activities of uranium metallogeny research and development of a geological database. The aim of this project was to set up a portfolio of research projects to improve the evaluation of national uranium ore potential. Between 2000 and 2002, a preliminary geological evaluation for uranium and REO of the Cerro Carmen prospect (2000-2002), located in Region III (Atacama), was completed as part of the specific co-operation agreement between CCHEN and ENAMI. Geophysical exploration work was undertaken (magnetometry, resistivity and chargeability), defining targets with metallic sulphur minerals with uranium and associated REE.

* Report prepared by the NEA/IAEA, based on previous Red Books, government data and company reports.

In 2001, a project portfolio document was developed that updated the metallogeny and geological favourability for uranium in Chile. A total of 166 research projects were proposed, ranging from regional activities to detailed scientific studies, to be undertaken sequentially in accordance with CCHEN capacities. In the extractive metallurgy area, work has been ongoing since 1996, through a co-operation agreement between CCHEN and ENAMI, to develop processes to produce commercial concentrates of rare earths. High purity concentrates of light REE as well as yttrium have been obtained.

In 2003, regional reconnaissance was undertaken for uranium and REE in Region I of the country, after which the CCHEN-ENAMI co-operation agreement was terminated. Through 2004, database work was continued by CCHEN, and commercial services were provided to the mining industry through 2010.

From 2008 to 2012, CCHEN completed a broad scope co-operation agreement with the National Copper Corporation (CODELCO Norte) for geological and metallurgical investigation of natural radioactive material occurrences. From 2009 to 2012, CCHEN and CODELCO Norte completed an agreement on activities to investigate recovery of uranium and molybdenum from copper ore leaching solutions.

Recent and ongoing uranium exploration and mine development activities

No uranium exploration and mine development activities have been carried out in recent years.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

No new uranium resources have been identified since the 2011 edition of the Red Book. Recoverable identified resources (RAR + IR) total 1 448 tU in the <USD 260 kg/U cost category.

Undiscovered conventional resources (prognosticated and speculative resources)

Prognosticated and speculative in situ conventional resources remain at 2 324 tU (<USD 260/kgU) and 2 360 tU (unassigned cost category), respectively. Undiscovered conventional resources account for a total of 4 684 tU.

Unconventional resources and other materials

Identified unconventional recoverable resources account for 1 169 tU (<USD 260/kgU), while undiscovered unconventional resources total 5 458 tU in situ. New unconventional resources have not been reported.

Identified conventional resources (reasonably assured and inferred resources)

(in situ tonnes U)

Deposit	Type	RAR	IR	Grade % U_3O_8	Rocks, hosting age
Cenozoic surficial deposits[1]	Surficial	28	40	0.023	Diatomite, volcanic ash with organic material (Pliocene – Pleistocene)
Cretaceous metasomatic[2]	Metasomatic	720	1 043	0.028-0.20	Intrusive, volcanic and metasomatic rocks (upper Cretaceous)
Cenozoic volcanic-related[3]	Volcanic-related	0	100	0.01-0.18	Magnetite and haematite tuffs. Secondary U-REE mineralisation (Oligocene Pleistocene)
Total		748	1 183		

Surface deposits:

1. Salar Grande (28 tU), Mina Neverman (?), Boca Negra (3 tU), Manuel Jesús (2.5 tU), Mina Casualidad (?), Mina San Agustín (?), Quebrada Vítor (?), Pampa Chaca (2 tU), Pampa Camarones (3.5 tU), Quebrada Amarga (2 tU), Quillagua (22 tU), Prosperidad (?), Chiu Chiu (5 tU).

Metasomatic deposits:

2. Estación Romero 326 tU (Carmen and Productora prospects), Cerro Carmen prospect (1 391.8 tU), Agua del Sol (15 tU), Sector Pejerreyes – Los Mantos (20 tU), Tambillos district (10 tU). The following estimates were produced at the prospect of the Diego de Almagro Anomaly-2 (Cerro Carmen prospect) in 1999-2000, as a result of detailed geological and radiometry work, together with magnetometry, excavation and sampling of exploration trenches, undertaken as part of the activities of the co-operation agreement between ENAMI and CCHEN: Calculations indicate that the deposit hosts a total of 595.3 tU as indicated resources, 796.5 tU as inferred resources, making a total in situ of 1 391.8 tU as identified resources (RAR + inferred). The cost of extracting these resources was not estimated, therefore not included in the identified resources tables.

Volcanogenic deposits:

3. In the El Laco iron ore deposit, produced during Cenozoic volcanism on the "altiplano" of Region II (Antofagasta), a total of 100 tU (in situ) was identified as inferred.

Uranium resources by deposit type

(in situ tonnes U)

Deposits, areas and other resources	RAR + IR	PR + SR	SR*
Surficial deposits	68.0	123.5	
Metasomatic deposits	1 762.8	4 060.0	
Volcanic-related deposits	100.0	500.0	
Unconventional deposits and resources	1 798.0	5 458.0	1 000
Deposit areas:			
1 – Surface deposits, Cenozoic	--	--	500
2 – Metasomatic deposits, Cretaceous	--	--	500
3 – Magmatic deposits, Cenozoic			250
4 – Polymetallic deposits, Cretaceous	--	--	100
Favourable areas:			
A – Acid volcanism, Tertiary	--	--	500
B – Intrusives, Jurassic-Cretaceous	--	--	500
C – Volcanic acid-sedimentary, Cretaceous	--	--	200
D – Main Cordillera, Palaeozoic magmatism	--	--	50
E – Sedimentary-volcanic, Middle Cretaceous	--	--	100
F – Nahuelbuta, Palaeozoic plutonism	--	--	300
G – Clastic sedimentary, Cretaceous-Tertiary	--	--	300
Total	3 728.8	10 141.5	4 300

* Undiscovered resources are expected to exist remotely from the known occurrences, either in the aforementioned uranium deposit areas or in favourable areas. In the case of unconventional resources, the figures correspond to uranium that could be recovered from the copper leaching plant solutions of the country's medium and large-scale mining activities. The latter could be several orders of magnitude greater, considering that large-scale national mining, both state-owned and private, produces large reserves of minerals in projects lasting up to 20 years. CCHEN has not updated its studies on this subject.

Surficial deposits

(in situ tonnes U)

Surface deposits	RAR	IR	PR	SR	% U_3O_8	Minerals
Boca Negra		3.0			0.02-0.600	Silica, yellow minerals
Manuel Jesús		2.5			0.10-0.190	Silica, yellow minerals
Casualidad					0.018	Silica, yellow minerals
San Agustín					0.20-0.250	Silica, yellow minerals
Poconchile					0.028	Silica, yellow minerals
Quebrada Vítor					0.028	Autunite
Pampa Chaca		2.0			0.028	Autunite
Pampa Camarones		3.5	3.5		0.030	Autunite, shronquingierite
Salar Grande	28.0		100.0		0.023	Carnotite
Quebrada Amarga		2.0			0.117	Carnotite
Quillagua		22.0			0.165	Carnotite
Chiu Chiu		5.0	5.0	15.0	0.04-0.140	Yellow minerals
Total	28.0	40.0	108.5	15.0		

Metasomatic deposits

(in situ tonnes U)

Metasomatic and hydrothermal deposits	RAR	IR	PR	SR	% U_3O_8	Minerals
Anomaly-2, Diego de Almagro (Cerro Carmen prospect)	595.3	796.5	1 400.0	1 500.0	0.03-0.10	Davidite, sphene, Ilmenite, anatase
Agua del Sol	15.0			50.0	0.02-0.06	Davidite
Sierra Indiana			15.0	15.0	0.02-0.08	Davidite
Estación Romero						
Carmen	20.0	10.0		50.0	0.01-0.12	Davidite
Producer	60.0	236.0	300.0	500.0	0.01-0.28	Autunite, torbernite
Tambillos	10.0			100.0	0.01-0.20	Uraninite, pitchblende
Pejerreyes – Los Mantos	20.0			130.0	0.01-0.05	Davidite, aut., torbernite
Total	720.3	1 042.5	1 715.0	2 345.0		

Volcanic-related deposits

(in situ tonnes U)

Volcanogenic deposits	RAR	IR	PR	SR	% U_3O_8	Minerals
Acid and intermediate volcanism, Regions I to III						Not investigated
El Laco sector, Region II		100	500			Aut., torbernite, REE
El Perro sector, Region III						Not investigated
Total		100	500			

Unconventional resources and other materials*

(in situ tonnes U)

Mines, prospects, materials	RAR	IR	PR	SR	% U_3O_8	Minerals
Copper-uranium paleochannels						
Sagasca – Cascada[1]	164				0.0046	Crisocola, U
Huinquintipa[2]	46				0.0030	Crisocola, U
Chuquicamata Sur[3]	950				0.0007	Crisocola, U
Quebrada Ichuno[4]				25	0.0060	Crisocola, U
El Tesoro[5]				50	0.0070	Crisocola, U
North Chuquicamata (oxides zone)[6]				1 000	0.0008	Oxides Cu, U
Gravel from Chuquicamata oxides plant[7]				2 000	0.0008	Oxides Cu, U
Seams of high-temperature copper						
Algarrobo – El Roble[8]			513		0.0400	Sulph., Cu, U
Carrizal Alto[8]				500	0.0250	Sulph., Cu, U
Tourmaline breccias[8]						
Campanani[8]						
Sierra Gorda[8]				60	0.0020	Sulph., Cu, U
Los Azules[8]			5			
Cabeza de Vaca[8]				5		
Uranium-bearing phosphorites						
Mejillones			1 300		0.0026	Colophane – U
Bahía Inglesa[9]	638				0.0062	Colophane – U
Total	1 798		1 818	3 640		

* Note: The figures shown in this table represent historical data and are not current. Studies need to be done to validate or eliminate these figures.

1. The Sagasca deposit is exhausted and the Cascada deposit (continuation of the mineralised body) is practically exhausted; however, new explorations in the area have found new mineralised bodies, so the figure could vary substantially.
2. Huinquintipa currently forms part of the Collahuasi Project, a contractual mining company belonging to Anglo American Plc and Xstrata Copper, a division of the Swiss mining company Xstrata Plc, each of which has a 44% stake. The remaining 12% belongs to JCR, a consortium of Japanese companies led by Mitsui & Co., Ltd. The oxidised mineral reserves amount to 53 million tonnes, for which copper extraction and production began in 2000 and will last for 20 years. The figures shown in the foregoing table could rise by a factor of between 10 and 20.
3. Chuqui Sur: Although this deposit is not exhausted, the surcharge makes it expensive to operate, so the uranium resources contributed to the Chuquicamata Division oxides plant could be zero. Accordingly, the figures indicated above could decrease significantly.
4. Quebrada Ichuno has not been studied and there are only preliminary works, so the figure mentioned above is maintained.
5. The uranium resources assigned to the El Tesoro mine correspond to preliminary geological reconnaissance data obtained in 1983. This deposit is currently a nationally important mining centre, 70% owned by Antofagasta Minerals S.A., which belongs to Antofagasta Plc, and 30% owned by the Marubeni Corporation of Japan. Its mineral reserves amount to 186 million tonnes, with a useful life of 21 years. Preliminary samples suggest uranium contents of between 5 and 200 ppm, with an average of between 15 and 20 ppm. Investigating this uranium source could change the figure indicated above substantially.
6. The "Chuquicamata Norte" prospect currently corresponds to the Radomiro Tomic mining centre, with reserves of 970 million tonnes of minerals that could be leached from copper and a useful life of 22 years. A programme of activities is currently being developed to recover uranium and molybdenum.
7. Estimations performed in the 1970s assigned a potential of 1 000 tU that could be recovered from copper leaching solutions obtained from the gravels of the old oxides plant of the Chuquicamata copper mine. This project began its activities in 1998 and will be active for 12 years. By the end of the period it will produce 467 000 t of fine copper. Recovery of uranium from these leaching solutions has not been researched.

   In addition to the uranium resources present in the leaching solutions from the aforementioned mines, there are other large copper deposits in the large-scale mining sector, whose leaching solutions have not been researched. An example is El Abra. This deposit, owned by Phelps Dodge Mining Co (51%) and CODELCO Chile (49%), started production of 800 million tonnes of is copper minerals for a 17-year period.
8. These figures have historical value only and as geological background data. The low copper content of these districts and the small volume of their reserves makes it difficult to recover their uranium content.
9. No experiments have been done to recover uranium from the uranium content in marine phosphorites. The only deposit currently being exploited is Bahía Inglesa, in Region III (Atacama), which produces a solid phosphate concentrate of direct use as fertiliser. In 2001, Compañía Minera de Fosfatos Naturales Ltda., (BIFOX LTDA.), which operates the aforementioned mine, began producing phosphoric acid, which would make it possible to recover uranium from the mother solutions.

Unconventional resources and other materials

(in situ tonnes U)

Deposit	RAR	IR	PR	SR	% U	Mineral
Unconventional	1 798	0	1 818	3 640	0.0008-0.1	Leaching solution 7 to 15 g/m^3 Oxide plants gravel Cu silicate and oxides, 20-70 ppm Sulphur oxide veins of 500-1 000 ppm
Total	1 798	0	1 818	3 640		

Speculative resources in uranium geological favourable areas

Growing knowledge of the distribution of uranium mineralisation in Chile has made it possible to define four areas of uranium occurrence and seven favourable areas, five of which have occurrences of uranium, collectively accounting for potential resources of 3 300 tU.

Areas of uranium occurrences, accounting for ~1 350 tU:

1. Upper Cenozoic surface deposits – potential in SR: 500 tU.
2. Upper Cretaceous metasomatic deposits – potential in SR: 500 tU.
3. Upper Cenozoic magmatic and hydrothermal deposits – potential in SR: 250 tU.
4. Upper Cretaceous polymetallic and uranium deposits – potential in SR: 100 tU.
5. Tertiary volcanogenic deposits – potential not investigated.

Areas favourable for uranium occurrences, accounting for 1 950 tU (only minimum potential is indicated owing to a lack of research):

A. Acid volcanism and tertiary-quaternary alluvial deposits, Main Cordillera, Regions I and II – potential: 500 tU.

B. Intrusive Jurassic and Cretaceous rocks, Coastal Range, Regions I and II – potential: 500 tU.

C. Acid volcanism and upper Cretaceous clastic sedimentary rocks; Central Valley, Regions II and III – potential: 200 tU.

D. Paleozoic magmatism, Main Cordillera, Region IV – potential: 50 tU.

E. Sedimentary-volcanic rocks of the Middle Cretaceous period, neogenic intrusives, Main Cordillera, Regions VI, VII and Metropolitan Region – potential: 100 tU.

F. Nahuelbuta Range, Paleozoic plutonism, Regions VIII and IX – potential: 300 tU.

G. Acid and intermediate sedimentary clastic volcanism, Tertiary, Main Cordillera, Regions VII, VIII and IX – potential: 300 tU.

Undiscovered conventional resources (prognosticated and speculative resources)

Deposit	Type	Prognosticated tonnes U	Speculative tonnes U	Grade % U	Rocks hosting age
Diatomite, volcanic ash with organic material[1]	Surficial	108.5	15.0		Pliocene – Pleistocene
Intrusive, volcanic and metasomatic rocks[2]	Metasomatic	1 715	2 345	0.025-0.17	Upper Cretaceous
Tuffs with high magnetite and haematite content. Mineralisation of secondary REE minerals observed[3]	Volcanic-related	500	0*	0.085-0.15	Oligocene – Pleistocene
Total		2 323.5	2 360*		

* 2 360 tU represents the speculative resources as tabulated and summed across the Surficial deposits, Metasomatic deposits and Volcanic-related deposits tables. However, it does not take into account an additional 940 tU of speculative resources (for a total of 3 300 tU) indicated elsewhere in the report (see section "Speculative resources in uranium geological favourable areas" and table "Uranium resources by deposit type").

1. Salar Grande (100 tU), Pampa Camarones (3.5 tU), Chiu Chiu (20 tU).

   No new uranium prospecting has been done in the area of Cenozoic surface deposits.

2. Diego de Almagro Anomaly-2 (1 400 tU); Diego de Almagro Alignment (1 500 tU); Agua del Sol (50 tU), Sierra Indiana (30 tU), Sector Estación Romero: Carmen prospect (50 tU) and Productora Prospect (800 tU), Tambillos district (100 tU), Sector Pejerreyes – Los Mantos (130 tU).

   In 1999-2000, at the Diego de Almagro Anomaly-2 (Cerro Carmen prospect), 1 400 tU was assigned as prognosticated and speculative undiscovered resources. The regional alignment that controls the mineralisation of this prospect extends 60 km to the north-west. This structure, visible in satellite images, involves other mining districts for which a potential of 1 500 tU of speculative resources is assigned.

3. In 1999-2000, data held by CCHEN was reviewed as part of the National Uranium Potential Evaluation Project. It was concluded that the acidic and intermediate volcanism present in a broad area of the Main Cordillera stretching from Regions I to III constituted an inclined plane dipping towards the west, ending in a lagoon environment situated in a central depression, with a similar condition occurring to the east. This volcanism covered the pre-volcanic landscape, preserving the surface drainage courses (now paleochannels). The leaching of these volcanic rocks contributed large amounts of uranium into the lagoon systems, paleochannels and other structures in which solutions circulate. This process is represented by extensive layers of calcilutites, diatomites (Pampa Camarones), layers of salt (Salar Grande), argillites, limestones, limolites and volcanic ash (Quillagua, Prosperidad, Quebrada Amarga, Chiu Chiu), with uranium contents ranging between 100 and 1 000 ppm. These uranium occurrences and mineralisations have been classified historically as "surface deposits". There are also paleochannels with copper and associated uranium (the Sagasca, Cascada, Huinquintipa, Quebrada Ichuno, Chuqui Sur, El Tesoro deposits and others). Within the volcanic area, uranium mineralisation (torbernite and autunite) has been discovered in volcanic structures containing iron (El Laco and El Perro). This environment is considered to have great potential and requires further research. In structures associated with the U mineralisation indicated above, 500 tU is assigned as EAR-II (now prognosticated).

Uranium production

Historical review

The uranium present in copper oxide ores could be recovered from the leaching solutions. A pilot-level trial was conducted in the Chuquicamata Division between 1976 and 1979, obtaining 0.5 t of yellow cake from copper-rich solutions containing 10 to 15 ppm U (0.001 to 0.0015% U), which was sent for purification at the CCHEN metallurgy pilot plant at the Lo Aguirre nuclear centre. The production of copper oxide minerals has quadrupled in Chile over the last decade.

The copper mining industry, particularly large-scale mining, has strategic (sub-economic) uranium potential in the large volumes of copper oxide leaching solutions. These resources are assigned a potential of 1 000 tU in mining centres not included in the previous table. However, no background studies have been performed to confirm these figures, either as mining resources or in terms of the volumes of solutions treated annually, so the information should be treated as unverified. Over the last decade, private firms, both domestic and foreign, have explored 12 "exotic copper" deposits in Chile, which correspond to paleochannels filled with gravel, mineralised with copper silicates, oxides and sulphates as a result of the natural leaching of porphyry copper deposits or other contribution areas. These mineralised bodies contain variable uranium contents ranging between 7 to 116 ppm (0.007 to 0.016% U). The leaching solutions in the plants that treat these copper oxide minerals display uranium levels of up to 10 ppm. This uranium content is technically recoverable using ion-exchange resins, at a likely production cost of over USD 80/kgU.

There has been no experience in recovering uranium from phosphorites in Chile. The only deposit currently being worked is Bahía Inglesa in Region III (Atacama), which produces a solid phosphate concentrate used directly as fertiliser. In 2001, Compañía Minera de Fosfatos Naturales Ltda. (Bifox Ltda.) began producing phosphoric acid from this deposit, opening the potential of recovering uranium from the acid.

Status of production capability and recent and ongoing activities

Other than the trial production mentioned above, no uranium has been produced in Chile.

Environmental activities and socio-cultural issues

The CCHEN runs a permanent programme to disseminate information on peaceful uses of nuclear energy, attached to the Office of Dissemination and Public Relations (Oficina de Difusión y Relaciones Públicas).

Regulatory regime

In Chile, there is no regulatory framework for the uranium production cycle activities.

Uranium requirements

Chile has achieved significant technological development in the manufacture of MTR-type (materials test reactor) combustible elements, based on U_3Si_2 (uranium silicide). In March 1998, the manufacture of 47 combustible elements began at the CCHEN combustible elements plant, ending in 2004. For this work, 60 kg of metallic uranium was purchased from Russia, enriched to 19.75% in ^{235}U, covering uranium requirements up to the indicated date. At the present time, 47 combustible elements have been manufactured, 16 of which are operating in the RECH-1 reactor, and another was sent to the Petten Research Centre in the Netherlands, to be classified under radiation in the high-flow reactor, which ended in November 2004.

Supply and procurement strategy

Should other loads of combustible elements be required, consideration will be given to purchasing enriched metallic uranium.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

There have been no changes in legislation relating to uranium in Chile.

Uranium stocks

There are no uranium stocks.

Reasonably assured conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	0	561	75
Total	0	0	0	561	75

Reasonably assured conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	0	561	75
Total	0	0	0	561	75

Reasonably assured conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Metasomatic	0	0	0	540
Surficial	0	0	0	21
Total	0	0	0	561

Inferred conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	0	887	75
Total	0	0	0	887	75

Inferred conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	0	887	75
Total	0	0	0	887	75

Inferred conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Volcanic-related	0	0	0	75
Metasomatic	0	0	0	782
Surficial	0	0	0	30
Total	0	0	0	887

Prognosticated conventional resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	0	2 324

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	0	2 360

Reasonably assured unconventional resources by mining method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	0	1 169	65
Total	0	0	0	1 169	65

Reasonably assured unconventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Co-product/by-product	0	0	0	1 169	65
Total	0	0	0	1 169	65

Reasonably assured unconventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Intrusive (porphyry copper)	0	0	0	754
Phosphate	0	0	0	415
Total	0	0	0	1 169

Prognosticated unconventional resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	0	1 818

Speculative unconventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	0	3 640

China (People's Republic of)

Uranium exploration and mine development

Historical review

Uranium exploration and mining in China started in the mid-1950s, mainly conducted by the Bureau of Geology (BOG), and the China Nuclear Uranium Corporation (CNUC), subsidiaries of the China National Nuclear Corporation (CNNC). Before the 1990s, uranium exploration focused on granite-related or volcanic-related deposits in Jiangxi, Hunan, Guangdong, and Guangxi in South China, resulting in the identification of deposits such as Xiangshan, Xiazhuang, Zhuguang, Ujing and Miaoershan. Except for a few large deposits, most are relatively small and typically mid- to low-grade and their mining costs are high.

At the beginning of the 1990s, when China initiated its nuclear energy programme and began building nuclear power plants, the demand for natural uranium increased very little. Given that there was an oversupply of natural uranium in the international market during that period, China slowed its uranium exploration activities and drastically cut its uranium exploration expenditures. During this period uranium exploration shifted, with a focus on ISL amenable sandstone-type deposits in Meso-Cenozoic sedimentary basins in northern China, given better economic potential and reduced environmental impact.

In the late 1990s, as nuclear power plant construction accelerated, demand for uranium steadily increased. Since 2000, the year-over-year national expenditures for uranium exploration gradually increased, with a focus on increasing uranium reserves and expanding the uranium production capacity of China. Exploration was focused on the Yili, Turpan-Hami, Junggar, Erlian, Ordos and Songliao Basins. From 2000 to 2006, annual drilling gradually increased from 40 000 m to 250 000 m. Since 2007, exploration drilling increased to at least 500 000 m per year.

Since the 1990s, the China National Petroleum Corporation (CNPC) also invested in uranium exploration in Tongliao, Inner Mongolia. Beginning in 2008, the China General Nuclear Power Corporation (CGN) also carried out uranium exploration along the northern margin of the Tarim Basin, Xinjiang, and in northern Guangdong Province. In recent decades the China Geological Survey carried out a uranium investigation and evaluation in the Ordos, Erlian, Songliao, Junggar and Qadam Basins.

Recent and ongoing uranium exploration and mine development activities

Domestic uranium exploration investment remained steady between 2019 and 2022 with positive results. The exploration focused on sandstone-type uranium deposits in northern China resulting in resource expansion in the Ordos, Yili, Songliao and Erlian Basins. New uranium occurrences were discovered in the Songliao, Junggar, Ordos and Erlian Basins. Progress has also been made in the exploration of the deeper parts and periphery of the known uranium ore fields in southern China.

Uranium exploration in northern China was principally focused on medium to large continental sedimentary basins, including from west to east the Yili, Junggar, Turpan-Hami, Qadam, Yingen-Ergyna, Ordos, Erlian and Songliao Basins, where systematic uranium exploration has been conducted. Uranium exploration involved geologic surveys, air-borne geophysics, radiometric surveys and electromagnetic surveys, with a small amount of drilling to delineate prospects for further investigations. Drilling focused on measuring and expanding the uranium resources/reserves of ISL amenable sandstone-type deposits, as well as evaluating sandstone-type deposits with low permeability to be exploited by conventional mining.

The exploration work in southern China mainly focused on volcanic-related and granite-related uranium deposits in the Xiangshan uranium ore field in Jiangxi Province, the Xiazhuang and Zhuguang uranium ore fields in Guangdong Province, and the Miaoershan uranium ore field in Guangxi Autonomous Region.

The total drilling completed between 2021 and 2022 amounted to 1 660 000 m (about 620 000 m in 2021 and 1 040 000 m in 2022). It resulted in an increase of uranium resources in northern China basins, such as the Yili, Ordos, Erlian and Songliao Basins. In southern China, there was a moderate increase of uranium resources in the deeper parts and on the periphery of the Xiangshan, Miaoershan, southern Zhuguang and Xiazhuang uranium ore fields.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2023, the identified in situ uranium resources in China totalled 405 700 tU, including 190 270 tU RAR and 215 430 tU inferred. Compared to the previous report, there is a significant increase both in RAR resources by 35 800 tU and in inferred resources by 30 400 tU. Approximately 64% of all identified resources are amenable for ISL mining and 62% belong to the cost category of <USD 80/kgU. In this cost category, 93% of the resources are amenable to ISL mining and the rest are for conventional underground mining.

The following table shows the distribution of uranium resources over 22 uranium ore fields, basins and deposits in 13 provinces or autonomous regions as of 1 January 2023.

Distribution of identified uranium resources in China (as of 1 January 2023)

Province	Ore field/deposit	U resources in situ, tU
Jiangxi	Xiangshan	27 400
	Ganzhou	28 900
	Taoshan	8 000
Guangdong	Xiazhuang	11 900
	Southern Zhuguang	20 700
	Heyuan	2 300
Hunan	Xiangcaodawan	7 600
Guangxi	Ziyuan	9 900
Xinjiang	Yili	59 100
	Turpan-Hami	10 100
	Sawafuqi	1 300
Inner Mongolia	Ordos	98 700
	Erlian	61 900
	Tongliao	29 000
	Bayingebi	7 500
Hebei	Qinglong	6 700
Yunnan	Tengchong	4 300
Shaanxi	Lantian	1 200
Gansu	Longshoushan	1 650
Zhejiang	Dazhou	2 100
Liaoning	Benxi	350
Sichuan	Ruoergai	5 100
Total (in situ)		405 700

Undiscovered conventional resources (prognosticated and speculative resources)

China has conducted systematic domestic uranium resource prediction and evaluation with prognosticated resources estimated to be around 2 million tU. Favourable target areas for uranium mineralisation include the Erlian, Ordos, Songliao, Junggar, and Tarim sedimentary basins in northern China, and the deeper part and periphery of the known uranium deposits in southern China. With further investment of uranium exploration, additional uranium resources are expected to be discovered.

Unconventional resources and other materials

There are unconventional uranium resources associated with phosphate rocks in China, mainly distributed in Hunan, Guizhou and Sichuan Provinces. The grade is relatively low. Up to now, systematic assessment of unconventional uranium resources has not been conducted, nor was data available.

Uranium production

Historical review

The over 60-year history of China's natural uranium production includes both a boom in the first two decades and a decline from the late 1980s to the 1990s, with a large fluctuation of uranium production. In the early 2000s, there was a recovery and increase in uranium production of China, driven principally by China's nuclear power plant development and the increase in the international uranium spot price.

With the rapid development of China's nuclear power plant programme, demand for natural uranium for nuclear power plants was projected to increase year after year, and China responded by accelerating domestic uranium mining, with initial focus on existing uranium production centres, such as the Yining. Known uranium resources of operating mines supported stable and increased production. Secondly, the development of new uranium production centres based on uranium deposits with known resources and favourable technical/economic parameters, such as the Tongliao and Erlian production centres, was also accelerated. Thirdly, construction of new uranium production centres was promoted, and a series of pilot tests and feasibility studies were carried out at some recently discovered ISL sandstone-type uranium deposits with abundant resources, such as the sandstone-type uranium deposits in the Ordos Basin.

Status of production capability

Uranium production in China in 2021 and 2022 amounted to 1 540 tU and 1 550 tU, respectively. China is expected to produce 1 600 tU in 2023.

As a response to production cost challenges brought by the sustained low uranium price, Chinese uranium companies completed a reorganisation of the domestic industrial structure from 2019 to 2022. First, several conventional mining uranium production centres with depleted uranium resources or with high production costs were closed or mining was suspended. Second, ISL mining of sandstone uranium deposits in northern China was kept active, including further expansion of ISL production capacity in Xin Jiang and Inner Mongolia. Uranium production by ISL mining dominated in northern China and was supplemented by underground mining in southern China. The overall capacity of uranium production has remained steady after the reorganisation. Among the four previously operating underground uranium mining centres in China, the Shaoguan production centre is still in operation, the Lantian production centre was closed, and the Chongyi, Qinglong and Fuzhou production centres were put under care and maintenance. The capacity of the Yining and Tongliao ISL production centres has been expanded and the ISL production centre has been built in the Erlian Basin.

In detail:

- The Fuzhou production centre in Fuzhou City, Jiangxi Province is an underground mine, which mainly exploited Xiangshan volcanic-type uranium resources through conventional leaching and ion-exchange processing. The centre was put under care and maintenance due to high production costs.
- The Shaoguan production centre in Shaoguan City, Guangdong Province is an underground mine which exploited the Xiazhuang and Zhuguang granite-related type uranium resources using heap leaching and ion-exchange processing. Resources of the Xiazhuang deposit were depleted. Other deposits in Guangdong Province are in operation.
- The Chongyi production centre in Ganzhou City, Jiangxi Province exploited the Lujing and Taoshan granite-related type deposits by underground mining and heap leaching of mined ore. Production was suspended at this centre due to high production costs.
- The Lantian production centre in Lantian County, Shaanxi Province was an underground mine which mainly exploited Lantian granite-related type uranium deposits with an in-place blast leaching process. This uranium mine was closed due to depletion of resources.
- The Qinglong production centre in Qinglong County, Hebei Province is an underground mine which mainly exploited Qinglong volcanic-related type uranium resources with heap leaching and solvent extraction. This centre was suspended due to high production costs.
- The Yining ISL production centre, located in Yining City, Xinjiang Autonomous Region, mainly exploits sandstone-type uranium resources in the Yili and Turpan-Hami Basins using conventional ion-exchange processing of solutions. Expanding construction of the Mongqiguer ISL project in this centre increases production capacity.
- The Tongliao production centre in Tongliao City, Inner Mongolia is an ISL mine which exploits sandstone-type uranium resources in the southern Songliao Basin using an ion-exchange process. The ISL facilities of this centre are being expanded and production capacity will further increase in future.
- The Erlian production centre in Xilinguole County, Inner Mongolia is an ISL mine which exploits sandstone-type uranium resources in the Erlian Basin using ion-exchange processing of leaching solution. The ISL capacities of this centre are being expanded and production will further increase.

Uranium production abroad

CNNC and CGN have been involved in several uranium mining projects, mainly in Namibia, Kazakhstan and Niger. In 2014, CNNC bought a 25% equity stake from Paladin Energy in its Langer Heinrich uranium mine, which has been in care and maintenance since September 2018 due to high production costs. In August 2022, Paladin's board of directors approved a decision to restart operation in 2024 and reach production in 2025 at Langer Heinrich. On 26 November 2018, CNNC signed a share-purchase agreement with Rio Tinto and bought a 68.62% equity stake of the Rössing uranium mine in Namibia and the project delivery from Rio Tinto to CNNC was completed in July 2019. Uranium production at Rössing in 2021 and 2022 was 2 444 tU and 2 255 tU, respectively. The CGN Husab uranium mine in Namibia produced 3 310 tU and 3 357 tU in 2021 and 2022, respectively. The CNNC Azelik uranium project in Niger has been in care and maintenance since the end of 2014. The CGN-Kazatomprom-held Semizbay and Irkol mines in Kazakhstan produced 962 tU and 957 tU in 2021 and 2022, respectively. In July 2021, CGN acquired a 49% stake of the JV Ortalyk, which owns and operates the Central Mynkuduk mine and the Zhalpak mine that is under construction. The Central Mynkuduk produced 1 579 tU in 2021 and 1 639 tU in 2022.

Uranium production centres technical details

(as of 1 January 2023)

Production Centre	Centre #1	Centre #2	Centre #3	Centre #4	Centre #5	Centre #6	Centre #7	Centre #8
Name of production centre	Fuzhou*	Chongyi*	Yining	Qinglong*	Shaoguan	Tongliao	Erlian	Ordos
Production centre classification	Suspension	Suspension	Operation	Suspension	Operation	Operation	Operation	Prospective
Date of first production	1966	1979	1993	2007	1967	2015	2022	2026
Source of ore:								
Deposit name(s)				Qinglong				
Deposit type(s)	Volcanic	Granite	Sandstone	Volcanic	Granite	Sandstone	Sandstone	Sandstone
Resources (tU)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Grade (% U)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mining operation:								
Type (OP/UG/ISL)	UG	UG	ISL	UG	UG	ISL	ISL	ISL
Size (tonnes ore/day)	1 000	600	N/A	200	650	N/A	N/A	N/A
Average mining recovery (%)	92	90	N/A	85	90	N/A	N/A	N/A
Processing plant:								
Acid/alkaline	Acid	Acid	CO_2+O_2**	Acid	Acid	CO_2+O_2**	Acid	CO_2+O_2**
Type (IX/SX)	IX	IX	IX	SX	IX	IX	IX	IX
Size (tonnes ore/day); for ISL (l/day or l/h)	1 000	600	N/A	N/A	N/A	N/A	N/A	N/A
Average process recovery (%)	90	84	N/A	92	90	N/A	N/A	N/A
Nominal production capacity (tU/year)	0	0	920	0	200	380	200	N/A
Plans for expansion	N/A	N/A	N/A	N/A	N/A	370	400	N/A
Other remarks	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* In 2017 and 2018, the Chongyi and Qinglong centres were closed; in 2022, the Fuzhou centre was closed.

** Considered a form of alkaline in situ leaching by some countries, as CO2+O2 ISL is alkaline at the beginning of the process, then neutral or slightly acidic at the end.

Ownership structure of the uranium industry

The uranium industry in China is owned by state enterprises. Six production centres (Fuzhou, Shaoguan, Chongyi, Qinglong, Yining and Erlian) are owned by CNNC (Table 2). The Tongliao production centre is a joint venture owned by CNNC and CNPC.

Overseas uranium exploration and development are undertaken by CNNC and CGN. CNNC is the biggest stakeholder of the Rössing uranium mine in Namibia and the Azelik uranium mine in Niger, and holds an equity stake in the Langer Heinrich uranium mine in Namibia. CGN is the biggest shareholder of the Husab uranium mine in Namibia and holds an equity stake in the Semizbay, Irkol, Central Mynkuduk and Zhalpak mines in Kazakhstan.

Employment in the uranium industry

The organisational structural adjustment of domestic uranium production was completed in China from 2019 to 2022. Most of the underground mining uranium production centres in southern China with relatively high costs have been closed, resulting in a significant reduction in the number of employees. ISL uranium production centres that have been expanded in northern China are highly automated, with no requirement for increased employment. In general, employment in China's uranium production sector is evidently declining.

Future production centres

Industrial ISL tests of sandstone-type uranium deposits are being carried out by CNNC at the Ordos Basin, in Inner Mongolia. Encouraging results have been achieved from the ISL tests, and a development plan has been made. Ordos may become a key uranium production centre in China in the future. Once the international uranium market rebounds, the suspended uranium production centres are expected to restart production.

Uranium requirements

As of 1 January 2023, the total installed capacity of the 54 nuclear power plants in operation in mainland China is 56.82 GWe, ranking China third in the world for net electrical capacity. Annual uranium requirements amount to about 10 000 tU. The total amount of electricity generated by nuclear power was 417.78 TWh in 2022 in mainland China, which represented a 2.6% increase compared with 2021. Furthermore, an additional 24 nuclear power plants with capacity of 26.81 GWe are under construction, making China first ranked in the world by development rate.

The Chinese government continued promoting nuclear power construction in coastal areas and adherence to the principle of development in a clean, low-carbon and eco-friendly manner, as well as ensuring safety. It is projected that the total installed capacity of nuclear power plants will reach 58.46 GWe by the end of 2023.

Based on preliminary projections, uranium requirements will amount to between 12 300 and 16 200 tU in 2030, and between 14 400 and 20 500 tU in 2035.

Supply and procurement strategy

To meet the demand of nuclear power plants planned within the development programme approved by the government, the policy "Facing Two Markets and Using Two Kinds of Resources" has been adopted. Uranium supply will be guaranteed through a combination of domestic production, development of non-domestic resources, and international trade. China regards international trade as an important means to supplement and balance domestic production and supply, and also to enhance business co-operation with global uranium trading companies, as well as to ensure a stable supply on both the spot and future markets.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Uranium supply has been given attention by the Chinese government, with an emphasis on safe, economic and diverse supply sources to ensure reliability. Moderate commercial stocks are also required. Several measures have been taken by the government to support the exploration and development of uranium resources, such as stable investment for domestic exploration; allowing non-government organisations to engage in uranium exploration activities; as well as promoting the establishment of overseas production centres.

Uranium prices

The uranium price has been gradually aligned with the international market price in order to follow the global trend of uranium prices. Accordingly, uranium is priced in China following the fluctuations of the international market.

Uranium exploration and development expenditures and drilling effort – domestic

(USD millions)

	2020	2021	2022	2023 (expected)
Industry exploration expenditures	13	13	17	17
Government exploration expenditures	99	99	173	173
Industry development expenditures	12	12	12	12
Government development expenditures	0	0	0	0
Total expenditures	124	124	202	202
Industry exploration drilling (m)	70 000	70 000	90 000	90 000
Industry exploration holes drilled	NA	NA	NA	NA
Government exploration drilling (m)	550 000	550 000	950 000	950 000
Government exploration holes drilled	NA	NA	NA	NA
Industry development drilling (m)	NA	NA	NA	NA
Industry development holes drilled	NA	NA	NA	NA
Government development drilling (m)	0	0	0	0
Government development holes drilled	0	0	0	0
Subtotal exploration drilling (m)	620 000	620 000	1 040 000	1 040 000
Subtotal exploration holes drilled	NA	NA	NA	NA
Subtotal development drilling (m)	NA	NA	NA	NA
Subtotal development holes drilled	NA	NA	NA	NA
Total drilling (m)	620 000	620 000	1 040 000	1 040 000
Total holes drilled	NA	NA	NA	NA

Uranium exploration and development expenditures – non-domestic

(USD millions)

	2021	2022	2023 (expected)
Industry exploration expenditures	17.77	15.28	3.36
Government exploration expenditures	NA	NA	NA
Industry development expenditures	2.97	4.87	23.60
Government development expenditures	NA	NA	NA
Total expenditures	20.74	20.15	26.96

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery %
Underground mining (UG)	0	5 800	57 290	62 010	NA
In situ leaching	45 400	106 860	128 260	128 260	NA
Total	45 400	112 660	185 550	190 270	NA

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery %
Conventional from UG	0	5 800	57 290	62 010	NA
In situ leaching	45 400	106 860	128 260	128 260	NA
Total	45 400	112 660	185 550	190 270	NA

Inferred conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery %
Underground mining (UG)	0	11 300	60 700	83 690	NA
In situ leaching	59 200	125 950	131 740	131 740	NA
Total	59 200	137 250	192 440	215 430	NA

Inferred conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery %
Conventional from UG	0	11 300	60 700	83 690	NA
In situ leaching	59 200	125 950	131 740	131 740	NA
Total	59 200	137 250	192 440	215 430	NA

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Underground mining	NA	430	160	NA	160
In situ leaching	NA	1 110	1 390	NA	1 440
Total	NA	1 540	1 550	NA	1 600

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Conventional	NA	220	70	NA	70
In situ leaching (ISL)	NA	1 110	1 390	NA	1 440
Heap leaching*	NA	210	90	NA	90
Total	NA	1 540	1 550	NA	1 600

* A subset of open-pit and underground mining, since it is used in conjunction with them.

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Sandstone	NA	1 110	1 390	NA	1 440
Granite-related	NA	210	160	NA	160
Volcanic-related	NA	220	0	NA	0
Total	NA	1 540	1 550	NA	1 600

Ownership of uranium production in 2022

Domestic				Foreign				Totals	
Government		Private		Government		Private			
Production tU	Weight %	Production tU	Weight %	Production tU	Weight %	Production tU	Weight %	Production tU	Weight %
1 550	100	0	0	0	0	0	0	1 550	100

Uranium industry employment at existing production centres

(person-years)

Year	2020	2021	2022	2023 (expected)
Total employment related to existing production centres	2 280	2 260	2 240	2 220
Employment directly related to uranium production	1 450	1 440	1 430	1 420

Czechia

Uranium exploration and mine development

Historical review

Uranium exploration in former Czechoslovakia began in 1946 and rapidly developed into a large-scale programme in support of the country's uranium mining industry. A systematic exploration programme including geological, geophysical, and geochemical surveys and related research was carried out to assess the uranium potential of the country. Areas with identified potential were explored in detail using drilling and underground exploration methods.

Exploration continued systematically until 1989, with annual exploration expenditures in the range of CZK 210-430 million (USD 10-20 million) and an annual drilling effort in the range of 70-120 km. Exploration was traditionally centred around vein deposits located in metamorphic complexes (Jáchymov, Horní Slavkov, Príbram, Zadní Chodov, Rozná, Olsí and other deposits), granitoids of the Bohemian massif (Vítkov deposit) and around the sandstone type deposits in northern and northwestern Bohemia (Hamr, Stráz, Brevniste, Osecná-Kotel, Hvezdov, Vnitrosudetská Pánev, Hájek and other deposits).

In 1989, the decision was made to reduce all uranium-related activities. Expenditures decreased to about CZK 150 million (USD 7 million) in 1990 and have not reached that level since. No field exploration has been carried out since the beginning of 1994.

Recent and ongoing uranium exploration and mine development activities

Recent uranium exploration activities have been focused on the conservation and processing of previously collected exploration data from Czech uranium deposits. Advance processing of the exploration data and building the exploration database will continue in the coming years.

In the 2021-2022 period, the geological survey data were processed (analysis and evaluation of rock samples, geological documentation, developing a feasibility study and final reports, and archiving). Exploration expenditures were CZK 1.2 million in 2021, CZK 0.5 million in 2022, and are expected to be CZK 1.0 million in 2023 (approximately USD 56 000, USD 23 000 and USD 47 000, respectively).

Uranium resources

Historically, most of the known uranium resources of Czechia occurred in 23 deposits, of which 20 have been mined out or closed. Of the three remaining deposits, only Rozná and Stráz were mined. Resources at the Stráz deposit are, however, limited due to the remediation process, and resources at the Rozná deposit have already reached the limits of economic profitability. Other deposits (the Osecná-Kotel part of the Stráz bloc and Brzkov) have resources that are not mineable because of environmental concerns.

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2023, total identified recoverable conventional resources (reasonably assured resources and inferred resources) amounted to 119 061 tU. There was a decrease of 46 tU from previous estimates as of 1 January 2021, due to the environmental remediation activities at the Stráz deposit.

In detail, the reasonably assured resources recoverable at a cost of <USD 130/kgU amounted to 758 tU. These are recoverable resources in existing production centre at the Stráz deposits. Reasonably assured resources recoverable at a cost of <USD 260/kgU amounted to 50 802 tU, a decrease of 46 tU compared to the estimates as of 1 January 2021. The remaining resources of the Rozná deposit, in the amount of 187 tU, are also included in this cost category.

Inferred resources recoverable at a cost of <USD 260/kgU amounted to 68 259 tU and are unchanged compared to estimates as of 1 January 2021. These high-cost resources are located in the Rozná deposit and especially in the Stráz block (the Stráz, Hamr, Osecná-Kotel, and Brevniste deposits), but remain unmined due to environmental concerns.

Undiscovered conventional resources (prognosticated and speculative resources)

As of 1 January 2023, total undiscovered conventional resources (prognosticated resources and speculative resources) amounted to 239 915 tU. Prognosticated resources at a cost <USD 260/kgU amounted to 222 915 tU and are unchanged from previous estimates as of 1 January 2021. These resources occur mainly (98%) in the sandstone deposits of the Northern Bohemian Cretaceous Basin (Stráz block, Tlustec block and Hermanky deposits) and to a lesser extent (2%) in the metamorphic complex of Western Moravia (Rozná and Brzkov deposits).

Speculative resources at a cost around or greater than USD 260/kgU are estimated to amount to 17 000 tU and are reported in the unassigned cost category. Since these resources occur in Northern Bohemian Cretaceous sandstone deposits in a groundwater source protection zone, further exploration and evaluation are not permitted.

Uranium production

Historical review

The history of uranium mining in Czechia dates to the early 19th century. Uranium ores have been mined for the glass, ceramic and ink industry in Jáchymov since 1858.

Industrial development of uranium production in former Czechoslovakia began in 1946. Between 1946 and the dissolution of the former Soviet Union in 1991, all uranium produced in former Czechoslovakia was exported to the former Soviet Union.

The first production came from the Jáchymov and Horní Slavkov mines, which completed operations in the mid-1960s. Príbram, the main vein deposit, operated from 1950 to 1991. The Hamr and Stráz production centres, supplied by sandstone deposits, started operation in 1967. Peak annual national production of about 3 000 tU was reached around 1960 and production remained between 2 500 and 3 000 tU/yr from 1960 until 1989/1990 and declined thereafter. A cumulative total of 112 289 tU was produced in Czechia during the period 1946-2022, of which about 84% was produced by underground and open-pit mining methods and the remainder was recovered by in situ leaching.

Status of production facilities, production capability, recent and ongoing activities, and other issues

Formally, only one production centre remains in Czechia. It is a chemical mining centre in Stráz pod Ralskem (Northern Bohemia), Stráz sandstone deposit, with resources of 758 tU recoverable at cost <USD 130/kgU.

At the Stráz pod Ralskem chemical mining centre, the former acid in situ leaching (~180 m underground) production centre, produced 24 tU in 2021 and 22 tU in 2022. Uranium produced at this centre is a product of environmental remediation activities that began in 1996. Production capability during remediation (without acid) has decreased because of lower uranium concentration in solutions. Production in 2023 is expected to amount to 19 tU. In the long term, a gradual decline in production is expected.

The former Dolní Rozínka centre (Rozná processing plant) produced 4 tU in 2021 and 0 tU in 2022 from water treatment only. The operation was terminated and decommissioning started as of 1 January 2017. The underground of the Rozná mine is gradually being flooded. Part of the facilities at the former production centre (Rozná mill) is maintained in operation only for the uranium extraction from mine water treatment and expected uranium production in 2023 is 2 tU.

Uranium is also obtained from mine water treatment at former facility Príbram, with a total recovery of 6 tU in 2021, 4 tU in 2022 and 4 tU expected in 2023.

Ownership structure of the uranium industry

All uranium activities, including exploration, production and related environmental activities, are being carried out by the state-owned enterprise DIAMO, a mining and environmental engineering company based in Stráz pod Ralskem.

Uranium production centre technical details

(as of 1 January 2023)

	Centre #1
Name of production centre	Stráz pod Ralskem
Production centre classification	Existing
Date of first production	1967
Source of ore:	
Deposit name(s)	Stráz
Deposit type(s)	Sandstone
Recoverable resources (tU)	758
Grade (% U)	0.030
Mining operation:	
Type (OP/UG/ISL)	ISL
Size (tonnes ore/day)	-
Average mining recovery (%)	60 (estimated)
Processing plant:	
Acid/alkaline	Acid
Type (IX/SX)	IX
Size (tonnes ore/day) For ISL (kilolitre/day)	– 10 000
Average process recovery (%)	60 (estimated)
Nominal production capacity (tU/year)	100
Plans for expansion	No
Other remarks	Since 1996, production occurs through the remediation process.

Employment in the uranium industry

Total employment in the Czech uranium production centres amounted to 1 066 jobs in 2021 and 1 067 in 2022 (i.e. employment related to the production including head office, auxiliary divisions, mining emergency services).

Employment directly related to uranium production at Stráz pod Ralskem centre was 560 in 2021 and 555 in 2022; however, all uranium production is associated with remediation.

Future production centres

No other production centres are committed or planned in the near future. A potential production centre at the Brzkov deposit is a possibility to be discussed in the distant future.

Secondary resources of uranium

Production and/or use of mixed oxide fuels

The Czech power utility CEZ, a.s. is the sole owner and operator of nuclear power plants in Czechia and does not use MOX fuels in its reactors.

Production and/or use of re-enriched tails

CEZ does not use re-enriched tails in its reactors.

Production and/or use of reprocessed uranium

CEZ does not use reprocessed U in its reactors.

Environmental activities and socio-cultural issues

Managing environmental activities and social issues takes place under the government programme accompanying the downsizing of the Czech uranium mining industry. These activities began in 1989. Although this programme was formally terminated in 2009, extensive environmental remediation projects and some associated social issues continue to be addressed with the help of national and EU funding.

This programme has been aimed at gradually decreasing employment to match declining uranium production and at developing alternative (mainly environmental) projects to address social issues.

In general, the environmental activities include project preparation, environmental impact assessments, decommissioning, tailing impoundments and waste rock management, site rehabilitation and maintenance, water treatment, and long-term monitoring.

The key environmental remediation projects are as follows:

- Remediation of the after-effects of the ISL used in Stráz pod Ralskem that impacted a total of 266 million m^3 groundwater and an enclosure of 600 ha surface area; approximately 150 kt/year of contaminants (total dissolved solids) are extracted from underground.
- Rehabilitation of the tailing impoundments in Mydlovary, Príbram, Stráz pod Ralskem and Rozná (a total of 18 ponds with a total area of 593.7 ha).
- Rehabilitation (including reprocessing) of the waste rock dumps in Príbram, Hamr, Rozná, Western Bohemia and other sites (a total of 370 dumps with a capacity of 48.09 million m^3).
- Mine water treatment from former uranium facilities in Príbram, Stráz, Horní Slavkov, Olsí and others, amounting to a total of approximately 13 million m^3/year, which results in the recovery of about 5 tU annually.
- Post remediation monitoring and long-term stewardship of the mining legacy sites.

Most of the environmental expenses (about 85%) are funded by the state budget, with the remainder financed by the EU (9-12%) and DIAMO (3-6%). Since 1989, CZK 57 142 million (about USD 2 682 million) were spent on the environmental remediation projects, excluding social programmes and social security. The projects, which are due to continue until approximately 2040, are expected to have a total cost of more than CZK 60 000 million (about USD 2 817 million).

The social part of the programme (obligatory spending, compensation, damages and rent) is financed entirely by the state budget.

Expenditures related to environmental activities and social issues

(CZK millions)

	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Uranium environmental remediation	53 053	1 871	2 218	57 142	2 032
Social programme and social security	10 485	87	78	10 650	68
Total	63 538	1 958	2 296	67 792	2 100

Uranium requirements

There are two nuclear power plants with a total of six units in operation in Czechia: the older Dukovany Nuclear Power Plant with four VVER-440 reactors, which have been uprated to 510 MWe (gross), and the newer Temelin Nuclear Power Plant with two VVER-1000 reactors, which have been uprated to 1 080 MWe (gross). The sole owner and operator of these nuclear power plants is the Czech power company CEZ, a.s.

There is a general consensus that it will be necessary to build new units in Czechia, and a goal has been set to commission the first new unit by 2040 with others to follow. CEZ is focused on long-term operation projects of both current nuclear power plants, and preparation work for new builds at both sites. Negotiations between the Czech government and CEZ concerning the construction of new units, as well as the tendering procedure, are ongoing; however it has already been agreed that the first unit with an output of up to 1 200 MWe (gross) shall be built at the Dukovany site by a subsidiary called Elektrarna Dukovany II. In the most promising scenario, four new units will be developed, together with ten small modular reactors (SMRs) located at current coal-fired station sites. CEZ has already pre-qualified seven different types of SMR technology for further assessment and plans to select the most advantageous design soon (an output of approximately 300 Mwe gross has been used in the tables below).

Total uranium requirements of both nuclear power plants have been averaging 700 tU/year on a long-term basis, though future annual requirements will vary depending on outage planning due to the ongoing projects to implement longer fuel cycles (16 months at Dukovany and 18 months at Temelin).

Supply and procurement strategy

CEZ has been obtaining uranium on the basis of medium- and long-term contracts, as well as taking advantage of low spot market prices. Some uranium is purchased in world markets, and some is purchased in the form of fabricated fuel, delivered from the Russian fabricator TVEL as a package.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

The programme to wind down the Czech uranium industry from the end of the 1980s has already been formally terminated. An extensive programme for the environmental remediation of former uranium production facilities continues.

The "State Energy Policy of the Czech Republic" (approved by Government Decree No. 362/2015 Coll.) assumes a balanced energy mix and a share of up to 50% of nuclear energy in total domestic electricity production after 2040.

To provide the necessary raw material resources, the government adopted the "Raw Materials Policy in the Field of Mineral Materials and their Resources" (updated by Government Decree No. 441/2017 Coll.), which ranks uranium among the critical super strategic raw materials in line with the European "Raw Materials Initiative". This document considers the priority use of domestic uranium resources if economically and environmentally feasible.

According to the government's "Concept of the Raw Materials and Energy Security of the Czech Republic", a feasibility study of early development at Brzkov uranium deposits was completed in 2014, as well as new technological possibilities for uranium mining that strictly respect environmental concerns.

The government of Czechia approved mining activities by DIAMO at the Brzkov deposit (Vysocina region); however, there has been significant opposition by local municipalities and strong public resistance to the resumption of uranium mining in the area.

Uranium stocks

The Czech power company CEZ maintains uranium stocks at the level of about two and a half years of forward reactor consumption in all forms of processed uranium. A substantial portion of these stocks is in the form of fabricated fuel stored at the nuclear power plant sites.

Uranium prices

Uranium prices are not available as they are commercially confidential. In general, uranium prices in supply contracts incorporate price indicators from the world market according to agreed formulas.

Uranium exploration and development expenditures and drilling effort – domestic

(CZK millions)

	2020	2021	2022	2023 (preliminary)
Private* exploration expenditures	0.0	0.0	0.0	0.0
Government exploration expenditures	0.2	1.2	0.5	1.0
Private* development expenditures	0.0	0.0	0.0	0.0
Government development expenditures	0.0	0.0	0.0	0.0
Total expenditures	0.2	1.2	0.5	1.0

* Non-government.

Reasonably assured conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	0	0	1 665	90
In situ leaching acid	0	0	758	49 137	60
Total	0	0	758	50 802	

Reasonably assured conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	0	0	1 665	90
In situ leaching acid	0	0	758	49 137	60
Total	0	0	758	50 802	

Reasonably assured conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	758	49 137
Metamorphite	0	0	0	1 665
Total	0	0	758	50 802

Inferred conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	0	0	459	90
In situ leaching acid	0	0	0	67 800	60
Total	0	0	0	68 259	

Inferred conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	0	0	459	90
In situ leaching acid	0	0	0	67 800	60
Total	0	0	0	68 259	

Inferred conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	0	67 800
Metamorphite	0	0	0	459
Total	0	0	0	68 259

Prognosticated conventional resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	0	222 915

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	0	17 000

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Underground mining*	94 467	10	4	94 481	6
In situ leaching	17 762	24	22	17 808	19
Total	112 229	34	26	112 289	25

* Pre-2020 totals may include uranium recovered by heap and in-place leaching.

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Conventional	91 710	0	0	91 710	0
In-place leaching*	3	0	0	3	0
Heap leaching**	125	0	0	125	0
In situ leaching	17 762	24	22	17 808	19
Other methods***	2 629	10	4	2 643	6
Total	112 229	34	26	112 289	25

* Also known as stope leaching or block leaching.
** A subset of open-pit and underground mining, since it is used in conjunction with them.
*** Includes mine water treatment and environmental restoration.

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Sandstone	27 998	24	22	28 044	19
Granite-related*	60 903	6	4	60 913	4
Metamorphite	23 307	4	0	23 311	2
Metasomatite	0	0	0	0	0
Lignite and coal	1	0	0	1	0
Other/unspecified	20	0	0	20	0
Total	112 229	34	26	112 289	25

* Includes uranium recovered from mine water treatment; 6 tU in 2021, 4 tU in 2022 and 4 tU preliminary in 2023.

From 1945 to 1985, historical uranium production by deposit type was derived from the statement of production centres (more than one type of deposit was processed at the only production centre).

Ownership of uranium production in 2022

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
26	100	0	0	0	0	0	0	26	100

Uranium industry employment at existing production centres

(person-years)

	2020	2021	2022	2023 (preliminary)
Total employment related to existing production centres	1 546	1 066	1 067	1 068
Employment directly related to uranium production	793	560	555	554

Mid-term production projection (tonnes U/year)

2025	2030	2035	2040	2045	2050
40	40	30	20	10	10

Mid-term production capability (tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	0	40	40	0	0	40	40

2035				2040			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	0	30	30	0	0	20	20

2045				2050			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	0	10	10	0	0	10	10

Net nuclear electricity generation (TWh net)

	2021	2022
Nuclear electricity generated (TWh net)	30.7	31.0

Installed nuclear generating capacity to 2050

(MWe net)

2021	2022	2025		2030		2035		2040		2045		2050	
3 940	3 940	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
		3 940	3 960	3 940	3 980	3 940	4 580	5 060	7 720	7 300	11 460	5 410	9 550

Annual reactor-related uranium requirements to 2050 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
665	658	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
		530	910	530	910	530	1 045	725	1 640	1 115	2 365	850	1 910

Total uranium stocks

(tonnes natural U-equivalent)

Holder	Natural uranium stocks in concentrates	Enriched uranium stocks	Enrichment tails	LWR reprocessed uranium stocks	Total
Government	0	0	0	0	0
Producer	>200	0	0	0	>200
Utility	NA	NA	0	0	NA
Total	NA	NA	0	0	NA

Denmark/Greenland

Uranium exploration and mine development

Historical review

Uranium exploration and assessment activities have been performed across Greenland. The earliest exploration for uranium was carried out using Geiger counters over selected areas of southern Greenland from 1955 to 1956, leading to the discovery of radiation anomalies associated with the Kvanefjeld deposit, a large low-grade U-Th-REE deposit associated with the Mesoproterozoic Ilímaussaq layered alkaline intrusive rock complex. In 1973, Denmark, including Greenland, joined the European Economic Community when uranium exploration was encouraged in member states to secure the community's uranium resources.

Since the Kvanefjeld deposit in southern Greenland was discovered in the mid-1950s, exploration of the area continued through 1984 with various geophysical and geochemical surveys, drilling, detailed geological mapping, and test mining and assaying work. Resources at the time were estimated at 27 000 tU, with 16 000 tU in the "additional resources" category. Additional activities in southern Greenland included a regional exploration programme from 1979 to 1986 involving airborne gamma spectrometry, drainage geochemistry and geological studies. Three prospects were found: 1) uraninite in mineralised fractures and veins; 2) uranium-rich pyrochlore mineralisation in alkaline rocks; and 3) uraninite in hydrothermally mineralised metasediments. These prospects at the time were believed to represent 60 000 tU in the "speculative resources" category.

Between 1972 and 1977, a reconnaissance uranium exploration programme was conducted in eastern Greenland involving airborne gamma spectrometry, drainage geochemistry, ground scintillometry and geological studies, but no major discoveries were made. Additional reconnaissance in western Greenland with airborne gamma spectrometry and follow-up groundwork was performed, also without a major discovery.

Following a decision in 1985 by the Danish government to exclude nuclear power from its energy sources, a policy was introduced in 1988 to ban the mining of uranium and other radioactive elements in Greenland. Exploration activities continued, however, and in 1995 a stream sediment survey was undertaken that included analysis for uranium and thorium, as well as scintillometer readings covering 7 000 km^2 in northwest Greenland, but no prospects were found. In 2009, the "Self-Government Act" passed by the Danish Parliament granted Greenland control over its natural resources, and in 2013, the Greenland government lifted the ban on mining of uranium and other radioactive elements, generating renewed interest in evaluating the potential of Greenland's uranium resources.

In November 2016, an assessment of the uranium potential in Greenland was conducted jointly by the Geological Survey of Denmark and Greenland and the Ministry of Mineral Resources, Government of Greenland. Three uranium deposit types were considered: intrusive, sandstone-hosted and unconformity-related. The assessment concluded that intrusive and unconformity-related deposits have the highest potential for economic concentrations of uranium, and that southern Greenland has the highest potential for hosting undiscovered deposits.

Recent and ongoing uranium exploration and mine development activities

Since 2007, Energy Transition Minerals Ltd (ETML), formerly Greenland Minerals Ltd, a publicly listed company, had conducted exploration activities for REE-U-Zn mineralisation in the Kvanefjeld area, in southern Greenland, including drilling of 57 710 m of core. The business concept encompassed uranium and zinc by-products in addition to the main products of REE. A mining/exploitation licence application was submitted in July 2019, including updated environmental and social impact assessments (EIA and SIA) together with a navigational safety investigation study (NSS). It was expected that uranium would be recovered from leach solutions using industry standard solvent extraction to produce approximately 500 tonnes of U_3O_8 (425 tU) per year. The consultation period started in December 2020, and responses received to the EIA and SIA during the consultation period were to be summarised in the form of a white paper by the company. Final EIA and SIA reports were to be prepared with amendments according to the consultation comments and responses. Afterwards, the Government of Greenland was to decide on whether to accept the final EIA and SIA reports and white papers, and whether or not to grant an exploitation licence. An April 2021 election in Greenland, however, led to a change in government that passed a new law prohibiting exploration and exploitation of uranium as of December 2021. Passage of this new law led ETML to request arbitration proceedings with the governments of Greenland and Denmark concerning the impact of new legislation on its exploration licence for the Kvanefjeld REE, zinc and uranium project under development in southern Greenland.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

The Ilímaussaq igneous complex of southern Greenland hosts the REE-U-Zn-F deposit referred to as Kvanefjeld. It is a high-tonnage, low-grade uranium-enriched layered intrusive deposit, with concentrations of around 300 ppm U. Uranium was planned to be mined as a by-product from a proposed open-pit mine. ETML estimates that uranium will account for 5% of the revenue. Kvanefjeld is the only uranium deposit or occurrence in Greenland with reasonably assured uranium resources. The supply cost for uranium will be very low, as the majority of the costs will be borne by the production of the REE, the primary resource (Kvanefjeld is considered to be one of the largest REE deposits in the world). ETML has reported a uranium specific supply cost of approximately USD 13/kgU (USD 5/lb U_3O_8), which is incremental to the cost of the REE production. The total identified in situ reasonably assured conventional mineral resource inventory for Kvanefjeld is 102 820 tU. Additional in situ inferred mineral resources of 125 143 tU are estimated to be contained in 550 Mt of material in the Kvanefjeld and two other nearby zones (Sørensen and Zone 3). The established, and pilot plant tested, recovery factor of approximately 50% was used to calculate the recoverable uranium resources.

Undiscovered conventional resources (prognosticated and speculative resources)

Several uranium occurrences are known in Greenland: seven in southern Greenland, three in western Greenland and three in eastern Greenland. These include: (1) large, low-grade magmatic deposits; (2) small syn- to epigenetic pyrochlore mineralisation related to alkaline syenite and carbonatite; and (3) small, high-grade epigenetic uraninite mineralisation hosted in fracture zones. Most of these are showings and prospects, with Kvanefjeld the only one with a JORC-compliant reserve estimate. An evaluation of the potential for uranium deposits in Greenland is available at: https://eng.geus.dk/products-services-facilities/publications/minerals-in-greenland/geology-and-ore/geology-and-ore-28.

Unconventional resources and other materials

Unknown.

Uranium production

Historical review

No uranium has been produced in Greenland. However, 4 500 tonnes of ore were transported to the Risø National Laboratory, Denmark, for test work during the 1980s. Another 30 tonnes of ore were sent in 2014 to Outokumpu, Finland, where a pilot plant operation was conducted through the FP7 EURARE project.

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Co-product and by-product	0	0	0	102 820	50
Total	0	0	0	102 820	

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	0	0	0	102 820	50
Total	0	0	0	102 820	

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Intrusive	0	0	0	102 820
Total	0	0	0	102 820

Inferred conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Co-product and by-product	0	0	0	125 143	50
Total	0	0	0	125 143	

Inferred conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	0	125 143	50
Total	0	0	0	125 143	

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Intrusive	0	0	0	125 143
Total	0	0	0	125 143

Ecuador

Uranium exploration and mine development

Historical review

Uranium exploration in Ecuador began in the mid-1960s with the establishment of the Prospecting Department of the National Polytechnic School, which oversaw the first investigations for uranium and radioactive mineral occurrences in the country. During that period, the Ecuadorian Atomic Energy Commission (CEEA) was attached to the National Polytechnic School.

Between 1966 and 1967, the CEEA in co-operation with the International Atomic Energy Agency (IAEA; Dr James Cameron) outlined the first radioactive minerals research plan, leading to the discovery and evaluation of several radiometric anomalies between 1968 and 1970 using vehicle-borne gamma surveys. The areas investigated in the south of Ecuador in the late 1970s included Alamor, Sabanilla, Changuarhuayco, Zapotillo, Paletillas and Puyango. During the 1975-1978 period, geochemical surveys were carried out in the provinces of Azuay, Loja and Zamora Chinchipe, as well as further radiometric surveys around the Quijos river region in Napo province.

By the end of the 1970s, more than 300 radioactive anomalies had been identified as a result of 17 300 km^2 of airborne radiometric surveys in the areas of Manabí, Guayas and Cuenca, 17 000 km^2 of car-borne gamma surveys in the Cordillera, and geochemical surveys spanning 8 200 km^2 in the north, centre and south of the country.

Between 1982 and 1984, the CEEA, being responsible for uranium prospecting activities, carried out exploration in co-operation with the IAEA and the United Nations Development Program (UNDP). The areas studied included the Western and Eastern Cordilleran regions and the southwest of Ecuador. Radiometric surveys and geochemical studies of active stream sediments led to the detection of numerous anomalies. The most promising of these anomalies was found in the Puyango area (10 km^2), where the CEEA continued fieldwork that included 600 m of exploration drilling in four holes. In the 1990s, CEEA exploration programmes were suspended.

In 2008, the CEEA was merged with the Ministry of Electricity and Renewable Energy, taking the name of Undersecretariat of Nuclear Control, Investigations and Applications (SCIAN), later renamed as the Undersecretariat of Control and Nuclear Applications (SCAN). That same year, the "Program for the Development of Uranium Resources of Ecuador" was established. The short- and medium-term exploration plan included proposals for a new structure and organisation to take charge of developing work programmes, updating equipment, and setting up the necessary infrastructure, instruments, and tools (laboratories, petrographic and mineralogical studies, technical archive on uranium prospecting in Ecuador, etc.) for uranium exploration and geological research programmes. The priority was to summarise all research data from the last decades and to update the regional and geological contexts of uranium deposits in Ecuador. This programme recommended taking into consideration the following aspects: 1) regional airborne gamma-ray spectrometry surveys; 2) ground gamma-ray spectrometry surveys in the Eastern and Western Cordilleras; 3) detailed prospecting in seven anomaly clusters; 4) uranium exploration at the "El Limo-La Sota" district and the Puyango deposit (this point was not implemented); and 5) developing a uranium favourability, exploration and resources profile of Ecuador. This was originally to be undertaken between 2010 and 2014, but has not yet been implemented.

In 2009, as part of the IAEA Technical Cooperation Project, “Regional Upgrading of Uranium Exploration, Exploitation and Yellowcake Production Techniques Taking Environmental Problems into Account (RLA3010)”, an expert mission on “Uranium Exploration in Ecuador” was implemented. Among other activities, the mission included technical evaluation visits to the Puyango deposit and the anomaly area No. 44 in the province of Azuay. The uranium potential of anomaly No. 44 was considered to be low after the evaluation visit.

Recent and ongoing uranium exploration and mine development activities

Between 2019 and 2021, the Geological and Energy Research Institute (IIGE), assisted by the IAEA through SCIAN´s liaison, updated and reviewed historical information on uranium exploration in Ecuador, with the objective of taking up research carried out years ago by the National Polytechnic School and the CEEA.

In 2022, through the IAEA interregional project INT2022, the IIGE benefited from training that increased the technical capacities to carry out research proposals on uranium resources in the country in the short term.

In 2020, the Universidad Técnica Particular de Loja (UTPL) carried out a geochemical survey in the Chirimoyo and Guineo micro-basins in the Puyango area, finding V, U and Zn anomalies related to black limestones, bituminous limestones and calcareous shales of marine origin (Puyango Unit). Furthermore, in 2023 a study led by this university presented partial results from the La Sota area, suggesting that U is linked to P in a geochemical P-U-HREE-Ni association.

Despite these surveys and background research, the Regulation and Control of Energy and Non-Renewable Natural Resources Agency has not reported any private or state concessions in its mining portfolio related to uranium exploration in recent years.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Identified conventional resources have not been declared in the country to date.

Undiscovered conventional resources (prognosticated and speculative resources)

Undiscovered conventional uranium resources have not been assessed in the country to date.

Unconventional resources and other materials

In the Puyango sedimentary deposit (V, Zn, U, Cu, Pb), tabular-shaped uranium mineralisation is hosted by the Early Cretaceous Puyango Unit, which consists of black limestone, bituminous limestone and calcareous sandstone, underlain by the Aptiense Quebrada Los Sábalos Unit composed of silicified sandstones, conglomerates, volcanoclastic sands and very fine sandstones (with fossilised tree trunks). This deposit may be considered as a potential source of uranium, where uranium metal may be recovered as a minor co- or by-product to other metals.

As of 2023, the Geophysics and Geochemistry sectors of the Department of Geosciences of the UTPL estimated mineral resources of the Puyango deposit in the sequence of black limestones and calcareous black shales, which yield 4 300 tU, 39 000 tV and 19 900 tZn of speculative resources (SR).

Uranium production

Ecuador has never produced uranium and has no plans to start production.

Egypt

Uranium exploration and mine development

Historical review

Uranium exploration activity started in Egypt as early as 1956. Geophysical, radiometric and geologic exploration resulted in the discovery of many radioactive anomalies distributed across different geological environments in the Eastern Desert and Sinai. The geophysical work included local airborne gamma-ray spectrometric surveys and ground radiometric surveys over selected sites and exploration trenches. Reconnaissance exploration activity, including shafts and boreholes, revealed many uranium deposits distributed in several areas of the Eastern Desert and Sinai. Systematic uranium exploration in the southern Sinai and Gabal Gattar began in the early 1990s to provide uranium ore for planned processing facilities. Between 1998 and the end of 2000, airborne geophysical surveys covered 4 000 km^2 in the South Sinai project. The airborne gamma-ray spectrometric survey identified several anomalies and potential for uranium mineralisation. More than 500 surficial radiation anomalies were identified, and follow-up field surveys have continued to the present. The favourable regions studied by this exploration are related to the Um Bogma Formation to the southeast of Abu Zenima city. Outside of the airborne geophysical coverage area, uranium mineralisation at St. Kathrin and South El Tour in the granitic rocks of the South Sinai are also worthy of mention.

Over the past several years and in several projects, uranium exploration activity resulted in the identification of the most prospective regions in the country. The uranium exploration programme was undertaken by the Egyptian Nuclear Materials Authority (NMA), which is the government body responsible for nuclear raw materials in the country. However, only two projects had follow-up reconnaissance and general exploration studies, while two other projects underwent detailed exploration. During 2000-2018, the NMA developed the El Sella and Abu Rusheid areas of southern Egypt, which included geological mapping, a radiometric survey, trenching, sampling, chemical analyses and drilling boreholes that were surveyed for gamma radiation and representative samples.

The NMA discovered uranium mineralisation in the northern part of the Gabal Gattar granite batholith during the 1984-1985 field season. Within the framework of the resource evaluation programme, the first mining test shafts were excavated in 1998 and 1999 in the Sinai and Gabal Gattar prospects, respectively. The estimated resources for the Abu Rusheid, El Sella, Gattar and Sinai uranium deposit projects are reported in compliance with UNFC and IAEA classifications as mineral resources at a 100 ppm U cut-off grade and include measured, indicated and inferred categories.

Granitic rocks are known to have a much higher uranium content than other common rock types, and uranium exploration activities led to the discovery of several uranium anomalies and occurrences within or near the periphery of some granitic plutons in the Eastern Desert of Egypt (e.g. the Gabal Gattar, Gabel EI-Erediya, El Missikat and Um Ara areas). Secondary uranium minerals dominate the mineralogical composition of these deposits. Yellow mineral impregnations are found in fractured and albitised alkali-feldspar granites. The mineralisation occurs as stains along fracture surfaces and as acicular crystals filling cavities.

Recent and ongoing uranium exploration and mine development activities

From 1998 to 2001, exploration activities in co-operation with the China Nuclear International Uranium Corporation were carried out in two areas (South Sinai and Gabal Gattar).

In recent years, the NMA focused on the exploration of four prospects in the Eastern Desert and South Sinai. These activities involved exploratory trenching and shallow drilling programmes, supported by geophysical and geochemical surveys, to follow up subsurface extensions of the formations hosting uranium mineralisation. Uranium anomalies in southwestern Sinai are restricted to the early Carboniferous Um Bogma Formation. Uraniferous zones are associated with the lower and middle members of the Um Bogma Formation shales and dolomites.

During the 2011-2018 period, the NMA developed the southern part of the Sinai, Gattar, El Sella and Abu Rusheid projects. This work included geological mapping, a radiometric survey, trenching, sampling, chemical analyses, environmental impact assessment, database construction, drilling boreholes and gamma radiation logging of drilled boreholes. This data has been combined with equivalent uranium (eU) data and analyses of the drill core samples, which were assayed by Inductively Coupled Plasma (ICP) and X-Ray Fluorescence (XRF) methods.

From 2019 to 2023, exploration activities at the Abu Rusheid project included 91 trenches and drilling 13 boreholes with 653 m of core samples. Over 1 000 samples from exploration and evaluation were analysed for uranium to upgrade the resource category of the subsurface ore body from prognosticated to identified conventional resources (inferred) leading to pre-feasibility studies. During 2018-2023, NMA completed several exploration and evaluation activities at the El Sella project, including trenching, channel sampling and core drilling with chemical analyses. At the South Sinai and Gabal Gattar projects, the 2020-2023 core drilling programme included drilling on a 50 x 50 m grid in selected areas to upgrade the resource category of the subsurface ore body to measured resources leading to pre-feasibility studies.

During the second half of 2019-2020, NMA completed the development of many zones by percussion borehole and logging measurements. But upon finalisation during the first quarter of 2020 to 2021, the COVID-19 pandemic reduced all exploration and evaluation activities and caused the activity to be put on hold.

In the last two years, the decision was made to reduce all uranium-related activities. Expenditures of new exploration decreased due to the economic challenges, so no exploration of new areas has been carried out since the beginning of 2020.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2023, Egypt's total identified conventional uranium resources recoverable at a cost of <USD 260/kgU amounted to 16 115 tU (in situ resources), an increase of 13 600 tU compared to the 2021 estimate. This increase is due to the resource associated with the Abu Rusheid project, previously reported as prognosticated resources.

Abu Rusheid project

For the Abu Rusheid project, inferred resources are estimated to be around 13 600 tU, as reported in the following tables. Identified uranium resources increased due to drilling activity and re-evaluation of uranium resources. The uranium occurrences are associated with rare metals in the paragneiss (mylonitic rocks). However, previous Red Book reports indicate an estimated potential of 10 000 tU of in situ prognosticated resources for the Abu Rusheid area.

Abu Zenima project

For the Abu Zenima project, inferred resources amount to 515 tU. Reasonably assured resources (in situ) are currently being estimated. The early Carboniferous succession of sandstones, claystones and siltstones hosts anomalous zones with secondary uranium mineralisation. The occurrences are found in several locations around Abu Zenima, in the eastern Gulf of Suez. The economic potential has not yet been fully assessed because of difficult drilling conditions. However, some target areas are under development where secondary uranium mineralisation was identified at the surface. Detailed geologic work, diamond drilling and test mine work are being conducted. Future drilling programmes will confirm the reasonably assured resources.

Gabal Gattar project

The Gabal Gattar project's compliant resource estimates include 2 000 tU as inferred resources and reasonably assured resources, based on the results of the borehole core drilling. An elongated granite batholith trending over 40 km is host to vein-type uranium mineralisation associated with molybdenite, defined in eight uraniferous occurrences. These occurrences are characterised by intense secondary uranium minerals with characteristic yellow to greenish-yellow colours. Nearly all the recorded uranium occurrences are associated with strongly deformed and deeply hematitised zones. Since 2018, Gabal Gattar has been subject to subsurface exploration work, including deep drilling and trenching, to follow up prospective subsurface extensions of mineralisation and to correlate with surface occurrences.

Undiscovered conventional resources (prognosticated and speculative)

Egypt has conducted systematic uranium resource prediction and evaluation, with prognosticated resources estimated to be around 10 814 tU, with an increase in resources related to increased drilling activity and re-evaluation of uranium resources.

El Sella project

Additional potential resources may occur in the El Sella project area, where uranium exploration permits have been held over the past few years. Ongoing exploration is aimed at extending the existing deposit as well as identifying and evaluating new deposits, given the potential for additional resources. The area contains an estimated potential for 10 814 tU of in situ prognosticated uranium resources. Follow-up drilling is expected to continue through 2023-2024. With further exploration, additional uranium resources are expected to be discovered.

Unconventional resources and other materials

The Egyptian phosphate deposits represent one of the more promising unconventional uranium resources. Estimates of these phosphate ores reach about 700 million tonnes, with uranium content ranging between 50 ppm and 200 ppm (as reported in the 2009 Red Book). No reliable estimate of the uranium resources in Egyptian phosphate ores has been made since 2008, when it was reported in the 2009 Red Book that it is possible that the deposits contain up to 42 000 tU.

Black sands, a potential source of unconventional uranium resources, are considered the second most important unconventional source of uranium in Egypt. Black sands are estimated to contain about 6 million tonnes of radiogenic and rare earth elements with potential economic and industrial returns. At some locations, such as in the El Borols area, the monazite (one of the black sand ore minerals) contains up to 0.5% U and 6% Th, as well as 60% rare earth elements.

Uranium production

Historical review

Between 2007 and 2011, the NMA worked on the development of the small semi-pilot plant for the extraction of uranium from different rock types, and the evaluation of leaching and extraction efficiencies. Tests were carried out on uranium mineralisation from the Gattar (Eastern Desert) and Abu Zenima (South Sinai) projects to study the most suitable methods of dissolving uranium from granitic rocks (Gattar) and sedimentary carbonate rocks (Sinai), as well as the ideal factors for using the vat leaching system and extraction using the ion-exchange technique.

After completing the laboratory experiments, a flowsheet for the extraction of uranium from ores in the Gattar granite was developed. This was followed by the construction of the Gattar experimental yellowcake production unit with a capacity of 1 000 tonnes of ore materials at an average concentration of 200 ppm U (0.02% U), and a production rate of 300 kg of yellowcake annually. At the Abu Zenima project, a small heap leach pad was constructed in 2018 next to the experimental vat with a capacity of about 1 000 tonnes of uranium-bearing rock ore per batch, at an average concentration of 250 ppm U. It is now in operation, with a production rate of 700 kg of yellowcake annually.

Status of production facilities, production capability, recent and ongoing activities, and other issues

In November 2017, the NMA began establishing the first production unit to leach uranium, in South Sinai, with a capacity of 4 000 tonnes of uranium-bearing ore per batch, using a limited vat basin leaching process. At the Gattar project, the uranium is leached by placing the ores in vats or on a heap leach pad. In December 2019, the trial operation began extracting yellowcake by an ion-exchange process as an experimental production stage at the Abu Zenima project. No uranium has been commercially produced in Egypt; however, 5 000 tonnes of ore were transported to the Abu Zenima production unit for test work during 2022. Another 5 000 tonnes of ore were transported in 2020-2023 to the Gattar project, where a semi-pilot plant operation was constructed. Uranium production has been confined to Sinai and Gattar semi-pilot plant mines. The first production came from the South Sinai and Gabal Gattar production centres. The two projects' combined annual production is about 1 tonne of yellowcake (U in yellowcake 60%) via solvent extraction. A cumulative total of 3 tonnes of yellowcake has been produced up to February 2023, of which about 90% was produced using surface and open-pit mining methods.

Future production centres

Egypt developed mine and processing pilot projects at Gattar and Abbu Zenima in 2001 and is planning to do the same at Abu Rusheid and El Sella in 2025. Depending on the results of these pilot projects, production centres could be constructed in the future.

Gattar project

The existing pilot production centre includes vat leaching (1 000 tonnes of uraniferous granitic ore capacity) and small-scale heap leaching (2 500 tonnes ore). The committed production centre will include the construction of a heap leaching pad, with a capacity of 10 000 tonnes ore.

Abu Zenima project

The existing pilot production centre includes vat leaching (capacity 4 000 tonnes of ore) and a heap leaching pad (1 000 tonnes of uraniferous ore).

Abu Rusheid project

The planned pilot production centre will include vat leaching (with a suitable tonnage of basement uraniferous rocks) and an ion-exchange unit for uranium extraction.

El Sella project

The planned pilot production centre will include a heap leaching pad and an ion-exchange unit for uranium extraction.

Ownership structure of the uranium industry

The uranium industry in Egypt is expressed as a system of small experimental units that do not contribute to global production and are owned by the government.

Employment in the uranium industry

The uranium industry supporting Egypt's experimental units has depended on specialised workers in this field since 1999, in addition to new technical staff and workers gaining work experience.

Production and/or use of mixed oxide fuels

Egypt does not produce or use mixed oxide fuels.

Environmental activities

All trial mining, trenching and drilling operations, as well as laboratories, are subject to environmental control and radiation safety regulations following guidelines of the International Atomic Energy Agency, and to the supervision, follow-up and control of the Egyptian Nuclear and Radiological Regulatory Authority.

Uranium exploration and development expenditures and drilling effort – domestic

(Egyptian pounds – EGP)

	2020	2021	2022	2023 (expected)
Industry exploration expenditures	0	0	0	0
Government exploration expenditures	2 000 000	2 000 000	2 000 000	2 000 000
Industry development expenditures	0	0	0	0
Government development expenditures	1 000 000	1 000 000	1 000 000	1 000 000
Total expenditures	3 000 000	3 000 000	3 000 000	3 000 000
Industry exploration drilling (metres)	0	0	0	0
Industry exploration holes drilled	0	0	0	0
Industry exploration trenches (metres)	0	0	0	0
Industry trenches (number)	0	0	0	0
Government exploration drilling (metres)	1 550	800	950	950
Government exploration holes drilled	72	55	70	70
Government exploration trenches (metres)	330	400	520	520
Government trenches (number)	14	10	14	14
Industry development drilling (metres)	0	0	0	0
Industry development holes drilled	0	0	0	0
Government development drilling (metres)	200	400	650	650
Government development holes drilled	8	15	20	20
Subtotal exploration drilling (metres)	0	0	0	0
Subtotal exploration holes drilled	0	0	0	0
Subtotal development drilling (metres)	0	0	0	0
Subtotal development holes drilled	0	0	0	0
Total drilling (metres)	1 750	1 200	1 600	1 600
Total number of holes drilled	80	70	90	90

Inferred conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	0	0	15 600	
Open-pit mining (OP)	0	0	515	515	
Total	0	0	515	16 115	

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	515	515
Granite-related	0	0	0	2 000
Metamorphite	0	0	0	13 600
Total	0	0	515	16 115

Prognosticated conventional resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	10 814	10 814

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
NA	NA	NA

Finland

Uranium exploration

Historical review

Uranium exploration in Finland was first carried out between 1955 and 1988, initially by the companies Atomienergia Oy, Imatran Voima Oy and Outokumpu Oy, and from 1973 by the Geological Survey of Finland (GTK). In the late 1980s, exploration activities were stopped. Exploration began again in the 2000s by Areva (now Orano) and some junior companies. In 2010, Areva closed down its Finnish subsidiary, and its exploration assets in Finland were purchased by Mawson Resources Ltd (now Mawson Gold Ltd). Uranium exploration in Finland has slowed since 2011, as Mawson's focus of exploration has shifted increasingly to gold.

Recent and ongoing uranium exploration

There is currently no uranium exploration in Finland.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Finland reports a total of 1 500 tU of in situ reasonably assured conventional resources, recoverable at costs of USD 80-130/kgU in the Palmottu and Pahtavuoma uranium deposits. No inferred conventional resources are reported.

Undiscovered conventional resources (prognosticated and speculative resources)

None reported.

Unconventional resources and other materials

Unconventional resources of uranium in the Talvivaara black schist-hosted Ni-Zn-Cu-Co deposit are approximately 19 200 tU at an average grade of 0.0018% U in the measured and indicated resources of 1 068 Mt, and about 26 200 tU at an average grade of 0.0018% U in the total mineral resources (measured, indicated and inferred) of 1 453 Mt, calculated from the 2022 resource update by Terrafame Oy.

Uranium production

Historical review

Uranium production in Finland has been confined to the now remediated Paukkajanvaara mine that operated as a pilot-scale mine between 1958 and 1961. In all, 40 000 tonnes of ore were excavated, and the concentrates produced amounted to about 30 tU. As reported in the NEA 2006 Red Book Retrospective, the total historical production calculated from the mining register statistics is no more than 41 tU from 1958 to 1961.

Uranium production centre technical details

(as of 1 January 2023)

	Centre #1
Name of production centre	Terrafame mine in Sotkamo
Production centre classification	Committed
Date of first production	2024
Source of ore:	
Deposit name(s)	Talvivaara (Kuusilampi and Kolmisoppi)
Deposit type(s)	Black schist (metamorphosed black shale)
Recoverable resources (tU)*	8 600*
Grade (% U)	0.0018
Mining operation:	
Type (OP/UG/ISL)	OP
Size (tonnes ore/day)	41 000
Average mining recovery (%)	50
Processing plant:	
Acid/alkaline	Acid (heap leaching)
Type (IX/SX)	SX
Size (tonnes ore/day)	NA
Average process recovery (%)	90
Nominal production capacity (tU/year)	200
Plans for expansion	NA
Other remarks	Heap leaching by-product

* Overall recovery factor of 45% used in the estimate.

Future production centres

There is currently no uranium production in Finland. Between 2010 and 2015, Talvivaara Sotkamo Oy prepared for uranium recovery as a by-product from the Talvivaara deposit in Sotkamo, eastern Finland. The Talvivaara Ni-Zn-Cu-Co deposit is hosted by metamorphosed black shales in the Kainuu Schist Belt. It is a low-grade, large-tonnage deposit averaging 0.26 wt% Ni, 0.53 wt% Zn, 0.14 wt% Cu, 0.02 wt% Co and 0.0018 wt% U.

Production of nickel, cobalt and zinc from the Talvivaara ore deposit commenced in 2008. The production process includes open-pit mining, crushing, heap leaching and metals recovery. The leach solution percolates to the bottom of the leach pads and is either recirculated through the heap or fed to metals recovery. During metals recovery, nickel, zinc, cobalt and copper are precipitated from the pregnant leach solution (PLS) and filtered to produce saleable metal products. After the target metals have been recovered, the solution is further purified to remove unwanted metals, which are directed to process waste gypsum ponds.

In 2010, Talvivaara Sotkamo Oy announced plans to recover uranium as a by-product using solvent extraction, resulting from the fact that a large part of uranium dissolves in the PLS during heap leaching. Dissolved uranium has largely ended up in the process wastes and partly in the Ni-Co sulphide concentrate product. Uranium has been present as an impurity in the Ni-Co sulphide consigned to the Norilsk Nickel refinery at Harjavalta, western Finland. Uranium residuals have been extracted from the nickel products at the Harjavalta Nickel Refinery and reported to the Radiation and Nuclear Safety Authority (STUK). The Norilsk Nickel Harjavalta refinery has been licensed by the STUK to extract uranium at less than 10 tU/year. As of 31 December 2021, the total amount of natural uranium stored at Norilsk Nickel Harjavalta was about 3.6 tU.

During 2011-2013, the uranium solvent extraction plant was built as a new unit in the metals recovery complex of Talvivaara. In 2012, the Finnish government granted a uranium extraction licence to Talvivaara Sotkamo Oy in accordance with the nuclear energy legislation. In 2013, however, the Supreme Administrative Court returned the licence to the Finnish government for reassessment due to several changes in the operations of Talvivaara Sotkamo Oy after the licence decision, including the corporate reorganisation. Eventually, Talvivaara Sotkamo Oy filed for bankruptcy in 2014 due to its financial difficulties. State-owned company Terrafame Oy acquired the operations and assets of Talvivaara Sotkamo Oy from its bankruptcy estate in 2015, and as of 1 January 2023, was carrying on the mining operations in Sotkamo.

In 2017, Terrafame Oy applied to the Finnish government for a licence to recover uranium as a by-product at Terrafame's mine in Sotkamo, in accordance with the nuclear energy legislation. In February 2020, the Finnish government granted a uranium extraction licence to Terrafame. However, the licence was appealed to the Supreme Administrative Court. In June 2021, the Supreme Administrative Court confirmed the uranium extraction licence that had been previously granted by the government. The mine site in Sotkamo currently includes an almost fully completed uranium solvent extraction plant from the time of Terrafame's predecessor, Talvivaara Sotkamo Oy.

In December 2022, Terrafame commenced preparations for the extraction of uranium based on the results of the feasibility study. The preparations require a total investment of around EUR 20 million. Terrafame expects to start uranium production in Sotkamo in 2024. After the ramp-up phase, the uranium recovery plant is estimated to operate at full capacity by 2026, when it is expected to produce about 200 tU per year.

Secondary sources of uranium

Production and/or use of mixed oxide fuels

Finland does not produce or use mixed oxide fuels.

Production and/or use of re-enriched tails

Re-enriched tails have not been used in 2021 and 2022.

Regulatory regime

The Mining Act regulates exploration and mining activities in Finland. All licences under the Mining Act are decided by the mining authority Tukes. An environmental permit according to the Environmental Protection Act is required for mining. The mine closure process is regulated by mining and environmental legislation, as well as a number of EU and other specifications.

The Radiation and Nuclear Safety Authority (STUK) is the regulatory body for uranium production, as specified in the Nuclear Energy Act and the Radiation Act. Production of uranium or thorium needs a licence from the Finnish government according to the Nuclear Energy Act. A licence application must be submitted to the government. Statements from different authorities (including STUK) are required for the decision on the licence, which is prepared by the Ministry of Economic Affairs and Employment and decided by the government.

According to the Mining Act of 2011, an exploration licence is required for uranium exploration (e.g. for drilling and trenching). Permit applications concerning a uranium mine under the Mining Act and the Nuclear Energy Act are handled jointly and decided on in a single decision by the government. A permit for a uranium mine requires that the mining activities be in line with the overall good of society, that the municipality in question give its consent and that safety requirements be fulfilled.

STUK's regulatory control covers the radiation exposure of workers and the public, environmental monitoring, waste management, emergency preparedness, nuclear material accountancy and physical protection of nuclear materials. STUK verifies that safety and security requirements are fulfilled. Radioactive tailings are regarded as nuclear waste and are subject to funding for the future costs of waste management. Uranium concentrate export, controlled by the Ministry for Foreign Affairs, is also subject to national and international safeguards control.

The environmental impact assessment procedure is applied to all uranium mining projects, without any limitations on the annual amount of the extracted resources. In addition, other legislation to be applied for mining activities includes the Water Act, the Nature Conservation Act, the Wilderness Act, the Chemicals Act, the Land Use and Building Act, the Occupational Safety and Health Act, the Waste Act and various government decrees and decisions.

Uranium requirements

Five nuclear power plant units (three at the Olkiluoto Nuclear Power Plant and two at the Loviisa Nuclear Power Plant) with a total generating capacity of 4.4 GWe (net) are in operation. These five reactors require about 720 tU annually. Olkiluoto units are owned and operated by Teollisuuden Voima Oyj (TVO), and Loviisa units by Fortum Power and Heat Oy. In February 2023, the Finnish government granted a new operating licence until 2050 for both units of the Loviisa Nuclear Power Plant.

Finland's fifth nuclear power plant unit, TVO's Olkiluoto 3 (EPR; 1.6 GWe net), was connected to the national grid in March 2022. TVO selected European pressurised reactor (EPR) technology for the Olkiluoto 3 unit in 2003, and the Areva-Siemens Consortium started construction in 2005. Regular electricity production at the Olkiluoto 3 unit began in April 2023.

In 2010, the Finnish Parliament ratified the decisions in principle (DIP) for the construction of two new reactors, one at the existing Olkiluoto site (OL4) by TVO and a single reactor at the greenfield Pyhäjoki site by Fennovoima. According to the DIP, the deadline for submitting the applications for the construction licences of these units was the end of June 2015.

In June 2015, TVO decided not to apply for a construction licence for OL4 during the validity of the DIP made in 2010. The reason was the delay of the start-up of the Olkiluoto 3 power plant unit. Consequently, the DIP made by the Finnish government and approved by parliament expired at the end of June 2015.

In 2015, Fennovoima applied to the Finnish government for a construction licence for its Hanhikivi 1 unit. In May 2022, Fennovoima terminated the plant delivery contract with the Russian RAOS Project and cancelled its construction licence application concerning the Hanhikivi 1 Nuclear Power Plant.

Supply and procurement strategy

TVO procures its nuclear fuel for the Olkiluoto Nuclear Power Plant through a decentralised supply chain, entering into negotiations and making procurement contracts with each separate supplier at the various stages of the fuel production chain. There are several suppliers for each stage of the chain. Procurement operations are based on long-term contracts with suppliers. These companies have mining operations in many countries. Most of the uranium procured by TVO comes from Australia, Canada and Kazakhstan, and the nuclear fuel assemblies ordered by the company are fabricated in Germany, Spain or Sweden.

The fuel assemblies used at Fortum's Loviisa Nuclear Power Plant are currently of Russian origin. Nuclear fuel is acquired from the Russian company TVEL as a turnkey delivery, from the acquisition of the uranium to the fabrication of the fuel assemblies. Conversion, enrichment and fuel fabrication are carried out by TVEL, which acquires the uranium used in the fuel assemblies from ARMZ Uranium Holding Co.

Uranium policies, uranium stocks and uranium prices

Nuclear energy legislation

The legal basis of the use of nuclear energy in Finland consists of the Nuclear Energy Act and the Nuclear Energy Decree. The purpose of nuclear energy legislation is to ensure that the use of nuclear energy is in line with the overall good of society, safe for people and the environment, and that its use does not enable the proliferation of nuclear weapons. The use of nuclear energy creates several obligations for the licensee: the licensee must, among other things, ensure the safety of operations, manage the nuclear waste created through the operations, and assume responsibility for all nuclear waste management costs. Nuclear waste management costs are prepared for by collecting funds in advance in the price of electricity and depositing them in the National Nuclear Waste Management Fund.

The Nuclear Energy Decree and government decisions have been issued based on the Nuclear Energy Act. The government decisions concern nuclear plant safety, safety arrangements, preparedness arrangements, and the final disposal of operating waste and spent nuclear fuel. Based on the authorisation by the nuclear energy legislation, the STUK publishes detailed safety requirements for the use of nuclear energy. Radiation safety is regulated by the Radiation Act and the Radiation Decree. The Nuclear Liability Act stipulates that the licensee must have nuclear liability insurance that will compensate for injuries caused to outsiders by a possible nuclear accident, to the extent decreed by law.

Nuclear waste management

Spent nuclear fuel from the Olkiluoto and Loviisa nuclear power plants is stored in the water pools of the fuel storage facilities at Olkiluoto and Loviisa until finally disposed of in the Olkiluoto bedrock in the municipality of Eurajoki. Posiva Oy, a company owned by TVO and Fortum, is responsible for the final disposal of the spent nuclear fuel of the owners. Spent nuclear fuel from the nuclear power plants of TVO and Fortum will be packed in copper canisters and embedded in Olkiluoto bedrock at a depth of 400-450 m. The final disposal of spent nuclear fuel is based on the use of multiple release barriers to ensure that the nuclear waste cannot be released into organic nature or become accessible to humans. The release barriers include the ceramic, solid state of the fuel, the disposal canister, the bentonite buffer, the backfilling of the tunnels and the surrounding rock.

Posiva is currently constructing the final disposal facility in Olkiluoto. In 2015, Posiva received a construction licence from the Finnish government for its final disposal system, consisting of a nuclear fuel encapsulation plant and final disposal facility. The excavation of the final disposal facility began in 2016, and the construction of the encapsulation plant started in 2019. An operating licence application for Posiva’s encapsulation plant and disposal facility was submitted to the Finnish government in December 2021, and the current plan is to start final disposal of spent nuclear fuel in Olkiluoto in the mid-2020s.

Uranium stocks

The nuclear power utilities maintain reserves of fuel assemblies from seven months to one year’s use, although the legislation demands only five months’ use.

Uranium prices

Due to commercial confidentiality, price data are not available.

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Underground mining (UG)	0	0	500	500
Open-pit mining (OP)	0	0	1 000	1 000
Total	0	0	1 500	1 500

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional from UG	0	0	500	500
Conventional from OP	0	0	1 000	1 000
Total	0	0	1 500	1 500

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Metamorphite	0	0	500	500
Intrusive	0	0	1 000	1 000
Total	0	0	1 500	1 500

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Open-pit mining	15	0	0	15	0
Underground mining	15	0	0	15	0
Total	30	0	0	30	0

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Conventional	30	0	0	30	0
Total	30	0	0	30	0

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Sandstone	30	0	0	30	0
Total	30	0	0	30	0

Mid-term production projection (tonnes U/year)

2025*	2030*	2035*	2040*	2045*	2050*
NA	200	200	200	200	200

* By-product of nickel production from the Talvivaara black schist-hosted Ni-Zn-Cu-Co deposit (unconventional resources).

Re-enriched tails production and use

(tonnes natural U-equivalent)

Re-enriched tails	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Production	0	0	0	0	0
Use	843	0	0	843	0

Net nuclear electricity generation

	2021	2022
Nuclear electricity generated (TWh net)	22.6	24.2

Installed nuclear generating capacity to 2050

(MWe net)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
2 790	2 790	4 390	4 390	4 390	4 390	4 390	4 390	4 390	4 390	4 390	4 390	4 390	4 390

Annual reactor-related uranium requirements* to 2050 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
NA	NA	690	750	690	750	690	750	690	750	690	750	690	750

* Refers to natural uranium acquisitions, not necessarily consumption during the calendar year.

France

Uranium exploration and mine development

Historical review

Uranium exploration began in 1946, focusing on previously discovered deposits and a few occurrences discovered during radium exploration. In 1948, exploration led to the discovery of the La Crouzille deposit, which at one time was of major importance. By 1955, additional deposits had been identified in the granite areas of Limousin, Forez, Vendée and Morvan. Prospecting activities were subsequently extended to sedimentary formations in small intra-granitic basins and terrigeneous formations derived from eroded granite mountains, mainly located north and south of the Massif Central.

Recent and ongoing uranium exploration and mine development activities

No domestic activities have been carried out in France since 1999.

There is no domestic ownership of uranium production, only ownership in foreign countries through operations in Canada, Kazakhstan and Niger.

During the current Red Book reporting period, the state majority-owned company Orano S.A. (formerly Areva S.A.) has been working outside France focusing on the discovery of exploitable resources in Canada, Gabon, Kazakhstan, Mongolia, Namibia, Niger and Uzbekistan. In Canada, Kazakhstan and Niger, Orano is also involved in uranium mining operations. In addition, as a non-operator, it holds shares in several mining operations and research projects in different countries.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Orano no longer reports resources or reserves in France since the historic data on which these estimates are based do not conform to modern international standards.

Undiscovered conventional resources (prognosticated and speculative resources)

No systematic appraisal has been made of undiscovered resources.

Uranium production

Status of production facilities, production capability, recent and ongoing activities and other issues

Following the closure of all uranium mines in 2001, all ore processing plants were shut down, dismantled and the sites reclaimed.

In France, a total of 244 sites, ranging from exploration sites to mines of various sizes, 8 mills and 17 tailing deposits (containing a total of 52 Mt of tailings) are the result of the production of about 80 000 tU. All these sites have been remediated. Monitoring continues at only the most important sites, and 17 water treatment plants were installed to clean drainage from the sites. Orano is responsible for the management of 234 of these sites.

The purpose of remediation is to:

- ensure public health and safety;
- limit the residual impact of previous activities, to as low as reasonably achievable (ALARA);
- integrate the industrial sites into landscape;
- maintain a dialogue and consultation with local populations;
- allow the reconversion of the former sites to new activities, such as tourism, industry, agriculture and energy (solar panels).

Future production centres

There are no plans to develop new production centres in France in the near future.

Secondary sources of uranium

Production and/or use of mixed oxide fuels

The annual licensed capacity of MOX fuel production in France is about 195 tHM, roughly corresponding to 1 560 tU equivalent (tNatU) using the recommended Red Book conversion factor. Actual yearly production of MOX in France varies below this licensed capacity in accordance to contracted quantities. Most of the French MOX production is used to fuel French nuclear power plants (a total of about 125 t/yr, or 1 000 tNatU) and the remainder is delivered abroad under long-term contract arrangements.

Production and/or use of reprocessed uranium

In France, reprocessed uranium is produced at the la Hague reprocessing plant. Électricité de France (EDF) produces around 1 000 tU of spent fuel annually. Reprocessed uranium was recycled at the EDF nuclear power plant of Cruas. The last fuel assemblies containing reprocessed uranium were loaded in 2013. EDF signed in 2018 contracts for the recycling, starting in 2023, of reprocessed uranium (RepU) for use in PWRs. This solution enables EDF to diversify its uranium supply sources, allowing for savings of around 10-15% of its natural uranium requirements. It also ensures completeness of the French nuclear cycle, by reusing 96% of the nuclear material contained in spent fuel.

Regulatory regime

In France, mines are nationally regulated according to the mining code and processing plants according to regulations specified in the legislation governing the operation of installations that present environmental risks (ICPE – *installation classée pour la protection de l'environnement*). These regulations are applied by regional environmental authorities (DREAL – Directions régionales de l'Environnement, de l'Aménagement et du Logement) on behalf of the prefect (the state representative in a particular department or region).

To open a mine, the mining company must present a report to the regional authorities that will allow them to confirm that the project will be operated in accordance with all regulations. Once this is confirmed, a public enquiry must be held. If these processes are successfully completed, the mining company will be allowed to open the mine according to requirements laid out in an *Ordre du Préfet*. When mining is completed, the mining company must prepare a report for local authorities who can then give authorisation for decommissioning through an *Ordre du Préfet*.

After decommissioning, the mining company retains responsibility for the site, including monitoring and maintenance. In theory, according to the mining code, after remediation and a period of monitoring to verify that there is no environmental impact, the mining company can transfer the responsibility of the site to the state. However, if there is a problem, the state asks the mining company to remediate it.

There has not been a transfer of responsibility for a uranium mine from the mining company to the state because Orano, as the responsible mining company, is majority owned by the state. However, Orano is in discussions with the authorities regarding the transfer of responsibility.

The cost of mine remediation is the responsibility of the mining company. In the case of processing plants (mills), local authorities request financial guarantees for the costs of all remediation works and monitoring. A draft revision of the mining code is currently under development.

Uranium requirements

France has 56 nuclear power reactors in operation (supplying 61 370 MWe) and 1 EPR reactor under construction at the Flamanville site. The development strategy for nuclear power is related to the goals set forth by the Energy Transition for Green Growth Act and the Multiyear Energy Plan (MEP), published in April 2020. Nuclear power development will depend on developments in renewable energy and decisions of the Nuclear Safety Authority regarding the potential lifetime extension of the existing power plants.

In the MEP, a total of 14 power reactors are planned to be shut down to reduce the share of nuclear energy in France’s electricity generation mix from the 75% as of 2020 to 50% by 2035.

In 2006, Areva began work at the Tricastin site on construction of the Georges Besse II uranium centrifuge enrichment plant to replace the Eurodif gaseous diffusion plant that had been in service since 1978. In 2012, production at the Eurodif plant was stopped and the facility will be dismantled in the coming years. The Georges Besse II facility successfully reached its full production capacity of 7.5 million SWUs in 2016. The most recent qualification tests carried out have confirmed the performance capabilities of the plant’s equipment with its industrial facilities showing rates of efficiency of more than 99%.

Supply and procurement strategy

Since France is a net importer of uranium, its policy towards procurement is one of supply diversification. French entities participate in uranium exploration and production outside France within the regulatory framework of the host countries. Uranium is also purchased under short- or long-term contracts, either from mines in which French entities have shareholdings or from mines operated by third parties.

Uranium policies, uranium stocks and uranium prices

Uranium stocks

EDF possesses strategic uranium inventories, the minimum level of which has been fixed at the equivalent of a few years' forward consumption to offset possible supply interruptions.

Uranium prices

Information on uranium prices is not available.

Uranium exploration and development expenditures – non-domestic

(In EUR millions)

	2020	2021	2022	2023 (preliminary)
Industry exploration expenditures	0	0	0	0
Government* exploration expenditures	28	27	24	24
Industry development expenditures	0	0	0	0
Government* development expenditures	NA	NA	NA	NA
Total expenditures	28	27	24	24

* Orano S.A., a state majority-owned company. In previous reports, these expenditures were attributed to industry. Government expenditures refer to those corresponding to majority government funding.

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Open-pit mining[1]	5 427	0	0	5 427	0
Underground mining[1]	1 511	0	0	1 511	0
Open-pit and underground[2]	73 925	0	0	73 925	0
Co-product/by-product	115	0	0	115	0
Total	80 978	0	0	80 978	0

1. Pre-2020 totals may include uranium recovered by heap and in-place leaching.

2. Not possible to separate in historic records.

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Conventional	80 863	0	0	80 863	0
Other or unspecified methods*	115	0	0	115	0
Total	80 978	0	0	80 978	0

* Includes mine water treatment and environmental restoration.

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Sandstone	16 781	0	0	16 781	0
Granite-related	63 683	0	0	63 683	0
Metamorphite	395	0	0	395	0
Volcanic-related	1	0	0	1	0
Black shale	3	0	0	3	0
Other or unspecified	115	0	0	115	0
Total	80 978	0	0	80 978	0

Ownership of uranium production in 2022

Domestic				Foreign				Totals		
Government		Private		Government		Private				
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	Country
0	0	0	0	443	30.195	0	0	443	30.195	Canada
0	0	0	0	2 803	40.453	0	0	2 803	40.453	Canada
0	0	0	0	1 282	63.4	0	0	1 282	63.4	Niger
0	0	0	0	1 308	51	0	0	1 308	51	Kazakhstan

Mixed oxide fuel production and use

(tonnes natural U-equivalent)

Mixed oxide (MOX) fuel	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Production	25 902	43	58	26 003	65
Use	NA	NA	NA	NA	NA
Number of commercial reactors using MOX	22	22	22	22	22

Reprocessed uranium use

(tonnes natural U-equivalent)

Reprocessed uranium	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Production	30 988	920	909	32 817	849
Use	5 300	0	0	5 300	250

Net nuclear electricity generation (TWh net)

	2021	2022
Nuclear electricity generated (TWh net)	361	279

Installed nuclear generating capacity to 2050

(MWe net)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
61 400	61 400	61 400	63 000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Annual reactor-related uranium requirements to 2050 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
7 000	7 000	6 000	8 000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Germany

Uranium exploration and mine development

Historical review

After World War II, and until reunification in 1990, exploration for uranium occurred in two separate countries in what is today Germany:

Federal Republic of Germany (FRG) before 1990

Starting in 1956, exploration was carried out in several areas of geological interest: the Hercynian Massifs of the Black Forest, Odenwald, Frankenwald, Fichtelgebirge, Oberpfalz, Bayerischer Wald, Harz, the Paleozoic sediments of the Rheinisches Schiefergebirge, the Permian volcanics and continental sediments of the Saar-Nahe region and other areas with favourable sedimentary formations. The initial phase included hydrogeochemical surveys, car-borne surveys, field surveys and, to a lesser extent, airborne prospecting. Follow-up geochemical stream sediment surveys, radon surveys and detailed radiometric work, followed by drilling and trenching, were carried out in promising areas. During the reconnaissance and detailed exploration phases, both the federal and state geological surveys were involved, whereas the actual work was carried out mainly by industrial companies.

Three deposits of economic interest were found: (1) the partly high-grade hydrothermal deposit near Menzenschwand in the southern Black Forest; (2) the sedimentary Müllenbach deposit in the northern Black Forest; and (3) the Grossschloppen deposit in northeastern Bavaria. Uranium exploration ceased in Western Germany in 1988 but by then about 24 800 holes had been drilled, totalling about 354 500 m. Total expenditures were on the order of USD 111 million.

Former German Democratic Republic (GDR) before 1990

Uranium exploration and mining were undertaken from 1946 to 1953 by the Soviet stock company, SAG Wismut. These activities were centred around old mining locations of silver, cobalt, nickel, and other metals in the Erzgebirge (Ore Mountains) and in Vogtland, Saxony, where uranium had first been discovered in 1789.

Uranium exploration had started in 1950 in the vicinity of the radium spa at Ronneburg. Using a variety of ground-based and aerial techniques, the activities covered an extensive area of about 55 000 km^2 in the southern part of the GDR. About 36 000 holes in total were drilled in an area covering approximately 26 000 km^2. Total expenditures for uranium exploration over the life of the GDR programme were on the order of 5.6 billion GDR marks.

Uranium mining first began shortly after World War II in cobalt and bismuth mines near Schneeberg and Oberschlema (a former famous radium spa). During this early period more than 100 000 people were engaged in exploration and mining activities. The rich uraninite and pitchblende ore from the vein deposits was hand-picked and shipped to the USSR for further processing. Lower-grade ore was treated locally in small processing plants. In 1950, the central mill at Crossen near Zwickau, Saxony, was brought into operation.

In 1954, a new joint Soviet-German stock company was created, Sowjetisch-Deutsche Aktiengesellschaft Wismut (SDAG Wismut). The joint company was held equally by both governments. All production was shipped to the USSR for further treatment. The price for the final product was simply agreed upon by the two partners. Profits were used for further exploration.

At the end of the 1950s, uranium mining was concentrated in the region of eastern Thuringia. From the beginning of the 1970s, the mines in eastern Thuringia provided about two-thirds of SDAG Wismut's annual production.

Between the mid-1960s and the mid-1980s, about 45 000 people were employed by SDAG Wismut. In the mid-1980s, Wismut's employment decreased to about 30 000. In 1990, only 18 000 people worked in uranium mining and milling, and the number of employees has declined since that time as remediation activities are completed.

Recent and ongoing uranium exploration and mine development activities

There have been no exploration activities in reunified Germany since the end of 1990. Several German mining companies, however, did perform exploration abroad (mainly in Canada) through 1997.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Identified conventional resources were last assessed in 1993. These identified conventional resources occur mainly in the closed mines that are in the process of being decommissioned. Their future availability remains uncertain.

Undiscovered conventional resources (prognosticated and speculative resources)

All undiscovered conventional resources are reported as speculative resources in the cost category <USD 260/kgU.

Unconventional resources and other materials

None reported.

Uranium production

Historical review

Federal Republic of Germany (FRG) before 1990

In the FRG, a small (125 tonnes per year) uranium processing centre in Ellweiler, Baden-Württemberg, began operating in 1960 as a test mill. It was closed on 31 May 1989 after producing a total of about 700 tU.

Former German Democratic Republic (GDR) before 1990

Two processing plants were operated by SDAG Wismut in the territories of the former GDR. A plant at Crossen, near Zwickau in Saxony, started processing ore in 1950. The ore was transported by road and rail from numerous mines in the Erzgebirge. The composition of the ore from the hydrothermal deposits required carbonate pressure leaching. The plant had a maximum capacity of 2.5 million tonnes of ore per year. Crossen was permanently closed on 31 December 1989.

The second plant at Seelingstadt, near Gera, Thuringia, started ore processing operations in 1960 using the nearby black shale deposits. The maximum capacity of this plant was 4.6 million tonnes of ore per year. Silicate ore was treated by acid leaching until the end of 1989. Carbonate-rich ores were treated using the carbonate pressure leaching technique. After 1989, Seelingstadt's operations were limited to the treatment of slurry produced at the Königstein mine using the carbonate method.

A total of over 200 000 tU was produced in the GDR between 1950 and 1989.

Status of production facilities, production capability, recent and ongoing activities and other issues

There is no commercial production of uranium in Germany today. Decommissioning of the historic German production facilities started in 1989 (former FRG) and 1990 (former GDR). Between 1991 and 2020, uranium recovery from mine water treatment and environmental restoration amounted to a total of 2 631 tU. Since 1992, all uranium production in Germany has been derived from the clean-up operations at the Königstein mine. In 2020, conversion work of the water treatment facility at the Königstein mine finally ended uranium production in Germany. The existing system was adapted to future requirements, whereby the technological process phase of selective uranium separation was omitted owing to the decreasing content of uranium and heavy metals in the flood water in recent years. Future water treatment at the Königstein mine site will still be required but without any special separation of uranium. This brings an end to uranium mining in Germany after almost 75 years.

Ownership structure of the uranium industry

The production facilities in the former GDR were owned by the Soviet-German company Wismut (SDAG Wismut). After reunification, the German Ministry of Economy inherited the ownership from SDAG Wismut. The German federal government, through Wismut GmbH, took responsibility for the decommissioning and remediation of all production facilities. The government retains ownership of all uranium recovered in clean-up operations.

In August 1998, Cameco completed its acquisition of Uranerz Exploration and Mining Ltd (UEM), Canada, and Uranerz USA Inc. (UUS), from their German parent company Uranerzbergbau GmbH (Preussag and Rheinbraun, 50% each). As a result, there remains no commercial uranium industry in Germany.

Employment in the uranium industry

All employment is engaged in decommissioning and rehabilitation of former production facilities. Employment decreased from 911 in 2020 to approximately 800 in 2022.

Future production centres

None reported.

Uranium policies, uranium stocks and uranium prices

In accordance with the 2010 Energy Concept, the German government had decided to phase out the use of nuclear power for commercial electricity generation in stages by the end of 2022 at the latest. The accelerated nuclear phase-out was passed into law in 2011 by a broad consensus in the German parliament – the Bundestag – with the adoption of the Thirteenth Amendment to the Atomic Energy Act. The phase-out law entered into force on 6 August 2011. In the fall of 2022, the German government and the German Bundestag decided to allow limited extended operation for the last three nuclear power plants until 15 April 2023 at the latest. The three nuclear power plants – Emsland in Lower Saxony, Isar 2 in Bavaria and Neckarwestheim 2 in Baden-Württemberg – finally ceased power operation on 15 April 2023. This marked the end of nuclear power use in Germany. According to the Atomic Energy Act, the nuclear power plants must now be decommissioned and dismantled without delay. The first decommissioning application for Neckarwestheim 2 was already approved at the beginning of April 2023.

A total of 37 nuclear power plants have been built in Germany and put into commercial operation since 1962. In 2022, there were three nuclear power plants operating with installed generating capacity of approximately 4 GW. The shutdown of these last three nuclear power plants on 15 April 2023 ended the use of nuclear energy in Germany. The Grohnde, Gundremmingen C and Brokdorf nuclear power plants were already shut down in 2021.

Reasonably assured conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	0	3 000	
Total	0	0	0	3 000	

Reasonably assured conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	0	3 000	
Total	0	0	0	3 000	

Inferred conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	0	4 000	
Total	0	0	0	4 000	

Inferred conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	0	4 000	
Total	0	0	0	4 000	

Historical uranium production by processing method

(recoverable tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Unspecified	217 165	0	0	217 165	0
Other methods*	2 631	0	0	2 631	0
Total	219 796	0	0	219 796	0

* Includes mine water treatment and environmental restoration.

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	0	74 000

Ownership of uranium production in 2022

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
0	100	0	0	0	0	0	0	0	100

Uranium industry employment at existing production centres

(person-years)

	2020	2021	2022	2023 (expected)
Total employment related to existing production centres	911	857	800	750
Employment directly related to uranium production	NA	NA	NA	NA

Mixed oxide fuel production and use

(tonnes natural U-equivalent)

Mixed oxide (MOX) fuel	Total through end of 2020	2021	2022	Total through end of 2020	2023 (expected)
Production	0	NA	NA	NA	NA
Use	6 730	NA	NA	NA	NA
Number of commercial reactors using MOX		NA	NA		

* Reactors loading fresh MOX.

Re-enriched tails production and use

(tonnes natural U-equivalent)

Re-enriched tails	Total through end of 2018	2019	2020	2021	Total through end of 2022	2023 (expected)
Production	NA	NA	NA	NA	NA	NA
Use	NA	0	0	0	0	-

Reprocessed uranium use

(tonnes natural U-equivalent)

Reprocessed uranium	Total through end of 2019	2020	2021	2022	Total through end of 2022	2023 (expected)
Production	NA	0	0	0	0	-
Use	NA	NA	NA	NA	NA	NA

Net nuclear electricity generation

	2021	2022
Nuclear electricity generated (TWh net)	65.4	32.7

Installed nuclear generating capacity to 2050

(MWe net)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
8 113	8 055	0	0	0	0	0	0	0	0	0	0	0	0

Annual reactor-related uranium requirements to 2050 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
521	NA	0	0	0	0	0	0	0	0	0	0	0	0

Total uranium stocks

(tonnes natural U-equivalent)

Holder	Natural uranium stocks in concentrates	Enriched uranium stocks	Enrichment tails	LWR reprocessed uranium stocks	Total
Government	NA	NA	NA	NA	NA
Producer	NA	NA	NA	NA	NA
Utility	NA	NA	NA	NA	NA
Total	NA	NA	NA	NA	NA

Ghana

Uranium exploration and development

Historical review

In 1952, the first radioactive mineral prospecting was conducted by D. Ostle, P.H. Hale with other geologists from the Gold Coast Geological Survey Department and concluded on uranium deposits as speculative (SR). The United Kingdom Geological Survey in 1953 conducted a radiometric survey to determine thorium and uranium minerals in allanite and pyrochlore, and also concluded uranium deposits in Ghana as speculative (SR). Between 1968 and 1970, Uranerzbergbau-GmbH reported heavy mineral concentrations in sandstones of the Voltaian basin and pitchblende bearing pegmatites, as well as thorium concentrations in laterite, classified as prognosticated resources (PR). The International Atomic Energy Agency in 1975 and 1976 carried out uranium exploration in southern Ghana (Cape Coast) on pegmatites and concluded as speculative resources (SR).

Exploration activities of uranium deposits conducted in 1982, 2008 and 2010 yielded prognosticated resources in the Dahomeyan, Voltain and Keta basins.

Recent and ongoing uranium exploration activities

An African Regional Cooperative Agreement for Research (AFRA), with project code "Project Code: RAF2014", commenced in January 2022 with the objective of determining uranium and thorium concentrations in Takoradi Carboniferrous shales. The results obtained from geochemical analyses on 19 rock samples collected from the Takoradi Black Shales of Sekondian Group of Ghana show a Th and U contents range of 18.05-22.06 ppm and 6.89-22.6 ppm and the average contents of 20.74 ppm and 8.27 ppm, respectively.

Uranium resources

Ghana does not report any resources in any category.

Uranium production

No uranium production has occurred.

Guyana

Uranium exploration and mine development

Historical review

The British Guiana Geological Survey, a former independent department in charge of natural resources in Guyana and supported by the United Kingdom, was originally responsible for mineral development. The Geological Survey Department worked intensively through the colonial development and welfare project No. D 2792 (Continuation & Expansion of Geological Survey) from 1956 to 1960. This project made provision for the expansion of the Geological Survey Department to carry out intensive mineral development. In June 1958, a geologist with specific experience in the geology of uranium arrived in Georgetown to organise exploratory operations for radioactive minerals and other key minerals such as beryllium. An occurrence of radioactive material discovered on the railway line under construction between Kaituma River and the property of the Northwest Guiana Mining Company Ltd. was examined in some detail by ground and airborne surveys but proved to be euxenite (a refractory mineral). Nonetheless, investigations were extended to lithium minerals required in the nuclear power industry, as well as to radioactive minerals.

The Guyana Geology and Mines Commission (GGMC), established in 1979, is presently in charge of geological mapping throughout Guyana. The Geological Services Division (GSD) works to help the GGMC achieve its mission to "provide effective stewardship of our mineral and petroleum resources by ensuring increased opportunities for development (exploration, documentation and extraction), as well as to promote and support increased investment in the mining and related sectors". To examine and explore Guyana's uranium content, regional private programmes were launched.

The Moruwa Formation in Guyana was first investigated by Cominco Ltd during the period 1967-1975. Four holes were drilled, but the venture for them was not successful (Gibbs and Barron, 1993) even though they found high uranium-bearing lateritic conglomerate boulders in the river. In the 1970s and 1980s, there were reports of possible unconformity-type uranium deposits (Workman and Breede, 2012). Between 1968 and 1970, Denison Mines Corp. investigated the potential for uranium in palaeo-placers in the conglomerate Roraima Formation. An airborne scintillometer survey was part of the project. Eleven anomalies were discovered (several of them minor), and four were chosen for additional investigation, including diamond drilling (vertical holes). Anomalies were attributed to the mass impacts of cliff exposures and thorium concentrations in sediments, but no significant results were found.

Compagnie Générale des Matières Nucléaires ("COGEMA") then carried out exploration in Guyana from 1979 to 1984 and discovered numerous uranium prospects and showings through simple ground and airborne scintillometer surveys along the periphery of the basin. COGEMA first chose Mahdia and Kurupung as the bases for their stream sediment collection workers since they had daily air service from Georgetown at that time. Portable boats and helicopters equipped with scintillometers were employed to conduct effective sampling of the interior of the area. They moved unevenly and widely across the country to pick up any aberrant locations rather than identify and delineate anomalies on the ground like a grid survey would.

The survey crisscrossed the surrounding Anarabisi and Aricheng districts many times, so Kurupung was a fortunate choice. These resulted in 4 and 3.5 times the background radiation, respectively. COGEMA focused research on the area between Aricheng and Anarabisi. A number of sub-prospects were located within this district, and they were thoroughly studied utilising ground-based mapping, soil sampling, pitting, scintillometer surveys, and intensive drilling with diamond and percussion rigs. A number of possibilities were drilled in the Kurupung/Aricheng area. From stream sediments in Aricheng came the highest reading of 50 ppm uranium (0.005% U) in the country. Initially, 2 800 stream sediment samples were involved and 3 400 profile line kilometres were flown.

Merume, which is in the south, and Anarabisi, which is in the north, have uranium outcrops (uraninite and chalcocite) of 70 km spread out in eight locations (Workman and Breede, 2012). An assay sample from this vein contained 3 040 ppm U (0.304% U). A total of 253 diamond drill holes were drilled, with the deepest being ARNO 0001 at Aricheng North. Uranium mineralisation was identified in the Kurupung-Anarabisi granite batholith and in the Haimaraka basement shales.

COGEMA also investigated uranium in the Iwokrama Formation acid volcanics and differentiated granitoids between 1980 and 1984. In most accessible places north of the Takatu Graben, mainly in areas accessible by 4WD track or boat, extensive regional investigations were carried out. The completed tasks included granite sampling, alluvial mud sampling, ground and airborne scintillometer surveys, and later, systematic grid-based airborne radiometric surveys in a variety of regions, as well as extensive geological mapping and sampling. GGMC chemical data indicated that more U is found in stream sediments derived from granitic areas and Iwokrama Formation acid volcanics, and this was confirmed by COGEMA. In GGMC stream sediments, the maximum quantity of U and Th is 27 ppm, while the maximum amount of U and Th in rocks is 20.7 ppm (0.003% U) and 48.2 ppm, respectively. The maximum amount observed by COGEMA from the mud bank sample was 16 ppm U (0.0016% U). GGMC granite rock samples continued to show the highest uranium values; however, four laterite samples and two hornfelsed Roraima Formation mudstone samples also contained more than 10 ppm U (0.001% U).

Between 1980 and 1983, a United Nations team investigated a carbonatite complex for rare earth minerals at Muri Mountain, in southern Guyana on the border with Brazil. The work included an airborne radiometric survey, radioactive and magnetic ground surveys, stream sediment, soil and rock sampling, as well as diamond drilling. The GGMC reported assays in rock of up to 43 ppm U (0.0043% U).

Since 2012, no noteworthy uranium exploration has taken place in Guyana. However, there were three uranium exploration ventures of note: Prometheus Resources (Guyana) Inc. of U3O8 Corp. (hereafter referred to as "U3O8 Corp"), a Canadian company; Pharsalus Gold Inc., a wholly owned subsidiary of Australia-based Azimuth Resources Ltd and Raven Minerals Corp. U3O8 Corp. provided the most significant results.

The initial public offering of shares by U3O8 Corp. was made in December 2006. The company was given large-scale reconnaissance permissions and prospecting licences for uranium in the Rupununi, Potaro, Mazaruni, Cuyuni and Barama River basins. Prospecting was also undertaken in Kato, Monkey Mountain and Paramakatoi (Colchester and La Rose, 2010). Prior to this, the company's exploration had consisted primarily of confirmatory work at some of the more advanced historical prospects. This included rock chip sampling, sampling of discarded drill core, thin section and polished section work, and electron microprobe examination of mineralised samples. In 2007, exploration work included ground radiometric surveys designed to confirm airborne radiometric anomalies in the Kurupung batholith and to provide more detail on their form and location. The project covered the Kurupung batholith (granite and granodiorite) and surrounding country rocks (greenstone) next to areas of the Roraima Basin (epiclastic sedimentary strata). The initial diamond drilling was designed to twin and test mineralised intervals reported by COGEMA to the GGMC. After initial confirmation of the presence of mineralisation in the twin holes, drilling progressively stepped out to follow the mineralised structure along strike and down-dip. More than 7 305 metres of drilling was undertaken in 51 bore holes on the Aricheng North, Arichen South and Aricheng West structures. U3O8 Corp. resource drilling defined four uranium deposits in the Aricheng South, North, West and C zones of the Kurupung Project. These findings suggest that Kurupung could host a large uranium system comparable in size to other peer deposits such as Coles Hill in Virginia (United States), Michelin in Labrador (Canada) and Valhalla in Queensland (Australia). Currently, however, there are no active permits for any of the three companies.

Recent and ongoing uranium exploration and mine development activities

Since U_3O_8 Corp. left Guyana in 2012, there has been no significant exploration, but the GGMC continues to conduct annual geochemical projects to map the country's mineral potential. In a bid to fulfil this mandate, the GSD continues to play its part in exploring geology and mineral resources around the country. In recent years, GGMC chemical data from the Permission for Geological and Geographical Survey (PGGS) areas for both light and heavy rare earth elements have shown that uranium levels are higher than other elements, ranging from more than 2.7 to 296 ppm (0.0003% U to 0.03% U). Since 2020, however, no project work has been done.

GGMC is slated to continue to carry out geochemical survey projects in Guyana's interior, beginning in September 2021. The majority of uranium discoveries thus far, including the Aricheng South, West, North and C resources, will be used to identify potential targets that are now being investigated in the field in order to increase the inventory of mineralised structures for future resource extension. Development of resource estimates is possible, given the significant exploratory work already undertaken.

Uranium resources

In 2012, U_3O_8 Corp. estimated the uranium resources of the Aricheng structures (Kurupung area) in accordance with National Instrument 43-101.

Identified conventional in situ resources (reasonably assured and inferred resources)

Structure	Indicated			Inferred		
	Ore (t)	Grade (%U)	U (t)	Ore (Mt)	Grade (%U)	U (t)
Aricheng C	686 000	0.07	4 70	1 110 000	0.08	884
Aricheng West	749 000	0.07	5 30	2 518 000	0.06	1 549
Aricheng South	1 895 000	0.10	8 06	223 000	0.09	199
Aricheng North	782 000	0.08	1 430	422 000	0.08	315
Total Kurupung	4 112 000	0.08	3 236	4 273 000	0.07	2 947

Mineral resources were estimated using an inverse distance squared (ID2) block model, constrained to a geological model with a minimum horizontal width of 2 m. A cut-off grade of 0.042% U was used for reporting of the resources. No deductions for mining recovery or otherwise were included in this estimate and mineral resources were estimated using an assumed price of USD 55/lb U_3O_8 (USD 143/kgU).

Undiscovered conventional resources (prognosticated and speculative resources)

Guyana does not report resources in any other category than reasonably assured resources.

Environmental activities and socio-cultural issues

Many exploration concessions have had an immediate impact on ancestral lands (titled and untitled). Toshaos and leaders from Region 8 complain, for example, that large-scale uranium and gold licences associated with U_3O_8 Corp. and Mahdia Gold Corp. had a direct impact on the Patamona people's traditional lands and territory. Furthermore, they argue that the affected Amerindian villages lack basic information on these mining interests, as well as the specific mining and exploration intentions in Region 8.

Moreover, social conditions in mining villages could have received more attention. The GGMC, in partnership with the Ministries of Health and Education, could have developed, monitored and enforced minimum acceptable standards. The GGMC could have also worked with the Ministry of Health and the Guyana Forestry Commission. To comply with the standards of the Guyanese Environmental Protection Agency ("EPA"), the existing regulations contain a provision for the filing of an Exploration Plan.

Regulatory regime

Mining operations and environmental monitoring in Guyana are governed by the GGMC. Support is also given by the Environmental Protection Agency (EPA) and the Guyana Forestry Commission (GFC).

The regulatory regime for uranium mining in Guyana is the Guyana Geology and Mines Commission (GGMC), an independent body that regulates mining of minerals in Guyana.

All activities are covered by the following legislation:

- Order made under the Mining Act (No. 10 of 1989) Section 16 – This Order may be cited as the Guyana Geology and Mines Commission "Prospecting for Uranium, Radioactive Minerals and Rare Earth Elements" (Reservation Order 2006 that came into effect on 23 October 2006).
- The Mining Act, No. 20 of 1989 (the "Mining Act") grants licences and authorisation for mineral prospecting, mining and development, as well as geological and geophysical investigations. The GGMC reviews and approves all investment projects involving the extraction of mineral resources in general. The government of Guyana passed the Environmental Protection Act in 1996 that requires an environmental permit from the Guyana Environmental Protection Agency before a mining property can be put into production.

The GGMC is tasked with promoting all development, mining and mineral exploration. It also provides technical assistance and advice in mining, mineral processing, mineral utilisation and marketing of mineral resources. In its current form, the commission has a remit for: promotion of mineral development; research in exploration, mining, and utilisation of minerals and mineral products; enforcement of the conditions of mining licences; collection of rentals, fees, charges, levies, etc. payable under the Mining Act. The government of Guyana (GGMC) has granted licences and permissions regarding mineral prospecting, mining and development as well as geological and geophysical surveys. All investment projects that involve the extraction of mineral resources are generally reviewed and approved by the GGMC.

National policies relating to uranium

With respect to energy in the mining industries, it is the government's policy to:

- increase end-use energy conservation and efficiency;
- achieve grid-tied cogeneration of electricity and industrial steam;
- reduce the local environmental impacts of energy production;
- improve corporate management practices with respect to standards for energy management systems;
- enhance the socio-economic development of the surrounding communities.

Uranium stocks

None

Uranium prices

There is no uranium market in Guyana.

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	0	3 236	NA
Total	0	0	0	3 236	NA

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	0	3 236	NA
Total	0	0	0	3 236	NA

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Metasomatite	0	0	0	3 236
Total	0	0	0	3 236

Inferred conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	0	2 947	NA
Total	0	0	0	2 947	NA

Inferred conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	0	2 947	NA
Total	0	0	0	2 947	NA

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Metasomatite	0	0	0	2 947
Total	0	0	0	2 947

Hungary

Uranium exploration and mine development

Historical review

The first reconnaissance for uranium started in 1952 when, with Soviet participation, material from Hungarian coal deposits was checked for radioactivity. The results of this work led to a geophysical exploration programme (airborne and surface radiometry) in 1953 over the western part of the Mecsek Mountains. The discovery of the Mecsek deposit was made in 1954 and further work was aimed at the evaluation of the deposit and its development. The first shafts were excavated in 1955 and 1956 for the mining of sections I and II. In 1956, the Soviet-Hungarian uranium joint venture was dissolved, and the project became the sole responsibility of the Hungarian state. That same year, uranium production began. Production began to decline in the late 1980s and ended after 1998.

Recent and ongoing uranium exploration and mine development activities

A non-governmental mine development project started in 2007 with a focus on the area of the Mecsek deposit. To date, the Environmental Impact Studies submitted have failed to lead to the necessary license to develop a mine, even at reduced production rates. The company seeking the license has again submitted a modified Environmental Impact Study; however, the only way to establish a mining property is through public concession tendering, provided the government launches the tendering procedure.

Uranium resources

Hungary's reported uranium resources are limited to those of the Mecsek deposit. The ore is hosted by Upper Permian sandstones with a thickness of up to 600 m. During the Cretaceous period, the Permo-Triassic sandstones were folded into an anticline that makes up the framework structure of the Mecsek Mountains. The ore-bearing sandstone in the upper 200 m of the unit is underlain by a thick layer of Permian siltstone and covered by Lower Triassic sandstone. The thickness of the green-grey ore-bearing sandstone, locally referred to as the "productive complex", varies from 15 to 90 m. The ore minerals include uranium oxides and silicates associated with pyrite and marcasite.

Identified conventional resources (reasonably assured and inferred resources)

There has been no change regarding the identified conventional uranium resources since the previous edition of the Red Book. As of 1 January 2023, the identified conventional resources amounted to a total of 22 230 in situ tU (16 673 recoverable tU) according to the Hungarian National Mineral Resource Inventory (all are Inferred Resources [IR]; no reasonably assured resources [RAR] are reported).

Undiscovered conventional resources (prognosticated and speculative resources)

The prognosticated resources amount to a total of 14 845 tU (in situ), unchanged compared to the amount reported in the previous edition of the Red Book. These resources are tributary to the former Mecsek production centre. Speculative resources have not been estimated.

Uranium production

Historical review

The Mecsek underground mine and mill, situated near the city of Pécs, was the only uranium production centre in Hungary. Prior to 1 April 1992, it was operated by the state-owned Mecsek Ore Mining Company (MÉV). The mine began operation in 1956 and produced ore from a depth of 100 to 1 100 m until it was ultimately shut down in 1997. During operation, it produced about 500 000-600 000 tonnes ore/yr with an average mining recovery of 50-60%. The ore processing plant had a capacity of 1 300 to 2 000 tonnes ore/day and employed radiometric sorting, agitation acid leach (and alkaline heap leaching) with ion-exchange recovery. The nominal production capacity of the plant was about 700 tU/yr.

The Mecsek mine consisted of five sections with the following history:

- section I: operating from 1956 to 1971;
- section II: operating from 1956 to 1988;
- section III: operating from 1961 to 1993;
- section IV: operating from 1971 to 1997;
- section V: operating from 1988 to 1997.

The ore processing plant became operational in 1963. Prior to its operation, 1.2 million tonnes of unprocessed ore were shipped to the Sillimae metallurgy plant in Estonia. After 1963, processed uranium concentrates were shipped directly to the former Soviet Union.

Mining and milling operations were shut down at the end of 1997 because changes in market conditions made the operation uneconomic. Throughout its operational history, total production from the Mecsek mine and mill, including heap leaching, amounted to about 21 000 tU.

Status of production capability

Since the closure of the Mecsek mine in late 1997, the only production of uranium in Hungary has been as a by-product recovery of water treatment activities (see item (3) in the next paragraph), amounting to a total of about 2-6 tU/yr. During this reporting period 2-3 tU/yr were recovered. Section III of the historic mine workings below the water drainage horizon (formerly the main haulage adit) was completely flooded, and it is expected that Sections II-IV-V will be flooded by 2024.

Environmental activities and socio-cultural issues

Closure and large-scale site remediation activities at the Mecsek uranium production centre were carried out between 1998 and 2008. The remediation consisted of: 1) removing several hundred thousand tonnes of contaminated soil from various areas around the site to an on-site disposal facility; 2) remediation of tailing ponds and waste rock piles by the placement of isolating soil covers; and 3) abandonment and closure of underground mine workings, as well as groundwater extraction and treatment. Although the large-scale remediation programme was completed by the end of 2008, long-term care activities, such as groundwater remediation, environmental monitoring and maintenance of the engineered disposal systems, will likely need to continue for some years.

Since July 2016, long-term care of Hungarian uranium mining and ore processing legacy sites is under the direct responsibility of the Mining Property Utilization Company in the Public Interest (www.bvh.hu). As the legal successor of the former Mecsek mine (a state-owned venture), it is responsible for paying compensation, including damages for occupational disease, income and pension supplements, reimbursements of certified costs and dependent expenses to people formerly engaged in uranium mining. Costs associated with the environmental remediation of the Mecsek mine are provided in the following table.

Costs of environmental management

(HUF thousands)

	Pre-1998	1998 to 2008	2009 to 2022
Closing of underground spaces	NA	2 343 050	W
Reclamation of surficial establishments and areas	NA	2 008 403	W
Reclamation of waste rock piles and their environment	NA	1 002 062	W
Reclamation of heap leaching piles and their environment	NA	1 898 967	W
Reclamation of tailings ponds and their environment	NA	8 236 914	W
Water treatment	NA	1 578 040	W
Reconstruction of electric network	NA	125 918	W
Reconstruction of water and sewage system	NA	100 043	W
Other infrastructural service	NA	518 002	W
Other activities including monitoring, staff, etc.	NA	2 245 217	W
Total	5 406 408	20 056 616	W

NA = Not available. W = Withheld.

After remediation of the uranium mining and ore processing legacy sites, the annual cost of long-term care activities amounts to some HUF 600-750 million.

Regulatory regime

In Hungary, the mining activity is supervised and the licences for the entire territory of the country are issued by the Mining Authority, which is a division of the Supervisory Authority of Regulatory Affairs. There is no specific regulation dedicated to uranium mining; the general mining law applies to uranium ore production. In the past, the regional mining offices granted uranium exploration and production licences. Currently, the only way to obtain a new uranium exploration or production right (concession) is through public tendering, provided that the government decides to start such a procedure. In addition to the mining licence or concession, a number of other licences have to be obtained, such as environmental and land utilisation licences.

The mining companies, including uranium ore producers, must have financial guarantees supported by detailed expense calculations to cover the mine closure and decommissioning costs. The guarantees are checked and monitored by the Mining Authority.

Since uranium is nuclear material, the Mining Property Utilization Company (MPUC), based on HAEA Decree 4/2022 (IV. 29.) on the rules of accountancy for and control of nuclear materials, has the necessary safeguards licences issued by the Hungarian Atomic Energy Authority (HAEA), and fulfils its national and international reporting and data provision obligations to the HAEA, EURATOM and the IAEA. Data reported by the Company are verified by the safeguards inspectors of the HAEA, EURATOM and the IAEA, in course of on-site inspections.

The MPUC also has the necessary physical protection licences regarding the usage, storage and transport of the nuclear material, based on Government Decree 190/2011 (IX. 19.) on physical protection requirements for various applications of atomic energy and the corresponding system of licensing, reporting and inspection.

Uranium requirements

In January 2020, the government approved the new National Energy Strategy 2030 and the National Energy and Climate Plan, and opted for the long-term maintenance of nuclear in the energy mix. In 2022, the MVM Paks Nuclear Power Plant Ltd. (Paks Nuclear Power Plant) generated 15 812 GWh electricity, which accounted for 47% of gross electricity generation and 34.6% of domestic electricity consumption. The 2022 Unit Capability Factors are as follows: Unit 1: 81.4%; Unit 2: 97.2%; Unit 3: 92.6%; Unit 4: 89.1%, the average for the plant is 89.1%.

The licensing procedure for the lifetime extension of the Paks Nuclear Power Plant from 30 to 50 years has been fully completed. Preparations are underway to further extend the operating lifetime for 20 more years. Regarding the two new units planned (units 5 and 6), the construction licence application was issued by the Hungarian Atomic Energy Authority (HAEA) on 25 August 2022.

National policies relating to uranium

Since the shutdown of the Hungarian uranium mining industry in 1997, there have been no uranium-related policies. The Energy Mineral Resources Utilisation and Stock Management Action Plan summarises the available Hungarian uranium resources. It concludes that if uranium ore mining is profitable, the government should consider partnerships with private investors in mining, through state-owned companies. However, there is at present no government measure or action planned to facilitate mining.

Uranium stocks

The by-product ($UO_4{\cdot}2H_2O$) of the water treatment activities at the former uranium mining and ore processing site (see the environmental activities above) is stored at the mine water treatment facility until export. At the end of 2020, the inventory amounted to 9 473 kgU. Export of 10 192 kgU to France in October 2021 was reported to HAEA by the MPUC in January 2021. At the end of 2022, the inventory amounted to 3 473 kgU.

Uranium prices

Uranium prices are not available as they are commercially confidential.

Uranium exploration and development expenditures and drilling effort – domestic

(EUR)

	2020	2021	2022	2023 (expected)
Private* exploration expenditures	NA	NA	NA	NA
Government exploration expenditures	0	0	0	0
Private* development expenditures	NA	NA	NA	NA
Government development expenditures	0	0	0	0
Total expenditures	NA	NA	NA	NA

* Non-government.

Inferred conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	0	0	22 230	75*
Total	0	0	0	22 230	75*

* Estimated.

Inferred conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	0	0	22 230	75*
Total	0	0	0	22 230	75*

* Estimated.

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	0	22 230
Total	0	0	0	22 230

Prognosticated conventional resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	0	14 845

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Underground mining*	21 000	0	0	21 000	0
Co-product/by-product	89	2	2	93	3
Total	21 089	2	2	21 093	3

* Pre-2018 totals may include uranium recovered by heap and in-place leaching.

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Conventional	20 475	0	0	20 475	0
Heap leaching*	525	0	0	525	0
Other methods**	89	2	2	93	3
Total	21 089	2	2	21 093	3

* A subset of open-pit and underground mining since it is used in conjunction with them.

** Includes mine water treatment and environmental restoration.

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Sandstone	21 089	2	2	21 093	3
Total	21 089	2	2	21 093	3

Ownership of uranium production in 2022

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
2	100	0	0	0	0	0	0	2	100

Uranium industry employment at existing production centres

(person-years)

	2020	2021	2022	2023 (expected)
Total employment related to existing production centres	NA	NA	NA	NA
Employment directly related to uranium production	NA	NA	NA	NA

Net nuclear electricity generation (TWh net)

	2021	2022
Nuclear electricity generated (TWh net)	15.13	14.95

Installed nuclear generating capacity to 2050

(MWe net)

2021	2022	2025		2030		2035		2040		2045		2050	
1 916	1 916	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
		1 916	1 916	3 100	4 284	4 284	4 284	4 284	4 284	4 284	4 284	4 284	4 284

Annual reactor-related uranium requirements to 2040 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
330	327	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
		339	339	566	799	799	799	799	799	799	799	799	799

Total uranium stocks

(tonnes natural U-equivalent)

Holder	Natural uranium stocks in concentrates	Enriched uranium stocks	Enrichment tails	LWR reprocessed uranium stocks	Total
Government	0	0	0	0	0
Producer	3	0	0	0	3
Utility	0	0	0	0	0
Total	3	0	0	0	3

India

Uranium exploration and mine development

Historical review

The history of exploration for atomic minerals, including uranium, in India dates to the discovery of the occurrence of monazite-bearing black sand along the southern and southwestern coast of India in 1909. The first report of uranium in India was in 1913 when an occurrence of gummite (altered uraninite) and a 36-pound pure uraninite nodule was discovered from a pegmatite at Bihar.

In India, exploration for uranium is carried out by the Atomic Minerals Directorate for Exploration and Research (AMD). The AMD emerged from a dedicated wing of the Survey of India (GSI) named the Rare Minerals Survey Unit (RMSU) created during the Second World War (1939-1945). Subsequently, after the promulgation of the Atomic Energy Act and the constitution of the Atomic Energy Commission (AEC) in 1948, the RMSU was brought under the AEC in 1949.

The first extensive surveys for uranium began in 1949 in the Singhbhum Shear Zone (SSZ), Eastern India and the first exploratory drilling for uranium commenced in 1951 in Jaduguda in the SSZ. Until the mid-1970s, uranium exploration was mainly confined to uranium provinces in the SSZ, Jharkhand, and in the Umra-Udaisagar area in the Aravalli Fold Belt in Rajasthan, targeting vein-type mineralisation. This resulted in the discovery of 16 low-grade uranium deposits of varying sizes in the SSZ, Jharkhand, and one deposit at Umra, Rajasthan. Exploratory mining commenced in Jaduguda as well as in Umra in 1957. Seven out of the sixteen deposits in the SSZ are under exploitation. Exploration is currently being carried out in several sectors of the 200 km long SSZ, especially in the central and southern sectors.

The introduction of airborne surveys during the late 1950s was a boon to the exploration activities of AMD. India has been one of the pioneers in using airborne surveys for uranium exploration. AMD commenced airborne surveys in 1955 with an indigenously designed and developed total gamma-ray count system to cover large areas of the country.

Uranium exploration was expanded to other favourable geological domains, which resulted in establishing several small uranium deposits such as Bodal and Bhandaritola, Chhattisgarh, in Paleoproterozoic amphibolites; Jajawal, Chhattisgarh, in Paleoproterozoic sheared migmatites of the Chhotanagpur Granite Gneiss Complex; and Walkunji, Karnataka, in basal quartz-pebble conglomerates of the Dharwar Group. There was a shift in the uranium exploration strategy in the 1970s and, subsequently, the Proterozoic and Phanerozoic sedimentary basins contiguous to fertile granitoid-rich provinces became potential targets for exploration.

During the mid-1970s, exploration targeted sandstone-type uranium deposits. The exploration for sandstone-type uranium mineralisation resulted in the discovery of a high-grade, medium-tonnage deposit at Domiasiat (Kylleng-Pyndengsohiong-Mawthabah) in the Cretaceous sandstones of the Meghalaya. Exploration in contiguous sectors has established several small uranium deposits.

During the mid-1980s, a low-grade, stratabound deposit hosted by dolostones of the Vempalle Formation was established at Tummalapalle, Andhra Pradesh, in the Proterozoic Cuddapah Basin. Since the dolostone ore was not amenable to conventional leaching procedures typical at that time, exploration in this sector was discontinued. However, the development of an economically viable alkali pressure leaching process rejuvenated the exploration activities in the Vempalle Formation along the southern part of the Cuddapah Basin, targeting carbonate-hosted uranium mineralisation. Intensive multi-parametric exploration carried out in Tummalapalle and adjacent sectors led to the identification of substantial uranium resources in the southern part of the Cuddapah Basin. The Tummalapalle uranium deposit is under exploitation.

During the early 1990s, a near-surface deposit was discovered adjacent to the unconformity contact between basement granites and the overlying Mesoproterozoic Srisailam Quartzite at Lambapur, Telangana (Andhra Pradesh). These occurrences were investigated, and several exploration areas were subsequently identified. Favourable geological criteria and sustained exploration efforts resulted in establishing deposits at Peddagattu and Chitrial along the unconformity contact between the basement granites and overlying quartzites of the Srisailam Formation. Exploration in the adjacent Palnad Sub-basin identified a small deposit at Koppunuru. Exploration is continuing in the Palnad Sub-basin.

Sustained exploration in the North Delhi Fold Belt (NDFB), in parts of Rajasthan and Haryana, targeting metasomatic-type uranium mineralisation, led to the discovery of the Rohil uranium deposit, in Rajasthan. Exploration is being carried out in various sectors of the ~300 km long "Albitite Line" in Rajasthan and Haryana. Intensive exploration in adjacent sectors of Rohil established another deposit in Jahaz, Rajasthan.

During the late 1990s, multi-parametric exploration in the Neoproterozoic Bhima Basin led to the discovery of a medium-grade and small-tonnage uranium deposit in Gogi, Karnataka, hosted by brecciated limestone and granite along the Gogi-Kurlagare-Gundahalli fault located in the southern part of the basin. Sustained exploration in this geological domain has established other uranium deposits in Kanchankayi and Hulkal.

Starting in the 2010s, AMD identified substantial uranium resources. Progressive advancement through adaptation of integrated multidisciplinary exploration techniques, coupled with major thrust in high-resolution heliborne- and ground-based geophysical data, exploration supported by state-of-the-art hydrostatic drilling rigs and analytical equipment, has facilitated systematic planning for future augmentation of uranium resources in favourable geological domains in the country.

Recent and ongoing uranium exploration and mine development activities

In the past few years, exploration activities have been concentrated in the following areas:

- Proterozoic Cuddapah Basin, Andhra Pradesh and Telangana.
- Mesoproterozoic Singhbhum Shear Zone, Jharkhand.
- Mesoproterozoic North Delhi Fold Belt, Rajasthan and Haryana.
- Cretaceous Mahadek Basin, Meghalaya.
- Neoproterozoic Bhima Basin, Karnataka.
- Mesoproterozoic Kaladgi Basin, Karnataka.
- Mesozoic Satpura Gondwana Basin, Madhya Pradesh.
- Mesoproterozoic Chhotanagpur Granite Gneiss Complex, Uttar Pradesh, Madhya Pradesh and Jharkhand state.
- Cenozoic Siwalik Group, Himachal Pradesh.
- Proterozoic Aravalli Fold Belt, Rajasthan.
- Other geological domains with potential are under active exploration such as the: basement fractures surrounding the southern part of Cuddapah Basin, Andhra Pradesh; Shillong Basin, Assam; basement crystalline terrain, Arunachal Pradesh; Vindhyan, Bijawar and Chhattisgarh basins, Uttar Pradesh, Madhya Pradesh and Chhattisgarh states; Kotri-Dongargarh belt, Chhattisgarh.
- Extensive exploration including ground and heliborne geophysical (ZTEM, TDEM, magnetic and radiometric), ground geological, radiometric, and geochemical surveys, and drilling are planned in other geological domains of the country that have the potential to host uranium mineralisation.

Proterozoic Cuddapah Basin, Andhra Pradesh and Telangana

The Cuddapah Basin (Paleo- to Neoproterozoic) of the Dharwar Craton of Southern Peninsular India is one of the major uranium provinces hosting uranium mineralisation at various stratigraphic levels. Three types of uranium mineralisation/deposits have been identified in the Cuddapah Basin: carbonate-hosted stratabound-type, unconformity-related, and fracture-controlled.

- Carbonate uranium deposits

The southern part of the Cuddapah Basin hosts a unique, low-grade and large-tonnage uranium deposit in the dolostones of the Vempalle Formation in the Tummalapalle-Rachakuntapalle sector. This formation occurs at the lower stratigraphic sequence of the Cuddapah Basin. Uranium mineralisation has been traced intermittently over a strike length of 160 km from Reddipalle in the north to Maddimadugu in the south-east. The vast extent of the deposit, its stratabound nature hosted by phosphatic dolostone, and point-to-point correlation with nearly uniform grade and thickness of the mineralisation over considerable lengths along the strike and dip, make the deposit unique. Two ore lodes with an average thickness of 2.30 m and 1.75 m, separated by a lean/unmineralised band of 1.0-3.0 m, are under active exploration at vertical depths of up to 1 100 m. Sustained exploration activities over the 21 km segment within the 160 km long belt have added substantial uranium resources. Intensive exploration in the eastern extension of the Tummalapalle-Rachakuntapalle sector has established sizeable ore blocks, named Rachakunatapalle East and Gidankivaripalle. Exploration is continuing in several sectors of the 21 km long belt.

- Proterozoic unconformity uranium deposits

The northwestern margin of the Cuddapah Basin, comprising the Meso- to Neoproterozoic Srisailam and Palnad Sub-Basins, is known for the potential for unconformity-related uranium deposits. Intensive exploration over the past few decades in the northern part of the Srisailam Sub-Basin has established three low-tonnage, low-grade uranium deposits named Lambapur, Peddagattu, and Chitrial (stratiform fracture-controlled deposit subtype). Exploration efforts along the northern margin of the Palnad Sub-basin have resulted in locating a low-grade and low-tonnage deposit at Koppunuru. Sustained exploration is continuing in potential sectors having a similar lithostructural setup. Substantial dimensions of uranium mineralisation occurring close to the unconformity between the basement granite and Gulcheru quartzite have been established in the Kappatralla outlier. Uranium mineralisation along the unconformity contact is also established in the Sarangapalli area in the Palnad Sub-basin, where the ore lode under active exploration transgresses the basement granite, quartzite and pebbly arenite of the overlying Banganapalle Formation.

- Sandstone, mafic dykes/sills in Proterozoic sandstone subtype uranium deposits

The Gulcheru quartzite of the Cuddapah Supergroup, overlying the basement granitoid in the southern parts of the Cuddapah Basin, is intensely fractured, faulted and intruded by east-west trending basic dykes. Uranium mineralisation is associated with the quartz-chlorite-breccia occurring along the contact between the Gulcheru quartzite and basic dykes. Furthermore, the fracture systems within the crystalline basement, proximal to the southern and southwestern margins of the Cuddapah Basin, are known to host uranium mineralisation and are currently under exploration (e.g. Kamaguttapalle-Kammapalle, Sivramapuram–Pincha and Madhavaram-Katimayakunta). The fracture zones occurring within the Cuddapah Basin around the basement inlier at Ipuru are also being investigated.

Mesoproterozoic Singhbhum Shear Zone, Jharkhand

The Singhbhum Shear Zone (SSZ) is a 160 km long, arcuate belt of tectonised rocks fringing the northern boundary of the Singhbhum craton along the contact with the Singhbhum Group rocks. Exploration efforts since the early fifties led to the identification of several low-grade and low- to medium-tonnage uranium deposits, some of which are under active exploitation. The established uranium deposits are mainly located in the central and eastern sectors of the shear zone. Intensive exploration in various sectors in the SSZ has added significant resources to the uranium inventory.

Notable among them are the Singridungri-Banadungri, Rajdah, Jaduguda North, Bangurdih and Narwapahar sectors. Intensive exploration carried out for polymetallic mineralisation, including uranium, has led to discovery of peridotite-hosted uranium mineralisation (U-Mg-Cr-Cu-Ni-Mo-Fe-REE) in the Kudada-Turamdih area in the central part of SSZ in the Proterozoic Iron Ore Group. The deposit is being developed through systematic exploratory drilling.

Mesoproterozoic North Delhi Fold Belt of Rajasthan and Haryana

The metasediments of the North Delhi Fold Belt, comprising the Khetri, Alwar, and Bayana-Lalsot Sub-Basins in the states of Rajasthan and Haryana, are the host to several uranium occurrences. The approximately 200 km long north-northeast to south-southwest NNE-SSW trending "Albitite Line" passing through the Delhi Supergroup and Banded Gneissic Complex is the site of extensive sodic metasomatism and holds great potential to host metasomatite-type uranium mineralisation. Integrated exploration including litho-structural, heliborne and ground geophysics and drilling resulted in the discovery of a fracture-controlled metasomatite-type uranium deposit near Rohil, Rajasthan. The entire "Albitite Line" holds immense potential for the discovery of additional uranium resources. Extensive ground and heliborne geophysical surveying and drilling have been carried out in several sectors along the "Albitite Line" for the delineation of metsomatite type uranium mineralisation. This has resulted in establishing a small-tonnage uranium deposit at Jahaz, Rajasthan. Further, these exploration efforts have resulted in establishing promising new sectors in Gumansingh-Ki-Dhani, Narsinghpuri and Hurra-Ki-Dhani, in the contiguous area of Rohil, which have similar geological settings. More recently, low-grade U-REE mineralisation associated with albitised metasediments in the form of multiple steep dipping ore lodes with varying thickness has been established in Geratiyon ki Dhani, Rajasthan over 1 200 m strike length and 450 m of depth. The deposit is being developed by systematic exploratory drilling.

Cretaceous Mahadek Basin, Meghalaya

The Upper Cretaceous Lower Mahadek Formation, exposed along the southern margin of the Shillong plateau, Meghalaya, is a potential host for uranium mineralisation. This geological domain has been under exploration since the late 1970s. Substantial exploration over the years led to the discovery of seven low- to medium-grade, low- to medium-tonnage, uranium deposits at Domiasiat, Wahkyn, Wahkut, Gomaghat, Tyrnai, Umthongkut and Lostoin.

Neoproterozoic Bhima Basin, Karnataka

The Bhima Basin comprises calcareous sediments with minor arenaceous lithostratigraphic units of the Bhima Group, which were deposited over basement granite and have been affected by several east-west trending faults. A small, medium-grade uranium deposit has been established at Gogi along the Gogi-Kurlagare-Gundahalli fault. Intensive multi-parametric exploration also established another deposit at Kanchankayi, Karnataka, adjacent to the Gogi uranium deposit. Current exploration efforts are concentrated in the east of the Kanchankayi sector, around Hulkal, along the northeastern extensions of the Gogi uranium deposit.

Palaeozoic – Mesozoic Satpura Gondwana Basin, Madhya Pradesh

The Gondwana age sedimentary basins of India comprise a suitable environment for hosting sandstone-type uranium mineralisation. The lower Motur Formation of the Satpura Gondwana Basin of Central India has been identified as the potential geological domain for hosting sandstone-type uranium mineralisation. Extensive surface and subsurface exploration in the Motur Formation has delineated significant uranium mineralisation in the Dharangmau – Kachhar sector. Exploration is continuing in this geological domain.

Mesoproterozoic Kaladgi Basin, Karnataka

The east-west trending Meso-Neoproterozoic Kaladgi Basin is located on the northwestern margin of the western Dharwar Craton. The unmetamorphosed sediments of the Kaladgi Supergroup overlie the basement granitoids and Chitradurga schists. The northern and western extensions of the basin are covered by the Deccan Traps. The basement is comprised of schist belts with slivers of graphite-bearing meta-pelites and granites with associated tectonism. Significant surface uranium mineralisation over a considerable extent hosted by arenites has been identified near Deshnur. Subsurface exploration in the western part of the Kaladgi Basin led to the emergence of another prospective sector in the Suldhal-Gujanal-Malarmardi area, where uranium mineralisation is hosted by the lower conglomerate, basal arenite and basement schist close to the unconformity.

Mesoproterozoic Chhotanagpur Granite Gneissic Complex (CGGC), Uttar Pradesh, Madhya Pradesh and Jharkhand

The Chhotanagpur Granite Gneiss Complex (CGGC) forms part of the prominent Mesoproterozoic linear mobile belt in East and Central India lying between the Narmada-Son-Brahmaputra lineaments designated as the "Central Indian Tectonic Zone" (CITZ) in the North and the Central Indian Suture (CIS) to the south. The CGGC hosts a thick pile of arkosic to psammo-pelitic metasediments that have undergone multiple phases of tectonic, plutonic, thermal and metamorphic events, which resulted in the extensive development of migmatites. The exposed rocks include banded gneisses and metasedimentary enclaves, overlain by the Mahakoshal supracrustals and sediments of the Vindhyan Supergroup in the north and Gondwana Supergroup in the south. Uranium mineralisation within migmatites is hosted by varied lithological units spread over a large area (350 km^2) in the Son valley crystallines, in the northwestern part of the CGGC. Intensive exploration is being carried out in potential blocks at Naktu, Kudar, Kudri, Jhapar, Kurludih and Anjangira, where the host rock is essentially an albite-rich pegmatoid leucosome mobilizate (PLM).

Cenozoic Siwalik Basin, Himachal Pradesh

The Siwalik Group constitutes a thick sequence of molasse deposits laid down in a long narrow fore-deep, formed to the south of the rising Himalayas during the Middle Miocene to the Pleistocene. The sediments are traceable in India from Jammu in the west to the Brahmaputra valley in the east. Multi-parametric exploration has helped in identifying numerous uranium occurrences spread over the entire Siwalik belt between Poonch (Jammu and Kashmir) in the west and Tanakpur (Uttar Pradesh) in the east. More than 350 uranium occurrences forming eight major clusters have been identified. The majority of these occurrences are confined to three distinct stratigraphic horizons: 1) the lower part of Upper Siwaliks; 2) the upper part of Middle Siwaliks; and 3) the upper part of Lower Siwaliks. The important uranium zones identified are: 1) Maler in Jammu and Kashmir; 2) Astotha-Khya-Loharian; 3) Galot-Andalada–Sibal-Loharkar; 4) Rajpura-Polian; 5) Romehra in Himachal Pradesh; 6) Morni-Nathai in Haryana; 7) Naugajiya Rao-Sanbarsot-Sakhumbari Rao; and 8) Kathaul-Danaur-Kholgarh in Uttar Pradesh. Among these, the Rajpura-Polian and Sibal-Loharkar sectors, Himachal Pradesh, where uranium mineralisation is hosted by sediments of the upper part of Middle Siwalik, are under active exploration.

Proterozoic Aravalli Fold Belt, Rajasthan

The Aravalli Supergroup (ASG) occupies the eastern part of the Aravalli Mountain Range from Nathdwara in the north to Champaner in the south over approximately 350 km with a width varying from 40 km to 150 km. It has an arcuate form with a northeast-southwest trend in the north, north-south in Udaipur and northwest-southeast in the south. The ASG can be divided into two distinct sedimentary facies: (1) the shelf facies, comprising mafic volcanic, coarse clastics and carbonates accumulated in the epicontinental sea along the pericontinental slope, and (2) the carbonate-free deep-sea facies, comprising dominantly metapelites with bands of quartzite. The ASG has undergone polyphase deformation and witnessed three main events of magmatism. The Aravalli Fold Belt is known for its uranium metallogeny of different styles, among which uranium mineralisation associated with carbon phyllite is the most promising. Several anomalies have been located in the Umra, Udaisagar, Kalamagra, Haldughati, Sukher, Oda-Kevda and Undwala areas. Multi-parametric exploration is ongoing in the Umra area.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

India's known conventional in situ uranium resources (reasonably assured resources and inferred) are estimated to be 334 995 tU (in situ) hosted in the following deposit types:

Deposit type	In situ resource (tU)	Proportion of deposits
Carbonate	201 721	60.2%
Metamorphite	75 228	22.5%
Sandstone	20 528	6.1%
Proterozoic Unconformity	18 072	5.4%
Metasomatic	12 937	3.9%
Granite-related	6 157	1.8%
Paleo-quartz-pebble-conglomerate	352	0.1%
Total	334 995	100%

As of 1 January 2023, the known conventional in situ resources include 324 529 tU of reasonably assured resources (RAR) and 10 466 tU of inferred resources (IR). This amounts to a substantial increase in RAR, compared to what was reported for the Red Book 2022. These changes are mainly due to appreciable resource additions in the contiguous area of the stratabound deposit in the southern part of the Cuddapah Basin and the extension of areas of known deposits in the Singhbhum Shear Zone, Bhima Basin and North Delhi Fold Belt.

Undiscovered conventional resources (prognosticated and speculative resources)

The prognosticated and speculative resources are estimated based on a greater degree of confidence obtained by carrying out multidisciplinary exploration in some of the potential geological domains. In parts of Andhra Pradesh, Meghalaya, Rajasthan, Jharkhand and Karnataka, potential areas for uranium resources were re-evaluated with a higher degree of confidence. As of 1 January 2023, undiscovered resource estimates remains unchanged as 144 160 tU under the prognosticated category and 59 360 tU under the speculative category, both as in situ resources.

Uranium production

Historical review

The Uranium Corporation of India Ltd (UCIL) was formed in October 1967 under the administrative control of the Department of Atomic Energy, Government of India. The UCIL operates six underground uranium mines (Jaduguda, Bhatin, Narwapahar, Turamdih, Bagjata and Mohuldih) and one open-pit mine (Banduhurang) in the multi-metal mineralised Singhbhum Shear Zone located in the Singhbhum East district of Jharkhand state. The ore produced from the mines is processed in two processing plants located at Jaduguda and Turamdih. In addition to these, UCIL has also constructed a uranium mine and a processing plant in the YSR district (formerly Kadapa) of Andhra Pradesh.

Status of production facilities, production capability, recent and ongoing activities, and other issues

In 2021 and 2022, the total uranium production reached 450 tU and 488 tU, respectively.

The total installed capacity of UCIL's three operating production plants is as follows:

- Jaduguda Plant: 2 500 t ore/day;
- Turamdih Plant: 3 000 t ore/day;
- Tummalapalle Plant: 3 000 t ore/day.

Recent and ongoing activities

Jaduguda mine

The Jaduguda uranium deposit lies within the metasediments of the Singhbhum Shear Zone. The host rocks are of Proterozoic age. There are two prominent parallel ore lenses: the Footwall lode (FWL) and the Hanging wall lode (HWL). These lodes are separated by a 100 m barren zone. The FWL extends over a strike length of about 600 m in a south-east to north-west direction. The strike length of HWL is about 250 m and is confined to the eastern part of the deposit. Both the lodes have an average dip of 40 degrees towards the north-east. Of the two lodes, the FWL is better mineralised. The Jaduguda deposit has been explored up to a depth of 880 m.

Entry to the mine is through a 640 m deep vertical shaft. An underground auxiliary vertical shaft, sunk from 555 m to 905 m, provides access to deeper levels. The cut-and-fill stoping method is practised, giving about 80% ore recovery. Deslimed mill tailings are used as backfill material. Ore is hoisted by the skip in stages through shafts to surface and sent to the Jaduguda mill by conveyor for further processing.

Bhatin mine

The Bhatin uranium deposit is located 4 km north-west of Jaduguda. A major strike-slip fault lies between the Jaduguda and Bhatin deposits. Both deposits lie in similar geological settings. The Bhatin mine began production in 1986. The ore lens has a thickness of 2 to 10 m with an average dip of 35 degrees and entry to the mine is through an adit, with deeper levels accessed by inclines. Cut-and-fill stoping is practised and deslimed mill tailings from the Jaduguda mill are used as backfill. Broken ore is trucked to the Jaduguda mill. UCIL plans to increase underground productivity of this mine by further mechanisation.

Narwapahar mine

The Narwapahar deposit (about 12 km west of Jaduguda) has been operating since 1995. In this deposit, discrete uraninite grains occur within chlorite-quartz schist with associated magnetite, with several lenticular-shaped ore lenses extending over a strike length of about 2 100 m, each with an average north-easterly dip of 30 to 40 degrees. The thickness of the individual ore lenses varies from 2.5 to 20 m. The deposit is accessed by a 355-metre-deep vertical shaft and a 7-degree decline from the surface. Cut-and-fill stoping is also practised using deslimed mill tailings of the Jaduguda plant as backfill. Ore is trucked to the Jaduguda plant for processing.

Bagjata mine

The Bagjata deposit, situated about 26 km east of Jaduguda, has been developed as an underground mine with a 7-degree decline for entry and a vertical shaft to access deeper levels. This mine was commissioned in 2008. Ore from the Bagjata mine is transported by road to the Jaduguda plant for processing. Cut-and-fill stoping is practised in the Bagjata mine and deslimed mill tailings from the Jaduguda mill are used as backfill.

Turamdih mine

The Turamdih deposit is located about 12 km west of Narwapahar. Discrete uraninite grains within feldspathic-chlorite schist form a series of ore lenses with a very erratic configuration. The mine was commissioned in 2003 and three levels (70 m, 100 m and 140 m depth) have been accessed through an 8-degree decline from the surface and a vertical shaft has been sunk to provide access to deeper levels. Ore from this mine is processed at the Turamdih plant. Cut-and-fill stoping is also practised using deslimed mill tailings of the Turamdih plant. Considering the ore geometry, possibilities of adopting higher productivity sub-level stoping methods in specific segments of the orebody are being explored. Trial stoping in one such area has been undertaken.

Banduhurang mine

The Banduhurang deposit has been developed as a large opencast mine. The orebody is the western extension of ore lenses at Turamdih. The mine was commissioned in 2009 and ore is transported by road to the Turamdih plant for processing.

Mohuldih mine

The deposit is in the Seraikela-Kharswan district of Jharkhand, about 2.5 km west of Banduhurang. The mine was commissioned in 2012. The ore from the mine is treated at the Turamdih plant.

Tummalapalle mine

Hosted in carbonate rock, this deposit is in the YSR district (formerly Kadapa) of Andhra Pradesh. It is the first uranium production centre in the country located outside Jharkhand. This underground mine is accessible by three declines along the apparent dip of the orebody. The central decline is equipped with a conveyor for ore transport and the other two declines are used as service accesses. The ore is treated in the plant adjacent to the mine at Tummalapalle. Expansion of the mine and processing plant at Tummalapalle is planned to augment uranium production.

Jaduguda mill

Ore produced at the Jaduguda, Bhatin, Narwapahar and Bagjata mines is processed in the mill located at Jaduguda. Commissioned in 1968, the mill can treat about 2 500 t/day of dry ore. Following crushing and grinding (to 60% passing 200 mesh), the ore is leached in pachuca tanks using sulphuric acid under controlled pH and temperature. After filtration of the pulp, ion-exchange resin is used to recover the uranium. After elution, the product is precipitated using hydrogen peroxide to produce uranium peroxide as a final product containing about 88% U_3O_8. The treatment of mine water and reclaiming tailings water has resulted in reduced freshwater requirements, as well as increasing the purity of the final effluent. A magnetite recovery plant is also in operation at Jaduguda producing very fine-grained magnetite as a by-product.

Turamdih mill

Uranium ore from the Turamdih and Banduhurang and Mohuldih mines is being processed in the Turamdih mill. The mill, commissioned in 2009, can treat about 3 000 t/day dry ore. The plant adopts similar processing technology as that of Jaduguda. Presently, this plant produces magnesium diuranate as the final product. Plans to produce uranium peroxide as the final product are under implementation. This plant is being expanded to process 4 500 t/day dry ore.

Tummalapalle mill

The uranium processing plant at Tummalapalle in the YSR district (formerly Kadapa) of Andhra Pradesh is based on indigenously developed alkali leaching (under high temperature and pressure) technology. The plant was put into regular operation in January 2017 to process 3 000 t/day ore. The expansion of this plant to process 4 500 t/day ore has also been planned.

Uranium production centre technical details
(as of 1 January 2023)

	Centre #1	Centre #2	Centre #3	Centre #4	Centre #5	Centre #6	Centre #7	Centre #8
Name of production centre	Jaduguda	Bhatin	Narwapahar	Bagjata	Turamdih	Banduhurang	Mohuldih	Tummalapalle
Production centre classification	Existing	Existing	Existing	Existing	Existing	Existing	Existing	Existing
Start-up date	1967	1986	1995	2008	2003	2007	2011	2017
Source of ore:	Uranium ore	Uranium ore	Uranium ore	Uranium ore	Uranium ore	Uranium ore	Uranium ore	Uranium ore
Deposit name(s)	Jaduguda	Bhatin	Narwapahar	Bagjata	Turamdih	Banduhurang	Mohuldih	Tummalapalle
Deposit type(s)	Metamorphite	Metamorphite	Metamorphite	Metamorphite	Metamorph.	Metamorphite	Metamorphite	Carbonate (Strata bound)
Resources (tU)	-	-	-	-	-	-	-	-
Grade (% U)	-	-	-	-	-	-	-	-
Mining operation:								
Type (OP/UG/ISL)	UG	UG	UG	UG	UG	OP	UG	UG
Size (tonnes ore/day)	650	150	1 500	500	750	3 500	500	3 000 (4 500 planned)
Average mining recovery (%)	80	75	80	80	75	65	80	60
Processing plant:	Jaduguda				Turamdih			Tummalapalle
Type (IX/SX/AL)	IX/AL				IX/AL			ALKPL*
Size (tonnes ore/day)	2 500				3 000			3 000
Average process recovery (%)	80				78			70
Nominal production capacity (tU/year)	200				190			211
Plans for expansion	-				Turamdih mine (1 000 TPD) and Turamdih plant (4 500 TPD) are under expansion			Tummalapalle mine (4 500 TPD) and Tummalapalle plant (4 500 TPD) are under expansion
Other remarks	Ore being processed in Jaduguda plant				Ore being processed in Turamdih plant			

* Pressurised alkali leach. TPD = tonnes per day.

Uranium production centre technical details *(cont'd)*

(as of 1 January 2023)

	Centre # 9	Centre # 10	Centre # 11
Name of production centre	Gogi	Lambapur-Peddagattu	Kylleng-Pyndengsohiong Mawthabah (KPM)
Production centre classification	Planned	Planned	Planned
Start-up date	2024	2024	2028
Source of ore:	Uranium ore	Uranium ore	Uranium ore
Deposit name(s)	Gogi	Lambapur-Peddagattu	KPM
Deposit type(s)	Granite-related	Unconformity	Sandstone
Resources (tU)	-	-	-
Grade (% U)	-	-	-
Mining operation:			
Type (OP/UG/ISL)	UG	UG/OP	OP
Size (tonnes ore/day)	500	1 250	2 000 (250 days/yr working)
Average mining recovery (%)	60	75	90
Processing plant:	Gogi	Seripally	KPM
Type (IX/SX/AL)	AL	IX/AL	IX/AL
Size (tonnes ore/day)	500	1 250	2 000 (275 days/yr working)
Average processing ore recovery (%)	88	77	87
Nominal production capacity (tU/year)	130	130	340
Plans for expansion	-	-	-
Other remarks	Ore to be processed in the plant at Saidapur	Ore to be processed in the plant at Seripally	

Ownership structure of the uranium industry

In India, uranium prospecting/exploration and mining are carried out exclusively by the central government. The uranium industry is wholly owned by the Department of Atomic Energy, Government of India. The Atomic Minerals Directorate for Exploration and Research under the Department of Atomic Energy is responsible for uranium exploration programmes in India. Following the discovery and deposit delineation, the economic viability is evaluated. The evaluation stage may also include exploratory mining. Once a deposit of sufficient tonnage and grade is established, UCIL initiates activities for commercial mining and production of uranium concentrates.

Employment in the uranium industry

About 4 500 people are engaged in uranium mining and milling activities.

Future production centres

The uranium deposit located at Gogi in the Yadgir (former name Gulbarga) district, Karnataka, is planned for development as an underground mine. Exploratory mining work is in progress to establish the configuration of the orebody. The plant at Gogi will utilise alkali leaching technology.

A sandstone uranium deposit in the northeastern part of the country at Kylleng-Pyndengsohiong, Mawthabah (formerly Domiasiat) in West Khasi Hills District, Meghalaya State, is planned for development by open-pit mining, with a processing plant to be situated near the mine.

Uranium deposits located at Lambapur-Peddagattu in the Nalgonda district, Andhra Pradesh, are also slated for development, with an open-pit and three underground mines proposed. An ore processing plant is being proposed at Seripally, 50 km from the mine site. Pre-project activities are in progress.

Environmental activities and socio-cultural issues

There are no environmental issues related to the existing uranium mines and processing plants operated by UCIL. However, provisions are made for the management of environmental impacts. The organisation responsible for this task is the Health Physics Group of the Bhabha Atomic Research Centre, located in Mumbai. It carries out environmental health monitoring for radiation, radon and dust at uranium production facilities. The Health Physics Unit operates the Environmental Survey Laboratory at Jaduguda and has establishments at all operating facilities.

Regulatory regime

In India, all nuclear activities, including mining and processing of uranium and/or any other prescribed substance, fall under the purview of the central government and are governed by the Atomic Energy Act, 1962 (AE Act) and the rules made thereunder. The Department of Atomic Energy (DAE) oversees the development and mining of uranium and other prescribed substances including the administration and regulation of atomic minerals notified under the Mines and Minerals (Development and Regulation) Act, 1957 (MMDR Act, 1957). Accordingly, policies of the DAE and provisions of the AE Act and rules framed thereunder play a key role in the prospecting, exploration and mining of uranium. The exploration and mining of uranium and other atomic minerals are governed under the provisions of MMDR Act, 1957 as well as the rules made thereunder i.e. Atomic Minerals Concession Rules (AMCR), 2016 and Mineral Conservation and Development Rules (MCDR), 2017. In addition, all mining activities must comply with environmental regulations and the provisions of the Mines Act, 1952. The mining, milling and processing of uranium ore or any prescribed substances requires a licence under the Atomic Energy (Working of the Mines, Minerals and Handling of Prescribed Substances) Rules 1984 and the Atomic Energy Radiation Protection Rules, 2004, wherein the procedural details for obtaining a licence and conditions of the licence have been notified.

A mining lease for uranium or any atomic mineral is granted by the state government after the mining plan is approved by the Atomic Minerals Directorate for Exploration and Research (AMD) as per the provisions of the MMDR Act. The Atomic Energy Regulatory Board (AERB), an independent authority, regulates the safety and other regulatory provisions under the AE Act and ensures the safety of workers, the public and the environment with respect to the radiological aspects. The AERB oversees various aspects of mining and processing of atomic minerals that are required to conform to radiological safety, siting of the mill, disposal of tailings and other waste rocks, as well as decommissioning of the facility. The commissioning, operating and decommissioning of uranium mines require compliance with the provisions under different legislation and regulations.

Uranium requirements

As of 1 January 2023, the total installed nuclear capacity in India was 6 780 MWe (gross), which is comprised of 18 pressurised heavy water reactors, two boiling water reactors and two light-water reactors.

Construction/commissioning of four pressurised heavy water reactors (KAPP 3 and 4: 2 x 700 MWe and Rajasthan Atomic Power Station 7 and 8: 2 x 700 MWe), and one prototype fast breeder (500 MWe) is in progress.

Annual uranium requirements in 2022 amounted to about 1 350 tU and this would increase in tandem with increases in installed nuclear capacity. Identified conventional uranium resources are sufficient to support 10-15 GWe installed capacity of pressurised heavy water reactors operating at a lifetime capacity factor of 80% for 40 years.

With international co-operation in peaceful nuclear energy, installed nuclear generating capacity is expected to grow significantly as more international projects are envisaged. However, the exact size of the programme based on technical co-operation with other countries is yet to be finalised.

Supply and procurement strategy

Uranium requirements for pressurised heavy water reactors are being met with a combination of domestic and imported sources. Two operating boiling water reactors and two light-water reactors of VVER-type require enriched uranium and are fuelled by imported uranium. Future light-water reactors will also be fuelled by imported uranium.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Uranium exploration, mining, production, fuel fabrication and the operation of nuclear power reactors are controlled by the government of India. National policies relating to uranium are governed by the Atomic Energy Act 1962 and MMDR Act 1957 and the provisions made thereunder.

Imported light-water reactors to be built in the future will be purchased with an assured fuel supply for the lifetime of the reactor.

Uranium exploration and development expenditures and drilling effort – domestic

(Indian rupee millions)

	2020	2021	2022	2023 (expected)
Government exploration expenditures	3 616	4 615	5 263	6 145
Total expenditures	3 616	4 615	5 263	6 145
Government exploration drilling (m)	195 308	309 242	395 783	290 750
Total drilling (m)	195 308	309 242	395 783	290 750

* Non-government.

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	Cost range unassigned
Underground mining (UG)	NA	NA	NA	301 388
Open-pit mining (OP)	NA	NA	NA	23 141
Total	NA	NA	NA	324 529

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	Cost range unassigned
Conventional from UG	NA	NA	NA	301 388
Conventional from OP	NA	NA	NA	23 141
Total	NA	NA	NA	324 529

Reasonably assured conventional resources by deposit type
(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	Cost range unassigned
Proterozoic unconformity	NA	NA	NA	18 072
Sandstone	NA	NA	NA	17 638
Granite-related	NA	NA	NA	6 157
Metamorphite	NA	NA	NA	68 670
Metasomatic	NA	NA	NA	12 271
Carbonate	NA	NA	NA	201 721
Total	NA	NA	NA	324 529

Inferred conventional resources by production method
(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	Cost range unassigned
Underground mining (UG)	NA	NA	NA	8 372
Open-pit mining (OP)	NA	NA	NA	2 094
Total	NA	NA	NA	10 466

Inferred conventional resources by processing method
(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	Cost range unassigned
Conventional from UG	NA	NA	NA	8 372
Conventional from OP	NA	NA	NA	2 094
Total	NA	NA	NA	10 466

Inferred conventional resources by deposit type
(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	Cost range unassigned
Sandstone	NA	NA	NA	2 890
Paleo quartz-pebble-conglomerate	NA	NA	NA	352
Metamorphite	NA	NA	NA	6 558
Metasomatic	NA	NA	NA	666
Total	NA	NA	NA	10 466

Prognosticated conventional resources
(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	Unassigned
NA	NA	144 160

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
NA	NA	59 360

Historical uranium production by production method

(tonnes U in concentrate)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Open-pit mining[1]	NA	182	180	NA	180
Underground mining[1]	NA	268	308	NA	305
Total	NA	450	488	NA	485

1. Pre-2020 totals may include uranium recovered by heap and in-place leaching.

Historical uranium production by processing method

(tonnes U in concentrate)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Conventional	NA	450	488	NA	485
Total	NA	450	488	NA	485

Historical uranium production by deposit type

(tonnes U in concentrate)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Metamorphite	NA	344	336	NA	340
Carbonate	NA	106	152	NA	145
Total	NA	450	488	NA	485

Ownership of uranium production in 2022

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
488	100	NA	NA	NA	NA	NA	NA	488	100

Uranium industry employment at existing production centres

(person-years)

	2020	2021	2022	2023 (expected)
Total employment related to existing production centres	4 642	4 533	4 456	4 514
Employment directly related to uranium production	NA	NA	NA	NA

Mid-term production projection (tonnes U/year)

2025	2030	2035	2040	2045	2050
NA	NA	NA	NA	NA	NA

Mid-term production capability (tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
NA				NA			
2035				**2040**			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
NA				NA			
2045				**2050**			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
NA				NA			

Net nuclear electricity generation

	2021	2022
Nuclear electricity generated (TWh net)	39.76	41.97

Installed nuclear generating capacity to 2050

(MWe net)

2021	2022	2025		2030		2035		2040		2045		2050	
6 255	6 255	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Annual reactor-related uranium requirements to 2050 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
1 350	1 350	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Indonesia

Uranium exploration and mine development

Historical review

Uranium exploration, conducted by the National Nuclear Energy Agency of Indonesia (BATAN), started in the 1960s. At the end of 2021, BATAN merged, along with other research agencies, into the National Research and Innovation Agency (BRIN). Exploration continues in co-operation with the Geological Agency of the Ministry of Energy and Mineral Resources of Indonesia.

Three uranium deposit localities have been identified in Indonesia. The West Kalimantan uranium deposits (Kalan deposits) were discovered in 1973. The North Sumatra uranium deposits (Sibolga deposits) were discovered in 1980, and the West Sulawesi uranium deposits (Mamuju deposits) were discovered in 2013. From 1981 to 1991, pilot-scale mining and processing experiments were carried out at the Kalan deposit with a plant capacity of two tonnes of ore per day. The pilot test of 964 tonnes of ore (1 000 ppm) yielded 740.5 kg of yellowcake (U in yellowcake 60%) via solvent extraction. Environmental remediation of the plant site is ongoing (2020). The Kalan metamorphite deposit type uranium mineralisation consists of uraninite (tourmaline-sulphide association) in veins in schistose metapelites, metasiltstones and quartzites derived from a Cretaceous protolith, with thermal metamorphism associated with the intrusion of younger granites. Centimetre to decimetre scale uranium mineralised veins exhibit lithological controls with mineralisation mobilised along schistosity planes, and tectonic controls where mineralisation on schistosity planes has been remobilised into open, cross-cutting younger faults and breccias. Mineralised intersections range up to 1.4 m in thickness with a maximum grade of up to 0.28% U from the Kalan test mining tunnel. The Mamuju deposits occur in Tertiary alkaline volcanic rocks. The Sibolga deposits occur in Tertiary sandstones with uranium enrichments associated with black shales.

Up to 1996, reconnaissance surveys had covered 79% of a total of 533 000 km^2 identified for surveying based on favourable geological criteria and promising exploration results. Since that year, the exploration activities have been focused on the Kalan, Kalimantan, in which the most significant indications of uranium mineralisation have been found. During 1998-1999, exploration consisted of systematic geological and radiometric mapping, including a radon survey carried out at Tanah Merah and Mentawa, Kalimantan to delineate the mineralised zone. The results of those activities increased speculative resource estimates by 4 090 tU to 12 481 tU. From 2000 up to 2002, exploration drilling was carried out at upper Rirang (178 m), Rabau (115 m) and Tanah Merah (181 m) in West Kalimantan.

In 2003-2004, additional exploration drilling was conducted at Jumbang 1 (186 m) and Jumbang 2 (227 m). In 2005, exploration drilling was carried out at Jumbang 3 (45 m) and at Mentawa (45 m), in 2006 at Semut (454 m) and Mentawa (45 m) and in 2007 at Semut (174 m). In 2008, no exploration drilling was undertaken.

In 2009, exploration drilling was continued in the Kalan Area and detailed, systematic prospection in the Kawat area and its surroundings was also carried out. General prospection in the Bangka Belitung Province was also undertaken. Plans were adopted to extend exploration in Kalimantan and Sumatra by prospecting from general reconnaissance to systematic stages to discover new uranium deposits. In 2010, efforts were devoted to evaluating drilling data from the Kawat sector to re-evaluate estimates of speculative resources.

Uranium and thorium exploration in 2015 continued in the Mamuju area, West Sulawesi Province (alkaline volcanic-hosted mineralisation), and in the Ella Ilir area, West Kalimantan Province. In the Mamuju area, detailed ground radiometric mapping was conducted in the Takandeang, Taan, Ahu, Pangasaan and Hulu Mamuju sectors. Geophysical resistivity and induced polarisation surveys conducted in the Botteng and Takandeang sectors were followed by reconnaissance drilling for a total depth of 1 600 m, which was comprised of 570 m in the Botteng sector, 830 m in the Takandeang sector, and 200 m in the Taan sector. Drilling targets were anomalous uranium occurring as stratabound and supergene enrichment in volcanic deposits. Exploration in the Ella Ilir area included geological and radiometric mapping and reconnaissance drilling with 400 m of total depth. The drilling in this area focused on uranium veins in schistose metapelite and metatuff.

Recent and ongoing uranium exploration and mine development activities

In 2021, exploration activities were conducted in the Mamuju, Bangka Island and Melawi regions. The focus of exploration was on the southern Mamuju anomalous region, and on geological-radiometric-geomagnetic mapping conducted in Rantedoda. The exploration was focused on finding the continuation of uranium deposits in proximity to the rim of the volcanic complex. Several uranium anomalies were identified and are related to stratabound volcanic horizons, hydrothermal alteration and reductive sediment. At Bangka Island, a more detailed grid-based radon gas survey was conducted over the paleo-placer target, including petrographic and geochemistry analysis to confirm the deposit. In the Melawi region, the expansion of radiometric and radon gas mapping focused on evaluating the potential for uranium deposits in a sedimentary basin setting.

In 2022, uranium exploration activities were conducted in co-operation with the Energy and Mineral Resources Ministry to delineate potential rare earth element mining areas in the Melawi and Mamuju areas. At Melawi, exploration was conducted by the sampling of laterite soils to investigate the potential for uranium enrichments in the surrounding known rare earth placer boulder deposit of Rirang-Kalan. A review of uranium metallogeny in the Kalan basin was also conducted by sampling all primary uranium sectors, followed by laboratory analysis (XRF and Micro XRF). Also in the Melawi area, exploration was conducted at Ella Hilir, a metamorphite uranium deposit to evaluate possible contained rare earths. At Mamuju, a semi-detailed core drilling campaign was conducted to explore possible uranium and rare earth element enrichment in the laterite zone of alkaline rock. Drilling was conducted in 12 holes drilled to 50 m of depth, with a drill hole spacing of 300 m. Laboratory analysis by ICP-MS was performed for all systematic drill core samples and micro XRF scanning for confirmation of mineralisation. A further resource estimation will also be conducted in the area of exploration.

No mining activity is currently being considered.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

In situ measured and indicated resources amount to 7 391 tU (<USD 130/KgU), and the total in situ inferred resources are 4 065 tU (<USD 130/KgU). Inferred resources include those from the following localities: Mamuju (2 998 tU); Taan (431 tU); Takandeang including Salumati (165 tU) and Rantedunia (56 tU); Aloban including Sibolga (415 tU).

The Kalan Area consists of 16 sectors exhibiting uranium potential: Remaja, Lembah Hitam, Lemajung, Semut, Rirang, Rabau Hulu, Sarana, Tanah Merah, Amir Engkala, Jeronang, Jumbang, Ketungau, Parembang Kanan, Ririt, Dendang Arai, Bubu and Kayu Ara. Until 2018, Indonesia had reported 2 029 tU as a measured resource from the Remaja and Lembah Hitam Sector for the Red Book.

Undiscovered conventional resources (prognosticated and speculative resources)

Total undiscovered prognosticated and speculative resources amount to 37 292 tU. The undiscovered resources as prognosticated resources from the Kalan, Kawat, Mentawa and Mamuju areas are 30 179 tU. Additions to the speculative resources for the Mamuju area include the Hulu Mamuju Sector in 2019 (1 096 tU) and Ampalas Sector in 2020 (6 017 tU).

Unconventional resources and other materials

The uranium resource potential in the Bangka and Belitung areas comprises placer deposits of monazite within a tin deposit. Monazite, a uranium/thorium phosphate mineral, was deposited in the alluvium and has mostly accumulated as a tailings by-product material of tin mining. The resources from deposits in Bangka and Belitung islands total 25 236 tU. In Singkep, the uranium potential is in lateritic soil, with a resource of 1 100 tU. In Semelangan (West Kalimantan), uranium is present in bauxite lateritic deposits with resources of 624 tU. In Katingan (Central Kalimantan), monazite is present as a by-product material of zircon mining, with resources of 485 tU. Total unconventional resources are 27 445 tU.

Uranium exploration and development expenditures and drilling effort – domestic

(Indonesian rupiah [IDR])

	2020	2021	2022	2023 (expected)
Government exploration expenditures	598 560 000	354 000 000	2 500 000 000	792 085 000
Total expenditures	598 560 000	354 000 000	2 500 000 000	792 085 000
Government exploration drilling (m)	0	0	600	0
Government exploration holes drilled	0	0	12	0
Total drilling (m)	0	0	600	0
Total number of holes drilled	0	0	12	0

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	2 029	7 391	7 391	75
Total	0	2 029	7 391	7 391	75

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	2 029	7 391	7 391	75
Total	0	2 029	7 391	7 391	75

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Metamorphite	0	2 029	7 391	7 391
Total	0	2 029	7 391	7 391

Inferred conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	0	2 998	2 998	75
Unspecified	0	0	1 067	1 067	75
Total	0	0	4 065	4 065	75

Inferred conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	0	2 998	2 998	75
Unspecified	0	0	1 067	1 067	75
Total	0	0	4 065	4 065	75

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	415	415
Metamorphite	0	0	2 998	2 998
Volcanic-related	0	0	652	652
Total	0	0	4 065	4 065

Prognosticated conventional resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	0	37 292

Iran (Islamic Republic of)*

Uranium exploration and mine development

Historical review

Exploration

In 1935, the first occurrence of radioactive minerals was detected in the Anarak mining region. In 1959 and 1960, through co-operation between the Geologic Survey of Iran (GSI) and a French company, preliminary studies were carried out in Anarak and Khorassan (central Iran and Azarbaijan regions) to evaluate the uranium mineralisation potential.

Systematic uranium exploration in Iran began in the early 1970s to provide uranium ore for planned processing facilities. Between 1977 and the end of 1978, one-third of Iran (650 000 km^2) was covered by airborne geophysical surveys. Many surficial radiation anomalies were identified, and follow-up field surveys have continued to the present. The airborne coverage is mainly over the central, southeastern, eastern and northwestern parts of Iran. The favourable regions studied by this procedure are the Bafq-Robateh Posht e Badam region (Saghand, Narigan, Khoshumi), Maksan and Hudian in southeastern Iran and Dechan, Mianeh and Guvarchin in Azarbaijan. Outside of the airborne geophysical coverage area, uranium mineralisation at Talmesi, Meskani, Kelardasht and the salt plugs of south Iran are also worthy of mention.

Mine development

At the Saghand uranium mine (1 and 2), feasibility studies and basic engineering designs (1994-1995) and mining preparation reports (1996) led to the construction of administration and industrial buildings and procurement of equipment (1997-1998). Shafts No. 1 and No. 2 were sunk from 1999 to 2002 and the underground development of the Saghand mine began in 2003.

The Khoshumi area is composed of forty-seven anomalies that are related to metamorphite-type uranium deposits. Orefield No. 6 of this area was considered for feasibility studies. Five anomalies in Narigan turned out to be related to hydrothermal and metasomatite-type uranium deposits. Mineral deposit No. 3 in the Narigan area was a candidate for feasibility studies.

Recent and ongoing uranium exploration and mine development activities

Uranium exploration activities

Following the development of a comprehensive plan, reconnaissance for detailed exploration activities has been ongoing within favourable areas across the country, with a focus on granite-related, metasomatite, volcanogenic, intrusive and sedimentary deposit types.

Mine development activities

The development of mines No. 1 and 2 is being carried out in the Saghand mining and industrial complex. In mine No. 1 open-pit methods are used to access orebodies after overburden stripping. Ore at mine No. 2 is being extracted by underground methods. For this purpose, the

* Secretariat Report based on Red Book 2022, UxC Weekly reports, and the WNA website.

main and ventilation shafts have been sunk and adits are being drilled. Also, some stopes are being developed at different levels for ore production. The uranium ores extracted from mines No. 1 and No. 2 are transported to the uranium production centre after being mixed.

Feasibility studies of other uranium ore deposits such as Narigan and Khoshoumi are planned. The conceptual design of the Narigan deposit and the detailed design of the Khoshumi deposit have been completed.

Identified conventional resources (reasonably assured and inferred resources)

Based on exploration activities completed in recent years, the total in situ RAR is 4 316 tU. These resources are related to metasomatic, granite-related and metamorphite deposit types.

Total in situ inferred resources are mostly related to metasomatic deposits and amount to 5 535 tU.

As of 1 January 2023, in situ identified conventional resources total 9 851 tU at <USD 130/kgU cost category.

Undiscovered conventional resources (prognosticated and speculative resources)

Prognosticated resources amount to 9 800 tU in the <USD 130/kgU cost category, whereas speculative resources total 48 100 tU in the unassigned cost category. Ongoing exploration is focused on the following areas:

Kerman-Sistan metallogenic trend

The uranium mineralisation potential in this trend is associated with volcanic-related, metasomatic, granite-related and sedimentary types. Exploration is being conducted in several areas and considering the potential of these areas, some of them are expected to be selected for further exploration.

Naiin-Jandagh metallogenic trend

The uranium mineralisation potential occurs in granite-related, volcanic-related and polymetallic types. Surface studies are being undertaken in favourable areas and if results are positive, subsurface exploration will be performed.

Birjand-Kashmar metallogenic trend

The uranium mineralisation potential is associated with sedimentary, granite-related and volcanic-related types. Surface studies are being conducted on favourable areas, and if favourable results are obtained, further exploration, including borehole drilling and logging, will be undertaken.

Hamedan-Marand metallogenic trend

The uranium mineralisation potential is associated with granite-related, volcanogenic, intrusive and sedimentary types. Surface exploration has identified favourable areas for further subsurface exploration.

Unconventional resources

Recent studies have identified favourable areas for the investigation of potential unconventional resources. This includes phosphate rocks, non-ferrous ores, ferrous ores, carbonatite and black shales. The evaluation of the potential of these resources is being conducted through a staged approach that includes conceptual designs for mining, extraction and processing. Speculative unconventional resources in the unassigned cost category are estimated at 53 000 tU.

Uranium production

Historical review

Uranium ore recovered by open-pit mining of the Gachin salt plug (surficial type) was processed at the Bandar Abbas uranium plant beginning in 2006. The plant closed in 2016.

Status of production facilities, production capability, recent and ongoing activities and other issues

According to the Atomic Energy Organization of Iran (AEOI), eight uranium mines were operating in 2023, with some of the open-pit operations relying on uranium extraction via heap leaching. The AEOI also indicates that Iran's uranium reserves are much larger than previously estimated, and the country plans to operate six more uranium mines by the end of the first quarter of 2024.

The Bandar Abbas uranium plant began operating in 2006, with a nominal annual production capacity of 21 tU, and closed down in 2016. A second production facility, located near Ardakan, began operating in 2017. It has a nominal annual production capacity of 50 tU and will be supplied with ore from the Saghand uranium mine.

Ownership structure of the uranium industry

The owner of the uranium industry is the Government of Iran, and the operator is the AEOI.

Future production centres

In addition to the currently operating Ardakan uranium plant production centre, feasibility studies for the development of the Narigan production centre are underway.

Uranium production centre technical details

(as of 1 January 2023)

	Centre #1	Centre #2
Name of production centre	Gachim	Ardakan
Production centre classification	Closed down in 2016	Existing
Date of first production	2006	2017
Source of ore:		
Deposit name(s)	Gachim	Saghand
Deposit type(s)	Salt Plug (Surfical)	Metasomatic
Recoverable resources (tU)	84.1	500
Grade (% U)	0.068	0.0552
Mining operation:		
Type (OP/UG/ISL)	OP	OP/UG
Size (tonnes ore/day)	70	400
Average mining recovery (%)	80	90
Processing plant:		
Acid/alkaline	Acid	Acid
Type (IX/SX)	SX	IX/SX
Size (tonnes ore/day)	70	280
Average process recovery (%)	73	80
Nominal production capacity (tU/year)	21	50
Plans for expansion		Yes
Other remarks		

Uranium exploration and development expenditures and drilling effort – domestic

(In IRR millions [Iranian Rial])

	2020	2021	2022	2023 (expected)
Government exploration expenditures	NA	NA	NA	NA
Government development expenditures	NA	NA	NA	NA
Total expenditures	NA	NA	NA	NA
Government exploration drilling (m)	NA	NA	NA	NA
Government exploration holes drilled	NA	NA	NA	NA
Government exploration trenches (m)	NA	NA	NA	NA
Government exploration trenches (no.)	NA	NA	NA	NA
Government development drilling (m)	NA	NA	NA	NA
Government development holes drilled	NA	NA	NA	NA
Total drilling (m)	NA	NA	NA	NA
Total number of holes drilled	NA	NA	NA	NA

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	0	491	491	80-90
Open-pit mining (OP)	0	0	136	136	40-50
Unspecified	0	0	3 689	3 689	NA
Total	0	0	4 316	4 316	

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	0	491	491	80-90
Heap leaching* from OP	0	0	136	136	40-50
Unspecified	0	0	3 689	3 689	NA
Total	0	0	4 316	4 316	

* A subset of open-pit and underground mining, since it is used in conjunction with them.

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Granite-related	0	0	653	653
Metamorphite	0	0	136	136
Metasomatic	0	0	3 527	3 527
Total	0	0	4 316	4 316

Inferred conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	0	876	876	80-90
Unspecified	0	0	4 659	4 659	NA
Total	0	0	5 535	5 535	

Inferred conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	0	876	876	80-90
Unspecified	0	0	4 659	4 659	NA
Total	0	0	5 535	5 535	

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Granite-related	0	0	479	479
Metamorphite	0	0	25	25
Volcanic-related	0	0	128	128
Metasomatic	0	0	4 903	4 903
Total	0	0	5 535	5 535

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	9 800	9 800

Speculative conventional resources

(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	0	48 100

Historical uranium production by production method

(tonnes U in concentrate)

Production method	Total through end of 2020**	2021**	2022**	Total through end of 2022**	2023 (expected)
Open-pit mining*	99.1	4.2	4.2	107.5	NA
Underground mining*	60.2	16.8	16.8	93.8	NA
Total	159.3	21.0	21.0	201.3	NA

* Pre-2020 totals may include uranium recovered by heap and in-place leaching.

** Estimated based on Red Book 2022 and WNA website.

Historical uranium production by processing method

(tonnes U in concentrate)

Processing method	Total through end of 2020*	2021*	2022*	Total through end of 2022*	2023 (expected)
Conventional	159.3	21.0	21.0	201.3	NA
Total	159.3	21.0	21.0	201.3	NA

* Estimated based on Red Book 2022 and WNA website.

Historical uranium production by deposit type

(tonnes U in concentrate)

Deposit type	Total through end of 2020*	2021*	2022*	Total through end of 2022*	2023 (expected)*
Metasomatic	75.2	21.0	21.0	117.2	NA
Surficial	84.1	0.0	0.0	84.1	NA
Total	159.3	21.0	21.0	201.3	NA

* Estimated based on Red Book 2022 and WNA website.

Ownership of uranium production in 2022

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)*	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)*	(%)
21.0	100	0	0	0	0	0	0	21.0	100

* Estimated based on Red Book 2022.

Uranium industry employment at existing production centres

(person-years)

	2020*	2021*	2022*	2023 (expected)*
Total employment related to existing production centres	280	280	280	280
Employment directly related to uranium production	95	95	95	95

* Estimated base on Red Book 2022.

Mid-term production projection (tonnes U/year)

2025	2030	2035	2040	2045	2050
71.0	NA	NA	NA	NA	NA

Mid-term production capability (tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
71	NA	NA	NA	NA	NA	NA	NA

2035				2040			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
NA	NA	NA	NA	NA	NA	NA	NA

Net nuclear electricity generation

	2021	2022
Nuclear electricity generated (TWh net)	3.2*	6.0*

* Estimated by WNA based on operation of Bushehr-1 reactor unit.

Installed nuclear generating capacity to 2050

(MWe gross capacity)

2021*	2022*	2025*		2030**		2035**		2040**		2045**		2050**	
1 057 915 (net)	1 057 915 (net)	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
		2 114	2 114	2 863	5 075	6 975	7 925	6 975	7 925	NA	NA	NA	NA

* Based on estimates by WNA.

** Based on Red Book 2022.

Annual reactor-related uranium requirements to 2050 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
160	160	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
		320	325	490	910	1 230	1 390	1 230	1 390	NA	NA	NA	NA

Japan

Uranium exploration and mine development

Historical review

Domestic uranium exploration has been carried out by the Power Reactor and Nuclear Fuel Development Corporation (PNC) and its predecessor since 1956. About 6 600 tU of uranium resources were discovered in Japan before domestic uranium exploration activities were terminated in 1988. Overseas uranium exploration began in 1966 with activities carried out mainly in Australia and Canada, as well as other countries such as the People's Republic of China, Niger, the United States and Zimbabwe.

In October 1998, the PNC was reorganised into the Japan Nuclear Cycle Development Institute (JNC). The Atomic Energy Commission decided in February 1998 to terminate uranium exploration activities in 2000 and the JNC's mining interests and technologies were transferred to the private sector. In October 2005, the Japan Atomic Energy Agency (JAEA) was established by integrating the Japan Atomic Energy Research Institute and the JNC.

In April 2007, the Japanese government decided to resume overseas uranium exploration activities with financial support from Japanese companies through the Japan Organization for Metals and Energy Security (JOGMEC). JOGMEC has carried out exploration activities in Australia, Canada, Namibia, Uzbekistan and other countries since 2007.

Recent and ongoing uranium exploration and mine development activities

JOGMEC continues exploration activities in Namibia and Uzbekistan. Japanese private companies hold shares in companies developing uranium mines and also in those operating mines in Australia, Canada and Kazakhstan.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

About 6 600 tU of reasonably assured resources (recoverable) at <USD 130/kgU have been identified in Japan.

Uranium production

Historical review

The PNC established a test pilot plant with a capacity of 50 t ore/day at the Ningyo-toge mine in 1969. Its operation ended in 1982 with total production amounting to 84 tU. In 1978, a leaching test consisting of three 500 t ore vats with a maximum capacity of 12 000 t ore/year was initiated to process Ningyo-toge ore on a small scale. The vat leaching test was terminated at the end of 1987.

Secondary sources of uranium

Production of mixed oxide fuels

Production facilities

The JAEA plutonium fuel plant consists of three facilities, the Plutonium Fuel Development Facility (PFDF), the Plutonium Fuel Fabrication Facility (PFFF), and the Plutonium Fuel Production Facility (PFPF).

The PFDF, constructed for basic research and the fabrication of test fuels, started operating in 1966. As of 1 January 2021, approximately 2 tonnes of MOX fuel had been fabricated in the PFDF. The PFFF had two MOX fuel fabrication lines, one for the experimental fast breeder reactor Jōyō (FBR line) with a capability of 1 tonne MOX/yr and the second for the prototype advanced thermal reactor Fugen (ATR line) with 10 tonnes MOX/yr fabrication capability. The FBR line started operations in 1973, producing the initial fuel load for the experimental Jōyō sodium-cooled fast reactor. FBR line fuel fabrication ended in 1988 and Jōyō fuel fabrication was switched to the PFPF. The ATR line started operations in 1972 with MOX fuel fabrication for the Deuterium Critical Assembly in JAEA's O-arai Research and Development Center. Fuel fabrication for ATR Fugen was started in 1975 and ended in 2001. MOX fuel fabrication in both lines amounted to a total of approximately 155 tonnes.

The PFPF FBR line, constructed to supply MOX fuels for the prototype Monju FBR and the experimental Jōyō FR, has a production capability of 5 tonnes MOX/yr. The PFPF FBR line began operating in 1988 fabricating Jōyō fuel reloads. Fuel fabrication for the FBR Monju was started in 1989. As of 1 January 2023, approximately 16 tonnes of MOX fuels had been fabricated in the PFPF.

Use of mixed oxide fuels

Monju prototype fast breeder reactor

Monju achieved initial criticality in April 1994 and began supplying electricity to the grid in August 1995. However, during a 40% power operation test of the plant, a sodium leak accident in the secondary heat transport system in December 1995 interrupted operation. After carrying out an investigation to determine the cause, a two-year comprehensive safety review, and the required licensing procedure, the permit for plant modification (including countermeasures to reduce the likelihood of sodium leak accidents) was issued in December 2002 by the Ministry of Economy, Trade and Industry. The JAEA completed a series of countermeasure modifications in May 2007, implemented a modified system function test until August 2007, and then conducted an entire system function test. The existing 78 slightly used and 6 newly fabricated fuel assemblies were loaded by 27 July 2009. Following the system start-up test, Monju was restarted on 6 May 2010. The core confirmation test was completed on 22 July 2010 and 33 freshly fabricated fuel assemblies were loaded by 18 August 2010. However, after refuelling, the in-vessel fuel transfer machine was dropped on 26 August 2010 and removed by 24 June 2011.

The government formally decided on 21 December 2016 to decommission the Monju FBR in Fukui Prefecture. The spent nuclear fuel removal was to be completed by 2022, and preparations for dismantling the facility began in 2023. The dismantling of the facility is scheduled to be completed by 2047.

Experimental fast reactor Jōyō

The experimental fast reactor Jōyō attained criticality in April 1977 with the MK-I breeder core. As an irradiation test bed, the Jōyō MK-II core achieved maximum design output of 100 MW in March 1983. Thirty-five duty cycle operations and thirteen special tests with the MK-II core had been completed by June 2000. The MK-III high-performance irradiation core, with design output increased to 140 MW, achieved initial criticality in July 2003. Six duty cycle operations and four special tests with MK-III core were completed. The Jōyō net operation time reached around 70 000 hours and 588 fuel subassemblies were irradiated during MK-I, MK-II and MK-III core operations.

The new regulatory requirements for research reactors were launched on 18 December 2013. The JAEA submitted an application to comply with the new regulatory requirements for research reactors to Jōyō with MK-IV core (100 MW) on 30 March 2017. A safety review is being conducted.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Japan has relatively scarce domestic uranium resources and therefore relies on overseas uranium supply. A stable supply of uranium resources is to be ensured through long-term purchase contracts with overseas uranium suppliers, direct participation in mining development, and diversification of suppliers and countries.

Since the severe accident at the Fukushima Daiichi Nuclear Power Plant in March 2011, all operational reactors in Japan, which normally provide about 30% of electricity production, have been progressively taken out of service during scheduled refuelling and maintenance outages. As of 1 January 2023, ten reactors are in operation: Kansai Electric Power Company's Ooi Nuclear Power Plant units 3 and 4; Takahama Nuclear Power Plant units 3 and 4; Kyushu Electric Power Company's Genkai Nuclear Power Plant units 3 and 4; Sendai Nuclear Power Plant units 1 and 2; Shikoku Electric Power Company's Ikata Nuclear Power Plant unit 3; and Kansai Mihama Nuclear Power Plant unit 3.

Uranium exploration and development expenditures – non-domestic

(JPY million [Japanese yen])

	2020	2021	2022	2023 (preliminary)
Private* exploration expenditures	N/A	N/A	N/A	N/A
Government exploration expenditures	347	328	328	424
Private* development expenditures	N/A	N/A	N/A	N/A
Government development expenditures	N/A	N/A	N/A	N/A
Total expenditures	347	328	328	424

* Expenditures made by private companies. Government expenditures refer to those related to majority government funding.

Reasonably assured conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining	0	0	6 600	6 600	85
Total	0	0	6 600	6 600	85

Reasonably assured conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG			6 600	6 600	85
Total			6 600	6 600	85

Reasonably assured conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone			6 600	6 600
Total			6 600	6 600

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Open-pit mining[1]	39	0	0	39	0
Underground mining[1]	45	0	0	45	0
Total	84	0	0	84	0

1. Pre-2018 totals may include uranium recovered by heap and in-place leaching.

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2023	2023 (preliminary)
Conventional	45	0	0	45	0
Heap leaching*	39	0	0	39	0
Total	84	0	0	84	0

* A subset of open-pit and underground mining, since it is used in conjunction with them.

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2023	2023 (preliminary)
Sandstone	84	0	0	84	0
Total	84	0	0	84	0

Mixed oxide fuel production and use

(tonnes natural U-equivalent)

Mixed oxide (MOX) fuel	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Production	684	0	0	684	N/A
Use	1 170	20	63	1 253	N/A
Number of commercial reactors using MOX	4	1	1	4	N/A

Reprocessed uranium use

(tonnes natural U-equivalent)

Reprocessed uranium	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Production	645	N/A	N/A	N/A	N/A
Use	217	N/A	N/A	N/A	N/A

Net nuclear electricity generation (TWh net)

	2021	2022
Nuclear electricity generated (TWh net)	70.8 TWh	56.0 TWh

Installed nuclear generating capacity to 2040

(MWe net)

2021	2022	2025		2030		2035		2040	
		Low	High	Low	High	Low	High	Low	High
31 679	31 679	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Annual reactor-related uranium requirements to 2040 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040	
		Low	High	Low	High	Low	High	Low	High
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Jordan

Uranium exploration and mine development

Historical review

Uranium exploration in Jordan started in the 1980s with work by the Natural Resource Authority (NRA). The work included an airborne gamma-spectrometric survey covering the entire Hashemite Kingdom of Jordan, and ground radiometric surveys over selected sites and exploration trenches.

During the 1990s, reconnaissance and exploration studies revealed surficial uranium deposits distributed in several areas of the country:

- Central Jordan: 1 700 trenches and over 2 000 samples from exploration were analysed for uranium using a fluorometer, which revealed the occurrence of uranium mineralisation as minute mineral grains disseminated within fine calcareous Pleistocene sediments and as yellowish films of carnotite and other uranium minerals coating fractures of fragmented chalk or marl of Mastrichtian-Paleocene age. The results of channel sampling in three areas indicated uranium contents ranging from 120 to 1 870 ppm U (0.012% to 0.187% U) over an average thickness of about 1.3 m, with an overburden of about 0.5 m.
- The airborne gamma-spectrometric survey identified several other areas with radiation anomalies (Mafraq, Ruwayshid, Russeifa, Hasa-Qatrana, Dana, Wadi Al-Bahiyyah, Dubaydib, Al Awja and WadiSahabAlabyad) and potential for hosting uranium mineralisation. However, only three areas were covered by follow-up reconnaissance studies (Mafraq, Wadi Al-Bahiyyah and WadiSahabAlabyad).

In 2008, the Jordan Atomic Energy Commission (JAEC) was established, in accordance with the Nuclear Energy Law (Law No. 42) of 2007 and amendments in 2008. The JAEC is the official entity entrusted with the development and implementation of the Jordanian nuclear power programme. The exploration, extraction and mining of all nuclear materials, including uranium, thorium, zirconium and vanadium, are under the authority of the JAEC.

The Nuclear Fuel Cycle Commission of JAEC is in charge of developing and managing all aspects of the nuclear fuel cycle, including uranium exploration, extraction, production, securing fuel supply and services, nuclear fuel management and radioactive waste management. The JAEC uranium policy is to maximise sovereignty while creating value from resources and to avoid concessions to foreign companies. To attract investors and operate on a commercial basis, the JAEC created Jordan Energy Resources Inc. as its commercial arm.

In September 2008, the JAEC signed an exploration agreement with Areva S.A. (now Orano S.A.) and created the Jordanian French Uranium Mining Company (JFUMC), a joint venture created to carry out all exploration activities and which led to a feasibility study on developing resources in the Central Jordan Area. In January 2009, the JAEC signed a memorandum of understanding entitling Rio Tinto to carry out reconnaissance and prospecting in three areas (north of Al-Bahiyyah, Wadi SahbAlabiadh and Rewashid). Exploration activities by Jordanian teams in co-operation with the China Nuclear International Uranium Corporation were carried out in two other areas (Mafraq and Wadi Al-Bahiyyah).

During 2009-2012, the JFUMC explored the northern part of the central Jordan licence area, which included geological mapping, a radiometric survey, trenching, sampling, chemical analyses, development of an environmental impact assessment and a hydrogeological study, building a database inventory, and drilling a total of 5 691 boreholes that were surveyed for gamma radiation at 0.10 m intervals. These data have been integrated to intervals of 0.50 m, which is equal to the length of the drill core samples that were assayed by Inductively Coupled Plasma (ICP) and X-Ray Fluorescence (XRF) methods and used for calibration of the equivalent uranium (eU) data. Jordan terminated the mining agreement with the JFUMC at the end of 2012.

In 2013, the JAEC established the Jordan Uranium Mining Company (JUMCO) as a commercial arm to complete the exploration and resource estimation of the Central Jordan Uranium Deposits.

Recent and ongoing uranium exploration and mine development activities

During 2013-2018, JUMCO completed exploration activities, including trenching, channel sampling and chemical analyses. In June 2018, the third JORC compliant report was issued, including estimated resources for the Central Jordan Uranium Project (CJUP) deposit in measured, indicated and inferred categories. As of February 2018, the CJUP deposit total identified resources amounted to 35 029 tU at an average grade of 137 ppm U_3O_8 (0.012% U) and 94 ppm U_3O_8 (0.008% U) cut-off grade.

The hydrometallurgical process developed for the CJUP has been successfully demonstrated to purify and concentrate uranium in the form of sodium diuranate (SDU) and uranyl peroxide (UP). Successful steps and major milestones were achieved in the design and engineering of the uranium extraction process during the period 2017-2022. A pilot-plant was constructed and fully commissioned in 2021. As of 1 January 2023, hundreds of tonnes of uranium ore were processed by heap leaching technology to produce several kilograms of uranium concentrate.

JUMCO continues to optimise the hydrometallurgical processing and operating parameters to obtain all necessary data required to complete the detailed engineering design for a commercial plant, and as input parameters for the feasibility study of the project.

Supporting this work, a state-of-the-art analytical laboratory was established in 2020 at the CJUP site. The laboratory has been equipped, in co-operation with the IAEA, with the latest high-tech analytical equipment to conduct chemical and physical analyses related to uranium processing. This is an added value to CJUP and more broadly, to other national mining projects.

Implementation of the above CJUP phases has contributed positively to building domestic capacity, technical infrastructure, and training competent human resources in Jordan in certain specific specialised nuclear materials-related fields. The JUMCO team has successfully acquired the knowledge and required experience to progress further. More advanced understanding of governing process parameters is being developed. Moreover, sensitivity analysis has helped to understand the key parameters affecting the process. A systematic approach to knowledge acquisition has been adopted by JUMCO, including a regressive scientific experimental approach that was crucial to undertaking challenges and customising the developed process to match the targeted product profile.

JUMCO is planning to proceed towards the commercial production level in a sustainable and environmentally safe manner. The company is performing a pre-feasibility study (PFS) for CJUP to have better cost estimation that includes different scenarios. The PFS will be the baseline of a bankable feasibility study (BFS) in which more well-defined process will be considered.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2023, total in situ identified uranium conventional resources in Jordan amounted to 63 019 tU, including 6 785 tU of RAR and 56 234 tU of inferred resources. All resources are of surficial geological type and mineable by open-pit mining production methods. They are located within the Central Jordan Area and the Hasa-Qatrana Area.

Central Jordan Area

JORC compliant in situ resources estimates include 6 785 tU of reasonably assured resources and 28 244 tU of inferred resources.

Hasa-Qatrana Area

In the period 2010-2011, Jordan Energy Resources Inc. (JERI) conducted exploration work at the Hasa-Qatrana area located 95 km south of Amman. The deposits exhibit strong airborne gamma anomalies and several robust ground anomalies that are attributed to the high-grade phosphorite beds. During the exploration programme, a total of 443 trenches were excavated, and 1 943 geochemical samples collected and analysed, covering seven mineralised zones. A preliminary resource estimation was carried out, resulting in total in situ inferred resources of 27 990 tU.

Undiscovered conventional resources (prognosticated and speculative resources)

Wadi Al Bahiyya

This region covers an area of about 1 600 km² and exhibits strong airborne gamma anomalies and several ground anomalies are identified. A particular 9 km² area was thoroughly investigated, which revealed uranium concentrations ranging from 59-133 ppm U (70 to 157 ppm U_3O_8) within the carbonate target layer that has a thickness that varies from 1.5 m to 3 m. The radioactive zone is also abundant in vanadium with concentrations ranging from 700 to 1 500 ppm of V_2O_5.

Sahb El Abyad

In south-eastern Jordan, the Sahb El Abyad area has been found to have strong airborne gamma anomalies and was explored for uranium in 2009. The area is composed mainly of late Cretaceous and Tertiary chalky marls, limestone, cherts and phosphorites. The uranium mineralisation is similar to the central Jordan region. Geochemical sampling revealed a strong correlation between uranium and phosphorous. Uranium concentration was found to be in the range 85-127 ppm U (100-150 ppm U_3O_8).

Bayer

The Bayer area, located 150 km southeast of Amman, is characterised by a rocky desert terrain. Prospecting exploration and radiometric maps show a distinct uranium anomaly in an east-west direction. The area is composed of Tertiary sedimentary rocks such as chalky marls, limestone and cherts. Airborne gamma survey in this area illustrates a substantial east-west anomaly. In addition, car-borne and foot-borne surveys have revealed uranium anomalies along the base of hills with phosphorite layers.

Mafraq

The prospecting area covers nearly 93 km². Features of robust airborne and multiple strong ground gamma anomalies mirroring the lithology of the central Jordan region. Various channels and pit samples were systematically collected for analysis. Notably, carnotite yellow stains were observed, suggesting the presence of uranium and vanadium mineralisation in this region. However, exploration activities were suspended since the area is populated and privately owned.

Dubaydib

The area is situated 350 km south of Amman and 100 km to the east-northeast of Aqaba. It lies in the central part of the Dubaydib Sand Formation from the Ordovician period. The target layer is composed of fine-grained sandstone and siltstone that is brown to dark brown. In 2020, prospecting studies found high mineralisation of rare earth elements (REEs), trace elements and radioactive elements in Dubaydib. The presence of REEs is accompanied by radioactive elements such as uranium and thorium.

In total, it is estimated that about 70 000 tU of speculative resources are present in carbonate rock deposits (Wadi Al Bahiyya, Sahb El Abyad, Bayer, Mafraq) and sandstone deposits in the Dubaydib area.

Unconventional uranium resources and other materials

Unconventional uranium resources in Jordan amount to about 98 000 tU, related to phosphorites, and occur within the Al Risha and Eshidiyya areas.

Al Risha

Al Risha area in northeast Jordan is located 260 km east of Amman and 26 km east of Ar Ruweishid Municipality. It is a substantial resource of phosphorite, approximately 750 million metric tonnes as estimated in 2022. This region is characterised by the Umm Rijam Chert Formation, hosting phosphorite layers primarily within limestone formations, along with chert, chalk, chalky limestone and silicified limestone. Geophysical surveys have identified significant amounts of radioactive elements such as uranium, thorium, radium and radon in this area. Moreover, chemical analyses of collected samples have revealed notable grades of uranium within the phosphate ore, averaging 95 ppm U. The size of the deposit and notable uranium grade demonstrates the potential for extracting substantial quantities of uranium as a byproduct to fertilisers. Total speculative uranium resources for Al Risha are about 70 000 tU.

Eshidiyya

Eshidiyya basin is located in the southern part of Jordan, 125 km north-east of Aqaba. The upper Qatrana member of this basin is characterised by a thickness up to three metres of friable ore-grade phosphorite. Geochemical sampling within the upper member unit revealed uranium concentrations ranging from 30 to 271 ppm U, with an average of 158 ppm U. In addition, the lower phosphorite member displays an average uranium grade of 70 ppm U. The speculative uranium resources for Eshidiyya are about 28 000 tU.

Uranium production

Historical review

Jordan has not produced uranium in the past.

In 1982, a feasibility study for uranium extraction from phosphoric acid was completed by an engineering company (Lurgi A.G. of Frankfurt, Germany) on behalf of the Jordan Fertiliser Industry Company (subsequently purchased by the Jordan Phosphate Mines Company). One of the extraction processes evaluated was originally found to be economically feasible, but as uranium prices dropped in the 1990s, the process became uneconomic, and construction of an extraction plant was deferred.

In 2009, SNC-Lavalin, jointly with Prayon Technologies S.A., performed a technological and economic feasibility study for the recovery of uranium from the phosphoric acid produced at the Aqaba Fertilizer Complex. This study evaluated the internal rate of return to be 6.8%.

JUMCO is conducting research to develop optimised extraction parameters, including:

- Research on dynamic alkaline leaching of central Jordan ore, which has provided promising results of more than 90% recovery.
- The evaluation of process parameters and recovery of uranium at a laboratory scale, using 1-2 m high, 0.14 m diameter extraction columns. The results were promising with more than 85% recovery.

- The evaluation of the scale-up parameters and extraction process at a small-scale pilot-plant, using extraction columns, 6 m high and 0.5 m in diameter, for a semi-pilot scale heap leach. Recovery was in line with previous laboratory studies.
- Installation and commissioning of a pilot-scale uranium extraction plant (three cribs, 3 x 3 x 6 m) with a capacity of approximately 180 tonnes of ore that was commissioned for uranium extraction in 2021. The purpose of the pilot-scale plant is to master the developed process for extracting uranium from the local ores of central Jordan and to generate the technical data needed for finalising the detailed engineering of the commercial plant, and as input data for the bankable feasibility study.
- Mutual collaboration between Jordan and the International Atomic Energy Agency, which has enabled JUMCO to establish an on-site analytical laboratory to support the exploration and extraction activities; the laboratory was commissioned in 2020.
- Plans to build one cell heap leaching pad. This includes finalising engineering drawings, manufacturing units needed, supporting infrastructure, etc.

Status of production capability

Jordan does not have firm plans to produce uranium. JUMCO is investigating the aspects of uranium production in the country and will prepare a bankable feasibility study as soon as other related studies are finished.

Uranium requirements

Jordan has no commercial nuclear power reactors and has very limited domestic uranium requirements. The short-term uranium requirements are based on the operation of Jordan Research and Training Reactor (JRTR). The JRTR is operated by the Jordan Atomic Energy Commission (JAEC) at the Jordan University of Science and Technology (JUST). The JRTR was commissioned in 2017 as a centre for training, education, research, and production of medical and industrial radioisotopes.

The long-term uranium requirements depend on Jordan's nuclear energy policy and post-2030 national energy strategy. JAEC is actively working towards deploying nuclear power reactors in the early 2030s and conducting feasibility studies for a 300 MWe small modular reactor for electricity generation and water desalination in the same time frame. It is projected that the annual uranium requirement will reach approximately 50 tU.

National policies related to uranium

With Jordan’s dedication to establishing a peaceful nuclear energy programme for electricity generation and water desalination, JAEC is committed to the safe, cost-effective, and sustainable development and implementation of Jordan’s small modular reactor (SMR) project. This commitment includes the management of nuclear fuel for the SMR project, involving the creation of a national procurement policy and strategy to ensure cost-effectiveness, reliability, security of supply, energy security, and risk-based inventory management. An integral aspect of Jordan’s nuclear fuel cycle management is the targeted utilisation of the country’s natural uranium resources. The future SMR project owner/operator will actively promote the procurement of indigenously supplied uranium. This approach aims to secure a local supply at a price that supports the sustainability of local uranium production, contributing to the strategic economic development of Jordan. In this regard, JAEC has resumed uranium exploration and extraction within the country, implemented by Jordan Uranium Mining Company (JUMCO) in 2013.

Uranium exploration and development expenditures and drilling effort – domestic

(JOD millions)

	2020	2021	2022	2023 (expected)
Private exploration expenditures	0.00	0.00	0.00	0.00
Government exploration expenditures	0.00	0.00	0.00	0.00
Private development expenditures	0.00	0.00	0.00	0.00
Government development expenditures	1.74	2.55	2.04	2.22
Total expenditures	1.74	2.55	2.04	2.22

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	0	6 785	80
Total	0	0	0	6 785	80

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Heap leaching* from OP	0	0	0	6 785	80
Total	0	0	0	6 785	80

* A subset of open-pit and underground mining, since it is used in conjunction with them.

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Surficial	0	0	0	6 785
Total	0	0	0	6 785

Inferred conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	0	56 234	80 / NA
Total	0	0	0	56 234	

Inferred conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Heap leaching* from OP	0	0	0	28 244	80
Unspecified	0	0	0	27 990	NA
Total	0	0	0	56 234	

* A subset of open-pit and underground mining, since it is used in conjunction with them.

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Surficial	0	0	0	56 234
Total	0	0	0	56 234

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	70 000	NA

Speculative unconventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
98 000	0	NA

Kazakhstan

Uranium exploration

Historical review

Since the beginning of uranium exploration in 1944 in Kazakhstan, about 60 uranium deposits have been identified in six uranium ore provinces – Shu-Sarysu, Syrdarya, Northern Kazakhstan, Caspian, Balkhash and Ili. By the late 1970s, unique large deposits suitable for uranium mining by in situ leaching (ISL), such as Budenovskoye, Inkai, Mynkuduk, Moinkum, Kanzhugan and North and South Karamurun, were discovered.

Recent and ongoing uranium exploration and mine development activities

In 2020, JSC NAC Kazatomprom completed a geological prospecting study for sandstone roll front type mineralisation within the prospective areas of the Shu-Sarysu uranium province, and continued exploration of identified promising areas in 2021 and 2022.

From 2019 to 2022, exploration was undertaken at the Moinkum, Inkai and Budenovskoye deposits in the Shu-Sarysu Uranium Province and at the Northern Kharasan and Zarechnoye deposits in the Syrdaria Uranium Province:

- JV Katko LLP completed pilot production in the southern part of site No. 2 (Tortkuduk) of the Moinkum deposit and in 2022 received permission for its commercial development.
- Inkai JV LLP completed exploration of site No. 1 of the Inkai deposit.
- JSC NAC Kazatomprom completed exploration at site No. 3 of the Inkai deposit and continued exploration of site No.2.
- Budenovskoe LLP completed exploration at the sites No. 6 and 7 of the Budenovskoye deposit and started ISL pilot test in 2023.
- JV Kharasan continued exploration of the Northern Kharasan deposit.
- Exploration at the Zhalpak deposit was completed in 2020 and commercial uranium mining began in 2022.

The 2019-2022 exploration resulted in total resources additions of 102 202 tU, including 81 573 tU at sites No. 6 and No. 7 of the Budenovskoye deposit and 20 629 U at site No. 1 of the Inkai deposit.

Uranium exploration and development expenditures, drilling volumes – outside the country

No exploration and development of uranium deposits was carried out outside of Kazakhstan.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2023, identified in situ uranium resources available at a cost of <USD 260/kgU amounted to 989 495 tU, including 820 875 tU of resources amenable to ISL recovery. Total recoverable resources, with mining and processing losses taken into consideration, amounted to 873 405 tU, including 730 579 tU amenable to ISL mining.

Identified resources decreased insignificantly compared to the previous Red Book 2022 report. Resource depletion from mining during 2021 and 2022 was offset by the exploration resources additions at sites No. 6 and No. 7 of the Budenovskoye deposit and site No. 1 of the Inkai deposit.

In Kazakhstan, 95% of all identified uranium resources in the cost category of <USD 40/kgU, 93% of resources in category <USD 80/kgU, and 83% of resources of <USD 130/kgU, have been contracted by mining companies.

Prognosticated and speculative resources (P1+P2+P3)

In the reporting period, there was no revaluation of prognosticated and speculative resources.

Unconventional resources and other materials

Estimates are not made of Kazakhstan's unconventional uranium resources and other materials.

Uranium production

Historical review

The significant growth of uranium production in Kazakhstan over the last two decades relates to the sandstone-type uranium deposits development by ISL mining. ISL is the lowest cost uranium mining method that has a minimal impact on the environment when done properly.

Production capability and recent and ongoing activities

Uranium production in Kazakhstan in 2021 was 21 834 tU and 21 279 tU in 2022. As of 1 January 2023, the aggregated capacity of 14 uranium existing production centres in Kazakhstan was 25 200 tU/yr.

Uranium was produced at the Kanzhugan, Moinkum, Akdala, Mynkuduk, Inkai, Budenovskoye, North and South Karamurun, Irkol, Zarechnoye, Semizbay, and Northern Kharasan deposits. All uranium deposits were mined by ISL method. Uranium production at ISL mines in Kazakhstan is carried out using sulphuric acid to produce uranium-bearing solutions. Processing of uranium-bearing solutions utilises ion-exchange sorption-elution technologies with further uranyl salts precipitation, refining and final production of U_3O_8 concentrates.

Shu-Sarysu uranium province

The development of the Mynkuduk (Vostochny), Kanzhugan, and Moinkum fields (site No. 3) is carried out by the Kazatomprom-Sauran LLP. The development of the Mynkuduk deposit, Central section and Zhalpak deposit is carried out by Ortalyk LLP. JV Katco LLP operates two sites of the Moinkum deposit, site No. 1 (Northern) and site No. 2 (Tortkuduk). JV Inkai LLP operates the Inkai deposit (site No. 1) and sites No. 2 and No. 3 were returned to the state fund. In 2018, JSC NAC Kazatomprom obtained exploration contracts for areas No. 2 and No. 3 of the Inkai deposit. Appak LLP develops the Western site of the Mynkuduk deposit. JV Akbastau JSC operates deposit Budennovskoye (sites No. 1, No. 3 and No. 4), Karatau LLP develops site No. 2

of the Budenovskoye deposit and performs processing of solutions extracted from the sites No. 1 and No. 3 of the Budennovskoye deposit. JV South Mining Chemical Company LLP (SMCC) operates the Akdala and Inkai (site No. 4) deposits.

Syrdarya uranium province

JSC NAC Kazatomprom, through the Mining Group-6 LLP, operates the North and South Karamurun deposits. The Irkol deposit is being developed by Semizbay-U LLP. Baiken-U LLP carries out uranium production at the Northern Kharasan (site Kharasan-2) deposit. Khorasan-U LLP operates the Northern Kharasan (site Kharasan-1) deposit, and solutions processing is carried out by Kyzylkum LLP. JV Zarechnoye JSC develops Zarechnoye deposit. The Balausa LLP is working on the Bala-Sauskandykskoye uranium-vanadium deposit by open-pit methods. About 0.7 tU was mined and stockpiled as a by-product to vanadium.

Northern Kazakhstan uranium province

Stepnogorsk Mining Chemical Complex LLP stopped production at the Vostok and Zvezdnoe deposits and the underground mine was closed in 2013. The Semizbay deposit is being developed by Semizbay-U LLP.

Uranium production centre technical details

(as of 1 January 2023)

	Centre # 1	Centre # 2	Centre # 3	Centre # 4	Centre # 5	Centre # 6	Centre # 7	Centre # 8
Name of production centre	Kazatomprom-SaUran LLP		Mining Group-6 LLP	JV South Mining Chemical Company LLP	JV Katko LLP	JV Inkai LLP	JV Zarechnoe JSC	Karatau LLP
	Taukent Mining Chemical Plant	Stepnoye Mining Group						
Production centre classification	Existing	Existing	Existing	Existing	Existing	Existing	Existing	Existing
Date of first production (year)	1982	1978	1985	2001	2004	2004	2007	2007
Source of ore:								
Deposit name(s)	Kanzhugan, Moinkum (sites 1, 3)	Mynkuduk (Eastern site), Uvanas	North and South Karamurun	Akdala, Inkai (site 4)	Moinkum (sites 1, 2), Tortkuduk	Inkai (site 1)	Zarechnoye,	Budenovskoe (site 2)
Deposit type(s)	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone
Resources in situ (tU)	25 287	4 385	15 258	75 423	59 954	147 993	4 237	35 872
Grade (% U)	0.052	0.031	0.080	0.052	0.071	0.056	0.050	0.096
Mining operation:								
Type (OP/UG/ISL)	ISL	ISL	ISL	ISL	ISL	ISL	ISL	ISL
Size (tonnes ore/day)								
Average mining recovery (%)	87	90	91	90	85	85	90	90
Processing plant:								
Acid/alkaline	Acid	Acid	Acid	Acid	Acid	Acid	Acid	Acid
Type (IX/SX)	IX	IX	IX	IX	IX	IX	IX	IX
Size (kilolitre/day)	85 000	60 000	60 000	140 000	100 000	80 000	80 000	60 000
Average process recovery (%)	98.9	98.7	98.7	98.9	98.9	98.9	98.5	98.9
Nominal production capacity (tU/year)	1 000	1 300	1 000	3 000	4 000	2 500	1 000	3 200
Plans for expansion (yes/no)	No	No	No	No	No	Yes	No	Yes
Other remarks								

Uranium production centre technical details

(as of 1 January 2023)

	Centre # 9	Centre #10	Centre #11	Centre # 12	Centre # 13	Centre # 14	Centre # 15
Name of production centre	Ortalyk LLP	Appak LLP	Khorasan-U LLP	Bayken-U LLP	JV Akbastau JSC	Semyzbai-U LLP	Budenovskoe LLP
Production centre classification	Existing	Existing	Existing	Existing	Existing	Existing	Committed
Date of first production (year)	2007	2008	2008	2009	2009	2007	2023 pilot mining
Source of ore:							
Deposit name(s)	Mynkuduk (Central site), Zhalpak	Mynkuduk (Western site)	North Kharasan (site 1)	North Kharasan (site 2)	Budenovskoe (sites 1, 3, 4)	Semyzbai, Irkol	Budenovskoe (sites 6, 7)
Deposit type(s)	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone
Resources in situ (tU)	35 356	15 409	34 785	15 588	36 174	25 388	114 238
Grade (% U)	0.047	0.027	0.204	0.117	0.089	0.050	0.072
Mining operation:							
Type (OP/UG/ISL)	ISL	ISL	ISL	ISL	ISL	ISL	ISL
Size (tonnes ore/day)							
Average mining recovery (%)	90	90	90	90	90	87	NA
Processing plant:							
Acid/alkaline	Acid	Acid	Acid	Acid	Acid	Acid	Acid
Type (IX/SX)	IX	IX	IX	IX	IX	IX	IX
Size (kilolitre/day)	70 000	60 000	50 000	60 000	20 000	85 000	0
Average process recovery (%)	98.5	98.9	98.5	98.5	98.9	98.6	NA
Nominal production capacity (tU/year)	2 000	1 000	1 400	2 000	600	1 200	6 000
Plans for expansion (yes/no)	Yes	No	Yes	No	Yes	No	Yes
Other remarks							

Ownership structure of the uranium industry

In 2022, the JSC NAC Kazatomprom share of uranium production in Kazakhstan was 54% (11 417 tU). Seventy-five per cent of JSC NAC Kazatomprom is owned by the state-owned company Samruk-Kazyna JSC national wealth fund, and 25% of shares are traded at the London Stock Exchange. The production share of private foreign companies in Kazakhstan amounted to 13%, while the share of state foreign companies in Kazakhstan amounted to 33% of total production.

In 2022, JSC NAC Kazatomprom had shares in joint ventures with private companies from Canada, Japan, Kazakhstan and Kyrgyzstan (JV Inkai LLP, Appak LLP, Kyzylkum LLP, Khorasan-U LLP, Baiken-U LLP, JV Zarechnoe JSC), and with foreign state companies from China, France and Russia (Semizbay-U LLP, JV Katco LLP, SMCC LLP, JV Akbastau JSC, Karatau LLP, JV Zarechnoe JSC, Kyzylkum LLP, Khorasan-U LLP), JV Budennovskoye LLP, Ortalyk LLP.

Employment in the uranium industry

One of the important areas of personnel policy of JSC NAC Kazatomprom and its subsidiaries and affiliates (hereinafter referred to as Subsidiaries) is the development and training of personnel.

In order to train and re-train highly professional personnel, JSC NAC Kazatomprom and its enterprises co-operate with leading universities and colleges of the Republic of Kazakhstan and abroad. To date, these are 32 universities in specialised areas (for details see Kazakhstan country report in the Red Book 2022).

In 2020, JSC NAC Kazatomprom launched "Izbasar", its local programme for the development of young specialists. The purpose of the programme is to nurture talented leaders with the prospect of gradual career growth at the enterprises of JSC NAC Kazatomprom. The programme provides a unique experience of internships at several enterprises of the company and special training. Since 2023, the programme has focused on internal young employees of the company.

In 2023, the social project of educational grants "Murager" was launched, aimed at supporting applicants, college graduates and elementary students in the regions of the company's presence (Turkestan, Kyzylorda and East Kazakhstan regions). Thus, the company plans to contribute to the development of the regions and increase the level of education of the local population, including the popularisation of technical specialties for the purpose of further employment at the company's enterprises.

Activities of the Center for the Development of Professional Competencies (CDPC) of JSC NAC Kazatomprom are aimed at sustainable growth of professional competencies of engineering and technical workers and working personnel. Within the framework of the CDPC, professional development programmes for employees of mining enterprises of JSC NAC Kazatomprom have been developed and implemented in 14 profile areas of activity.

In order to preserve and facilitate transfer of knowledge in JSC NAC Kazatomprom, the School of Internal Trainers was successfully launched within which selected employees of the Company and Subsidiaries are certified as internal trainers to carry out coaching activities, sharing their experience and knowledge with colleagues. Much attention is also paid to professional development programmes for employees, including compulsory training in accordance with the legislation of the Republic of Kazakhstan, and for the implementation of targeted training programmes (leadership development, lean production, corporate culture, safety culture, etc.).

In addition, there are training centres where employees of JSC NAC Kazatomprom and Subsidiaries are trained in occupational, industrial, electrical and fire safety. Training is also provided in additional positions, such as a slinger, crane operation and a cradle worker, etc., with certificates issued after successful completion of the training.

The fulfilment of the licence and contractual obligations of the company and its contracting enterprises is carried out following the Code of the Republic of Kazakhstan "On Subsoil and Subsoil Use" and a number of ministerial decrees. According to the contract terms for subsoil use, the annual mandatory costs for training and retraining of personnel amounts to 1% of the annual costs of exploration and 1% of the annual costs of operation during uranium mining.

Total employment in existing production centres totalled 20 825 in 2021 and 20 558 in 2022, slightly less than in 2020 (21 186 persons).

Future production centres

Since 2019, exploration was conducted at sections 2 and 3 of the Inkai field. After exploration is complete, new ISL uranium production centres will be created.

The Budenovskoye LLP started pilot mining in 2023 at areas 6 and 7 of the Budenovskoye deposit and commercial ISL production is planned for 2024. According to the feasibility study, mine capacity will reach 6 000 t/y.

Secondary sources of uranium

Production and/or use of mixed oxide fuels

Mixed oxide (MOX) fuel is neither produced nor used in Kazakhstan.

Production and/or use of re-enriched tails

Uranium obtained through re-enrichment of depleted uranium tails is neither produced nor used in Kazakhstan.

Environmental activities and social cultural issues

Environmental activities

Subsoil users created a reclamation fund to eliminate the effects of operations on subsoil use in Kazakhstan. Contributions to the reclamation fund during the exploration and extraction of subsurface users are produced annually at a rate of at least 1% of the annual cost of exploration and production in a special deposit account in any bank in the state.

In the framework of ecological policy in Kazakhstan, a number of measures to improve environmental protection and encourage rational use of natural resources have been implemented in recent years.

Each uranium venture in Kazakhstan realised a short-term waste management plan, which includes measures to reduce their generation and accumulation. Reliable systems for monitoring the environment and radiation safety at uranium mines and production sites are in place. The purpose of environmental monitoring at the enterprises of the company is to provide reliable information about the impact of the enterprise on the environment and possible changes in adverse or dangerous situations.

Environmental safety has a significant role in the effective functioning of the system of industrial environmental monitoring.

Social and/or cultural issues

All contracts for uranium exploration and mining provided by the government require financial contributions to local social and cultural improvements. All subsoil users are obliged to finance the establishment, development, maintenance and support of the regional social sphere, including health care facilities for employees and local citizens, education, sport, recreation and other activities in accordance with the Strategy of JSC NAC Kazatomprom and by an agreement with local authorities.

Contributions from each operator amount to:

- USD 30 000 to 100 000 per year (during the exploration period);
- up to 15% of annual operational expenses or USD 50 000 to 350 000 per year (during the mining period).

Expenditures on environmental activities and social cultural issues in 2022

	KZT million
Improving technological processes, including reduction of fugitive emissions into the environment	292.4
Improving the efficiency of existing dust and gas collection and water treatment plants	47.4
Carrying out research activities in the field of environmental protection	406.6
Implementing environmental monitoring	328.4

Uranium demand

Domestic demand for natural and enriched uranium is not expected in Kazakhstan over the next decade. Construction of a nuclear power plant is under consideration.

Supply and procurement strategy

At present the entire volume of uranium produced in Kazakhstan is exported to the world market.

National policies relating to uranium

In January 2017, due to the prolonged downturn in the uranium market, Kazakhstan's national atomic company, JSC NAC Kazatomprom, reduced Kazakhstan's uranium production by approximately 10% for 2017. In December 2017, given the challenging market conditions, and in light of continued oversupply in the uranium market, JSC NAC Kazatomprom announced further production cuts by 20% below Subsoil Use Contracts for 2018-2020. In August 2019, JSC NAC Kazatomprom announced its intention to continue to flex down production by 20%, compared to the planned levels under Subsoil Use Contracts through 2021. Likewise, in August 2020, JSC NAC Kazatomprom announced its intention to continue to cut production by 20% until 2022. In September 2023, JSC NAC Kazatomprom decided to return to a 100% level relative to its subsoil use agreements for the first time since 2018.

On 13 November 2018, JSC NAC Kazatomprom made its stock market debut after raising USD 450 million from investors in London and Astana. JSC NAC Kazatomprom sold 15% of its stock in the dual-listing offering, which valued the company at USD 3 billion. The share of shares in free float eventually increased to 25% as a result of two secondary public offerings (SPOs) in September 2019 and June 2020.

Uranium exploration and development expenditures and drilling effort – domestic

(KZT million)

	2019	2020	2021	2022
Industry* exploration expenditures	5 980	4 617	2 274	1 808
Government exploration expenditures	0	0	0	0
Industry* development expenditures	1 165	750	1 888	2 552
Government development expenditures	0	0	0	0
Total expenditures	7 145	5 367	4 162	4 360
Industry* exploration drilling (m)	362 136	433 462	205 015	188 046
Industry* exploration holes drilled	539	641	541	493
Industry exploration trenches (m)	0	0	0	0
Industry trenches (number)	0	0	0	0
Government exploration drilling (m)	0	0	0	0
Government exploration holes drilled	0	0	0	0
Government exploration trenches (m)	0	0	0	0
Government trenches (number)	0	0	0	0
Industry* development drilling (m)	230 647	358 957	488 285	899 497
Industry* development holes drilled	664	617	1 142	2 042
Government development drilling (m)	0	0	0	0
Government development holes drilled	0	0	0	0
Subtotal exploration drilling (m)	362 136	433 462	205 015	188 046
Subtotal exploration holes drilled	539	641	541	493
Subtotal development drilling (m)	230 637	358 957	488 285	899 497
Subtotal development holes drilled	664	617	1 142	2 042
Total drilling (m)	592 773	792 419	693 300	1 087 543
Total number of holes drilled	1 203	1 258	1 683	2 535

* Non-government.

Reasonably assured conventional resources by production method

(tonnes U*)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	4 179	31 941	55 586	83
Open-pit mining (OP)	0	0	31 177	31 177	91
In situ leaching acid	305 338	404 454	404 454	404 454	89
Total	305 338	408 633	467 572	491 217	88

* In situ resources reported with recovery factors provided.

Reasonably assured conventional resources by processing method

(tonnes U*)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	4 179	31 941	55 586	83
Conventional from OP	0	0	31 177	31 177	91
In situ leaching acid	305 338	404 454	404 454	404 454	89
Total	305 338	408 633	467 572	491 217	88

* In situ resources reported with recovery factors provided.

Reasonably assured conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	305 338	404 454	404 454	404 454
Metasomatite	0	4 179	15 925	30 299
Phosphate deposits	0	0	29 184	38 455
Lignite-coal	0	0	18 009	18 009
Total	305 338	408 633	467 572	491 217

* In situ resources reported.

Inferred conventional resources by production method

(tonnes U*)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	4 896	29 144	77 137	83
Open-pit mining (OP)	0	0	2 849	2 849	91
In situ leaching acid	255 046	406 250	416 421	416 421	89
Co-product and by-product	0	1 871	1 871	1 871	91
Total	255 046	413 017	450 285	498 278	88

* In situ resources reported with recovery factors provided.

Inferred conventional resources by processing method

(tonnes U*)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	4 896	29 144	77 137	83
Conventional from OP	0	1 871	4 720	4 720	91
In situ leaching acid	255 046	406 250	416 421	416 421	89
Total	255 046	413 017	450 285	498 278	88

* In situ resources reported with recovery factors provided.

Inferred conventional resources by deposit type
(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	255 046	408 121	418 292	418 292
Metasomatite	0	4 896	29 709	72 845
Phosphate	0	0	0	4 857
Lignite-coal	0	0	2 284	2 284
Total	255 046	413 017	450 285	498 278

* In situ resources reported.

Prognosticated conventional resources
(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
85 783	113 728	115 258

Speculative conventional resources
(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
191 880	219 380	N/A

Historical uranium production by production method
(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (actual)
Open-pit mining*	21 618	0	0	21 618	0
Underground mining*	42 549	0	0	42 549	0
In situ leaching	316 416	21 834	21 279	359 529	21 112
Total	380 583	21 834	21 279	423 696	21 112

*Pre-2010 totals may include uranium recovered by heap and in-place leaching.

Historical uranium production by processing method
(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (actual)
Conventional	42 109	0	0	42 109	0
Heap leaching*	440	0	0	440	0
In situ leaching	316 416	21 834	21 279	359 529	21 112
U recovered from phosphate rocks	21 618	0	0	21 618	0
Total	380 583	21 834	21 279	423 696	21 112

* A subset of open-pit and underground mining, since it is used in conjunction with them.

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (actual)
Sandstone	316 416	21 834	21 279	359 529	21 112
Metasomatite	42 549	0	0	42 549	0
Phosphate	21 618	0	0	21 618	0
Total	380 583	21 834	21 279	423 696	21 112

Ownership of uranium production in 2022

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
11 417	54	-	-	7 037	33	2 825	13	21 279	100

Uranium industry employment at existing production centres

(person-years)

	2019	2020	2021	2022
Total employment related to existing centres	20 684	21 186	20 825	20 558
Employment directly related to uranium production	7 242	7 060	6 710	6 934

Mid-term production projection

(tonnes U/year)

2025	2030	2035	2040	2045	2050
29 000	29 000	21 000	12 000	N/A	N/A

Short-term production capability

(tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
28 000	29 000	28 000	29 000	26 000	29 000	26 000	29 000

2035				2040			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
14 000	22 000	14 000	23 000	9 000	13 000	9 000	14 000

Kenya

Uranium exploration and development

Historical review

Kenya has undertaken exploration for uranium since the 1950s, which has involved private companies and individual research. Since the 1980s, the exploration strategy in Kenya has been implemented through government, whereas exploration survey work on the ground has been funded and carried out by companies, citizens, or through government state corporations or agencies. Only recently, in 2021, did the Government of Kenya initiate through the State Department of Mining a countrywide geophysical survey in search of uranium deposits. The project is funded by the government to ensure full knowledge and access of data on resources.

Historic data pertaining to uranium exploration is limited as there is no public access to records or centralised information or databases. The table below provides information on the historical data collected by the Nuclear Power and Energy Agency (NuPEA) since 2012:

Company/individual research	Year	Analysis/evaluation methodologies	Region
	1952	Ground traverse, soil sampling and use of a ratemeter (radioactivity measurement of both the solid rocks and their soil cover in impulses per minute)	- Homa mountain - Ruri
United Kingdom Atomic Energy Agency	1958	Aerial Radiometric Survey	Unknown
Terra Surveys (Canada)	1977	Airborne Spectrometric Survey	Coast Province
H.T. Macharia and H. Limion (unpublished)	1978	Analysis of Airborne Spectrometric Survey	Coast Province
	1982	Regional Airborne Geophysical Survey	Kerio Valley and Environs
Kenya and France (BRGM)	Unknown (certainty beyond 1982)	Ground Radiometric Survey (follow up of Geosurvey Int'l work)	Kerio Valley
Mines and Geology Department	Unknown	Probably a similar approach by L.D. Sanders	- Barsaloi area of Samburu - Mount Elgon Region
David Otwoma et al	2012	Radiometric Survey	Homa Mountain Region in South Nyanza
Kenneth Andibo et al	2020	Ground traverse, soil and rock sampling and use of a ratemeter (radioactivity measurement of both the solid rocks and their soil cover in impulses per minute), elemental content analysis,	Cheptais, Mt. Elgon
	2021	Background radiation measurements	Ortum, West Pokot, Western Kenya
Ministry of Mining	2021 - Present	Planning and area selection, reconnaissance phase (Airborne Radiometric Survey 1:20000), ground-truthing validation	Whole country

Recent and ongoing uranium exploration and mine development activities

The Government of Kenya has established a multi-agency team led by the State Department of Mining to undertake exploration of mineral resources including uranium and thorium. The exploration has progressed considerably, with the prospecting phase finalised. The prospecting phase carried out a radiometric survey that utilised airborne geophysical Naturally Adsorbed Gas Survey (NAGS) acquisition technology. The survey was conducted at a nominal survey height of 80 m with survey lines spaced 200 m apart and tie lines spaced 2 000 m apart. The data sampling rates for the two types of measurements taken were 25 Hz for magnetics and 2 Hz for radiometrics. The data collected from the survey was used to interpret the geology of the area in order to revise existing geological maps and identify potential resource zones. The interpretation was conducted using a scale of 1:20 000 allowing for more detailed information to be captured in comparison to the older colonial maps.

Since 2021, the Government of Kenya has funded a countrywide geophysical survey in search of uranium deposits. As of 2023 approximately KES 2 billion has been spent on surveys that are currently in the ground-truthing validation phase. Exploratory drilling and trenching are yet to be undertaken.

The Government of Kenya has not undertaken any non-domestic exploration of uranium and thorium.

Uranium resources

Kenya does not report any uranium resources in any category.

Uranium production

There has been no past production of uranium.

Uranium requirements

Kenya has established a nuclear power programme that envisages introduction of a nuclear power plant with a capacity 600 MWe to the grid by the year 2038. The Energy Act 2019 established the Nuclear Power and Energy Agency (NuPEA) to fast track the development of the programme. The programme is guided by the IAEA milestone approach in the development of national infrastructure for nuclear power.

NuPEA has also conducted a feasibility study for a Kenya Nuclear Research Reactor (KNRR) project to be commissioned by 2030. The feasibility study reports the results of all preliminary studies for the establishment of a research reactor, including an infrastructure assessment, project justification, preliminary strategic plan, economic cost benefit analysis, and preliminary site investigation.

Kenya has developed a Nuclear Fuel Cycle Policy, which prioritises the procurement of enriched uranium as part of the nuclear power and research reactor technology bids.

Supply and procurement strategy

Kenya’s Nuclear Fuel Cycle Policy states that the government shall consider the purchase of fabricated fuel from the world supply market, whereby the supply comes from more than one supplier and from different countries with supply capability.

Regulatory regime

Despite the fact that Kenya is not actively undertaking uranium and thorium mining, there exists a legal and regulatory regime for oversight of future potential uranium and thorium mining.

The Nuclear Regulatory Act, No 29 of 2019 establishes the Kenya Nuclear Regulatory Authority (KNRA). Section 42 (1) and (2) of the Act mandates KNRA to develop requirements and guidelines for issuing licences for siting, exploration, mining and milling of U, Th or other radioactive elements, and decommissioning of the mines.

The Environmental Management Coordination Act (EMCA), 1999 (Amended 2015), established the National Environmental Management Authority (NEMA). The Act provides a framework for conducting an environmental impact assessment (EIA) for activities including the mining of minerals.

The Mining Act, No. 12 of 2016 provides a legal and regulatory framework for all mining activities in Kenya.

Madagascar

Uranium exploration and mine development

Historical review

The first uranium exploration activities in Madagascar date back to the "radium period" and focused on pegmatites at Itasy and secondary uranium occurrences at Antsirabe. Uranium deposits were discovered in a lacustrine basin in the central part of Madagascar. Small-scale mining started in 1909 and ended in 1939.

The first mission of the French Atomic Energy Commission (CEA) arrived in Madagascar in late 1946. From 1954 to the early 1960s, the CEA explored and mined uranothorianite from the Tranomaro area in southern Madagascar. From 1958 to 1963, the CEA explored for uranium in the Morondava Basin and discovered radiometric anomalies leading to the discovery of the Folakara deposit. After 1963, the CEA ceased all activity in Madagascar.

After geological, geophysical and geochemical surveys were completed by the CEA, the Office of National Mines and Strategic Industries (OMNIS), in partnership with the UNDP and the IAEA, continued to undertake geological, geochemical and drilling work in the central, southern and western parts of Madagascar, from 1976 to 1984.

In 1999-2000, OMNIS and COGEMA carried out a brief review of the uranium potential of Madagascar. Detailed exploration activities were only carried out at the Folakora deposit.

In 2003, as part of Madagascar's World Bank funded project, *Projet de Gouvernance sur les Ressources Minérales* (PGRM), the US Geological Survey conducted a preliminary assessment of undiscovered mineral resources, which included sandstone-hosed, metasomatite (U-Th skarn), and phosphate uranium-bearing deposit types. Areas permissive for uranium mineralisation were identified. A follow-up multi-resource assessment that included areas permissive for uranium mineralisation was carried out for the Anosy Region in 2006.

Uranium exploration was revived in 2015. Through OMNIS, the government of Madagascar renewed technical co-operation with the IAEA and carried out limited geological studies and exploration activities in the Makay region in the southern part of the Morondava Basin.

Recent and ongoing uranium exploration and mine development activities

Since 2015, OMNIS has, with the help of the IAEA, examined the general geology of the Morondava Basin and uranium mineralisation previously discovered in the Karoo formations in the Makay mountain range.

In 2016, OMNIS carried out several ground surveys, including field verification of preliminary geological maps and radiometric anomalies discovered by the CEA in the Makay area. Activities included geological mapping and structural, geochemical and radiometric studies. Trenches and pits were made, and stream sediments were collected.

In 2017, 16 trenches (10 m long) and 17 pits were completed in the Ambakaka and MAN 20 areas. Uranium anomalies and potentially significant structures were identified and explored. Rock samples were collected for analysis.

In 2018, OMNIS continued its uranium project with detailed exploration in two sectors: MAN 20 and Ambakaka areas. Rock samples were sent for analysis to CNEA in Argentina and CREGU in France.

In 2019, OMNIS continued detailed exploration activities in the Makay area (MAN 20), including geophysical and radiometric surveys (systematic scintillometer and radon coverage), coupled with tectonic/structural studies, trench and pit sampling, stream-sediment sampling, and geological mapping.

In 2020, because of the COVID-19 pandemic, uranium exploration activities (fieldwork) were forced to stop.

In 2021, OMNIS continued detailed uranium exploration activities in the Makay area: the Ambakaka River and the Androbotsy, Antsohy and Vinanikitony areas. Activities included geophysical and radiometric studies, geological studies and mapping, trenching and collection of rock pit samples for analysis.

In 2022, OMNIS continued detailed exploration in the Vinaninkitony area, in the southern part of Madagascar. Surface prospecting work included: radiometric-geochemical surveys, 5 trenches (10 to 25 m long and 2 m deep), 5 pits of 2 m deep, 16 vertical channels. A radiometric survey, at a 50 m x 50 m mesh, was carried out over a surface area of nearly 100 ha. A total of 160 rock samples were analysed at the OMNIS laboratory (T-XRF, ICP-MS). A technical report was made.

In 2023, OMNIS will continue detailed uranium exploration in the Ambakaka River, the Vinanikitony area and another site.

Uranium exploration and development expenditures

(in EUR)

	2016	2017	2018	2019	2021	2022
Government exploration expenditures	12 000	21 000	NA	20 000	25 000	30 000
Total expenditure	12 000	21 000	NA	20 000	25 000	30 000
Trenches (m)	0	160	0	NA	16	66
Trenches (no.)	0	16	0	16	06	5

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

At present there are no uranium resources in Madagascar that can be reported in the identified resources category.

Undiscovered resources

In 1981 and 1983, the IAEA International Uranium Resources Evaluation Project (IUREP) study estimated Madagascar's speculative resources to be in the range of 10 000-50 000 tU.

Uranium production

Madagascar was one of the first uranium producing countries. During the period 1909-1921, approximately 57 t of uranocircite, containing about 36 tU, were produced from a deposit located in the Antsirabe Basin. Also, between 1912 and 1927, betafite concentrates containing about 24 tU were produced from pegmatites in the Itasy-Antsirabe-Handoto area.

Between 1953 and 1966, the French Atomic Energy Commission and local miners produced uranothorianite from alluvial and primary deposits hosted in the Precambrian metasediments in the Fort Dauphin area. The most important mines were Marosohy, Amboanemba and Ambindrakembe. A total of 3 986 t of concentrate was produced. The total production is estimated at 785 tU and 3 000 tTh.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Exploration and mining activities in Madagascar are regulated by the Mining Code. Other policies and laws related to uranium include protection against the risks of ionising radiation, the management of radioactive waste, and the protection of nuclear material, nuclear installations and other sources of radiation.

Malawi

Uranium exploration and mine development

Historical review

The Kayelekera deposit was discovered in the early 1980s by the Central Electricity Generating Board of Great Britain (CEGB). Kayelekera is a sandstone-hosted uranium deposit, located close to the north tip of the North Rukuru Basin. This basin contains a thick (at least 1 500 m) sequence of Permian Karoo sandstones preserved in a semi-graben about 35 km to the west of and broadly parallel to the Lake Malawi section of the East African Rift System. Mineralisation lies within the uppermost 150 m of the Muswanga Member, which is the upper part of the Karoo Formation. The Muswanga Member consists of a total of eight separate arkose units with intervening silty mudstones in an approximate 1:1 ratio. Such a succession is indicative of cyclic sedimentation within a broad, shallow, intermittently subsiding basin. The arkose units contain most of the uranium mineralisation. They are on average about 8 m thick, are generally coarse grained and poorly sorted, and contain a high percentage of fresh, pink feldspar grains. The basal arkose units are usually a quartz-feldspar pebble conglomerate. Coffinite is the principal uranium-bearing mineral and it occurs together with minor uraninite. Near-surface weathering of primary ore has produced a zone of oxide ore characterised by yellow and green secondary uranium minerals (meta-autunite and boltwoodite). Approximately 40% of the total ore occurs within reduced arkose, 30% within oxidised arkose, 10% in mixed arkose, and 20% is considered of the mudstone type.

Extensive drilling from 1982 to 1988 defined an initial inferred resource of 9 800 tU at an average grade of 0.13% U. From 1989 to 1992, geotechnical, metallurgical, hydrological and environmental activities were conducted, as well as a feasibility study to assess the viability of a conventional open-pit mining operation. This work was completed in 1991 at a total cost of USD 9 million. The CEGB study concluded that the project was uneconomic using the mining model adopted and the low uranium prices of that time and so the project was abandoned in 1992.

In 1998, Paladin Resources Ltd (Paladin Energy Ltd as of 1 February 2000) acquired an interest in the Kayelekera Project through a joint venture with Balmain Resources Ltd, which at that time held exploration rights over the project area. Engineering and financial evaluation work indicated a positive outcome for the project. In 2004, additional drilling was completed to improve confidence in resource estimates, and the pre-feasibility study was updated. Resource drilling and bulk sample drilling for metallurgical test work was completed in 2005 and a bankable feasibility study was then undertaken. Paladin purchased Balmain's remaining stake in the project in 2005 and became the sole owner.

Uranium exploration increased as a result of expanding resources at the Kayelekera mine and the potential for discovery of additional deposits in a similar geological setting in the Karoo Group sedimentary rocks. Between 2010 and 2012, Paladin Energy completed exploration drilling in areas to the north-west and south of the mine area with objectives of extending the existing orebody, as well as identifying and evaluating new ore bodies, including Mpata to the east and Juma to the south.

In 2006, the Livingstonia project area was explored by Globe Resources who drilled 94 holes totalling 11 533 m. In July 2010, Resource Star did an additional 1 502 m of drilling in 13 holes to establish a JORC compliant inferred resource of 7.7 million tonnes ore grading 0.0229% U. In 2013, Resource Star, the operator of the Livingstonia Project, reported that thickened zones of mineralisation are open to the north-east, and the sparse drilling in the southern zone increases potential for additional mineralisation being defined.

Another potential uranium resource is the Kanyika Niobium Project held by Globe Metals and Mining Limited. Uranium is an important by-product in the complex niobium and tantalum ore in a pegmatite quartz vein, hosted in Proterozoic felsic schists. Niobium and tantalum products would be produced with uranium as a by-product. In 2011-2012, Globe Metals & Mining Limited continued development of the Kanyika deposit. Total drilling, reverse circulation and diamond drilling, amounted to 40 540 m. As of December 2012, total resources amount to 68.3 Mt of ore at an average grade of 0.28% Nb_2O_5, 0.0135% Ta_2O_5 and 0.0067% U (4 550 tU).

Recent and ongoing uranium exploration and mine development activities:

Lotus Resources Ltd (Lotus) through its subsidiary Lotus Africa Limited (LAL) acquired the Kayelekera Project in March 2020 and the Livingstonia prospect in 2021. Lotus owns 85% of LAL, with the remaining 15% held by the Government of Malawi.

In early 2022, the company released an updated mineral resource estimate for Kayelekera showing measured, indicated, inferred and stockpiled resources of 46.3 million pounds U_3O_8 (17 810 tU) grading 0.05% U_3O_8 (0.0425% U) The Kayelekera resource upgrade was completed as part of evaluation studies for the Restart Definitive Feasibility Study (DFS), which Lotus released in August 2022, showing that Kayelekera ranks as one of the lowest capital cost uranium projects globally, and that the project could purportedly recommence production within 15 months of a Final Investment Decision (FID). The Restart DFS is underpinned by an ore reserve of 23 million pounds U_3O_8 at 0.066% U_3O_8, with the mine plan based on 96% ore reserves and 4% inferred mineral resources.

Lotus is currently engaging with various nuclear energy utilities and the Malawi Government to support the restart of Kayelekera.

Lotus Resources' regional exploration conducted in 2022 successfully defined an inferred mineral resource estimate of 6.9 MT at 320 ppm U_3O_8, at Livingstonia, and at Chilumba intersected 12 m thick of U_3O_8 anomaly at 38 m depth (best intercept 3 m @382ppm).

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2023, Malawi's total recoverable identified resources were 18 640 tU. This is based on resources at three projects: the Kayelekera operating mine (14 412 tU), Livingstonia deposit (1 498 tU) (both sandstone deposits), and Kanyika niobium-tantalum deposit (2 730 tU), where uranium will be produced as a by-product. During 2021 and 2022, recoverable uranium resources increased by 2 368 tU, as a result of new resource evaluations completed by Lotus Resources Ltd for Kayelekera and Livingstonia deposits.

Uranium production

Historical review

The Kayelekera mine is located in Karonga District in the Northern Region of Malawi, about 600 km by road from the capital city of Lilongwe. This was the first mine to have produced uranium in Malawi. However, as a result of the sustained low uranium prices, the mine was placed into care and maintenance in February 2014.

Prior to care and maintenance, uranium production was by open pit with an annual production of 1 270 tU. Uranium was recovered using a solvent extraction process, with sulphuric acid as the lixiviant and sulphur dioxide/air mixture as the oxidant. The plant utilised a resin-in-pulp (RIP) process that was the first in the Western world for uranium production. Transport of the product was by road to Walvis Bay in Namibia, via Zambia, with first delivery undertaken on 17 August 2009.

Ground movements in the open-pit mine, which were first noted in 2010, continue to be monitored using installed prisms and inclinometers to provide information for timely management of emerging issues.

Status of production facilities, production capability, recent and ongoing activities, and other issues

In 2013, Kayelekera mine made progress on cost reductions, mainly on the acid supply front, where the project became acid independent through a number of measures. Improvements included increases in on-site acid production and the addition of the nano-filtration plant, which assisted with acid recycle. In addition to acid management, other improvements were realised in the milling, leach and RIP efficiencies, particularly with completion of modifications in the RIP section.

In 2014, the site was placed into care and maintenance. Following a period of reagent run-down, processing was completed in early May 2014. Care and maintenance was expected to cost about USD 12 M per year and is still ongoing, compared with operating losses of double that amount. It is expected that production will recommence once the uranium price improves.

Lotus Resources plans to use optimal power supply, achieved through a combination of cogeneration, solar/BESS and grid with some diesel required for certain periods. This will reduce carbon dioxide emissions by about 72% compared with previous operation.

Ownership structure of the uranium industry

Lotus Africa Limited (LAL), a company incorporated in Malawi on 1 August 2000 (Company Registration No. 5664), which owns the mining rights for Kayelekera mine, is in turn owned primarily by Lotus Resources Ltd, an Australian listed public company. Lotus holds 85% of the equity in LAL and the remaining 15% interest is held by the Republic of Malawi. The mine site is covered by the Mining License ML0152, granted over an area of 55 km² and expiring on 1 April 2037.

LAL also holds rights for EL417 (Rukuru), EL418 (Uliwa), EL489 (Nthalire), EL583 and EL595 (Livingstonia). All of these areas are important for LAL to explore for potential discovery of economic uranium resources that would extend the mine life of Kayelekera mine (KM).

Employment in the uranium industry

Paladin employed 759 people at the Kayelekera mine in 2012, of which 118 were expatriates and 68, or 9%, were female. The number was reduced to 120 when care and maintenance was announced in 2014. Lotus reduced the number further to 19, including 2 expatriates and 17 nationals. The team includes three female employees.

Future production centres

Globe Metals & Mining submitted the environmental impact assessment for the Kanyika Niobium Project for public review in May 2012. According to Globe, the aim of the project is to produce niobium and tantalum products with potential production of uranium and zircon. Uranium would be produced as a by-product at a nominal rate of 60 tU/yr in a form of ammonium di-uranate. Mining will involve the extraction of ore from a single open pit at a rate of 1.5 million tonnes per annum using conventional open-pit drill and blast, followed by truck shovel load and haul. The final open pits are expected to have dimensions in the order of 250 m in width, 2.2 km in length (north-south) and 130 m in depth. The project will produce approximately 52 million tonnes of solids to tailings over the mine life (estimated in excess of 20 years).

As of January 2023, Globe Metals and Mining had been issued with a Mining Licence and the Mine Development Agreement (MDA) was signed thereafter.

Uranium production centre technical details

(as of 1 January 2023)

	Centre #1	Centre #2
Name of production centre	Kayelekera	Kanyika
Production centre classification	Care and maintenance	Planned
Date of first production (year)	2009	NA
Source of ore:		
Deposit name(s)	Kayelekera	Kanyika
Deposit type(s)	Sandstone	Intrusive
Recoverable resources (tU)	14 400	2 730
Grade (% U)	0.066	0.008
Mining operation:		
Type (OP/UG/ISL)	OP	OP
Size (tonnes ore/day)	4 000	6 000
Average mining recovery (%)	75	NA
Processing plant:		
Acid/alkaline	Acid	NA
Type (IX/SX)	SX	NA
Average process recovery (%)	80	NA
Nominal production capacity (tU/year)	1 270	60
Plans for expansion (yes/no)	Yes	NA
Other remarks	Ramp up to 1 460 tU/yr	By-product

Environmental activities and socio-cultural issues

There are no updates for the current reporting period.

Uranium requirements

Malawi has no plans for nuclear power.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

All mining activities are under the control of the Department of Mines of the Ministry of Mining, with environmental matters falling under the Malawi Environment Protection Authority (MEPA) in the Ministry of Natural Resources and Climate Change. MEPA was established after the enactment of the Environment Protection Act of 2018.

Malawi does not have specific legislation or a regulation relating to uranium, but is working in co-operation with the International Atomic Energy Agency to develop appropriate legislation. In 2011, the National Assembly passed the Atomic Energy Act, which provides for adequate protection of people as well as the environment against harmful effects of radiation, nuclear material and radioactive materials. In 2023, the government assented to the 2023 Mines and Minerals Act, replacing the 2019 Act.

Reasonably Assured Resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	NA	11 572	81
Co-product and by-product	0	0	0	2 205	60
Total	0	0	NA	13 777	76

Reasonably Assured Resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	0	0	NA	11 572	81
Other or unspecified	0	0	NA	2 205	60
Total	0	0	NA	13 777	76

Reasonably Assured Resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	NA	11 572
Intrusive	0	0	0	2 205
Total	0	0	NA	13 777

Inferred Resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	NA	4 338	81
Co-product and by-product	0	0	0	525	60
Total			NA	4 863	78

Inferred Resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	NA	4 338	81
Co-product and by-product	0	0	0	525	60
Total	0	0	NA	4 863	78

Inferred Resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	NA	4 338
Intrusive	0	0	0	525
Total	0	0	NA	4 863

Historical uranium by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Open-pit mining[1]	4 217	0	0	4 217	0
Total	4 217	0	0	4 217	0

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Conventional	4 217	0	0	4 217	0
Total	4 217	0	0	4 217	0

Mid-term production projection

(tonnes U/year)

2025	2030	2035	2040	2045	2050
0	1 000	500	0	0	0

Mid-term production capability

(tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
N/A	N/A	1 000	N/A	N/A	N/A	1 000	N/A

2035				2040			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
N/A	N/A	1 000	N/A	N/A	N/A	N/A	N/A

2045				2050			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Mali*

Uranium exploration and mine development

Historical review

The French Atomic Energy Commission explored for uranium in Mali in the Adrar des Iforas region, a large crystalline geological province along the border with Senegal, between 1954 and 1956. Indications of uranothorianite and thorianite were discovered in large pegmatite lenses enclosed in highly metamorphosed hornblende- and pyroxene-schists of the Suggarian sequence. Numerous granites were also studied in the area, but only younger granites showed anomalous radioactivity, probably because of the presence of monazite as an accessory mineral.

Under an agreement with the government of Mali, German company Krupp carried out a reconnaissance survey in the eastern part of Mali in 1970 with no positive results. In 1971, Germany's Institute for Geosciences and Natural Resources (BGR) carried out a hydrogeochemical and radiometric reconnaissance survey in the western Kayes region of the country. Some anomalies were found but their character did not encourage further activities. In 1974, Japan's Power Reactor and Nuclear Fuel Development Corporation (PNC) initiated an exploration project in the Adrar des Iforas covering parts of the Taoudeni sedimentary basin.

In 1976, the Compagnie Générale des Matières Nucléaires (COGEMA) started exploration in the areas of Kenieba, Kayes, Bamako, Sikasso, Hombori, Douentza and Taoudenni. This work included airborne radiometric surveys in Kenieba and Taoudenni, and geophysical exploration (including drilling) in Kenieba (Faléa and Dabora). COGEMA ended its exploration project in 1983 and PNC limited its activities to a small area of 20 km^2. PNC continued work through the first quarter of 1985, using radon emanometry and very-low-frequency electromagnetic survey methods over an area of 14 km^2, and then ended its activities in the second quarter of 1985.

From 2007 to 2008, several other companies conducted uranium exploration in Mali. In 2007-2008, Australia's Oklo Uranium Ltd. conducted uranium exploration over the Kidal area, part of the underexplored northeastern part of Mali. Exploration covered the Adrar des Iforas, which is considered prospective for surficial paleo-channel-hosted uranium, alaskite/pegmatite, and vein-hosted uranium, and contains occurrences of uranium, gold, copper-lead-zinc and manganese. Target identification has been undertaken in the project area with 47% of an airborne geophysical survey completed in 2007. In 2008, potential uranium anomalies were located and tested with ground spectrometry, geochemical sampling and drilling.

At Faléa, COGEMA first discovered substantial uranium and copper values in the late 1970s, but the project did not advance because of the prevailing low commodity prices. Exploration conducted since 2008 by Rockgate Capital Corp. and Delta Exploration Inc. focused on defining and expanding these initial results.

The mineralisation at the Faléa project occurs within the Neoproterozoic to Carboniferous sedimentary sequence of the Taoudeni Basin, a shallow interior sag basin with flat to very shallow dips. Faléa is located along the southern edge of the western province of the Taoudeni Basin. In the previous editions of the Red Book, the Faléa deposit was classified as a sandstone-type deposit. Now it is classified as an unconformity-type deposit. With a few exceptions, mineralisation has been confined to the flat-lying Kania Sandstones unit, as well as within the

* Report prepared by the NEA/IAEA, based on previous Red Books and company reports.

units immediately above and below it. The distance from the surface to the mineralised horizon varies between 31.5 m to more than 350 m below the surface. The first mineralising event related to ore genesis is believed to have deposited copper (mostly in the form of chalcopyrite) and silver. The copper mineralisation occurs as disseminations, primarily within the Kania Sandstones, around which halos of uranium minerals precipitated (mostly as pitchblende and coffinite), thus acting as a chemical trap (reductant) for uranium mineralisation.

From January to August 2011, 160 diamond drill holes totalling 45 691 m focused on resource definition in the North Zone and initial exploration drilling at Bala, south of the Central Zone, East Zone and Road Fault. The programme resumed in October 2011, continuing through July 2012, and comprised 398 diamond drill holes totalling 88 350 m. Drilling continued to infill and step out in the North Zone and expanded north into the Bodi Zone. An additional 44 diamond drill holes were completed in the East Zone and 19 more in the Central Zone as part of an expanded resource definition programme.

In October and November 2012, a total of 15 936 m were completed in 66 diamond drill holes located in the Bodi and North Zone areas. Almost all work to date has been completed on the Faléa Permit.

In January 2014, Denison Mines Corp. concluded the purchase of Rockgate and commenced work on the Faléa project, including a detailed project review and reinterpretation of existing exploration data, and a comprehensive internal economic study. Results have shown the project to be uneconomic under current metal prices; however, the potential could improve if additional resources are discovered.

A versatile time-domain electromagnetic (VTEM) survey, including magnetic and radiometric surveys, was completed in March 2015. A small ground follow-up programme was completed in June 2015, including soil sampling and radiometric prospecting.

Recent and ongoing uranium exploration and mine development activities

In June 2016, GoviEx Exploration (Canada) acquired the Faléa project from Denison Mines. The project includes three exploration licences: Bala, Faléa and Madini. In 2017, GoviEx conducted a geophysical survey over the Faléa area. Radon measurements were carried out by Radon Ex. Ltd. New targets have been defined, which have yet to be developed, and are likely to increase the resources. No drilling was completed in 2017-2018. In 2018, GoviEx applied for new exploration licences for the Bala and Madini areas and renewed the Faléa licence for a second term.

In 2019, ASTER images of the Faléa area were interpreted for the identification of new exploration targets. In May and June 2020, soil and termitaria sampling were completed on the Faléa project. The geochemical results highlighted significant gold anomalies, in addition to already known U, Cu and Ag anomalies. During the fourth quarter of 2020, GoviEx conducted a core sampling and geophysics programme, which identified a significant correlation between the Birimian geology, the fault structures, and the geophysical chargeability anomalies in relation to gold mineralisation.

In 2020 and 2021, GoviEx completed Induced Polarization (IP) and resistivity surveys on the Faléa project area. The surveys were aimed at identifying the fault structures and the presence of chargeable bodies, which can be an indication of the presence of mineralised bodies below the unconformity. A total of 245-line km were covered over 27 blocks and an additional six high-resolution IP profiles were completed. The results from this work defined a large IP chargeable anomaly that extends southward for over 2 km from the Faléa deposit, that has not yet been drill tested.

In 2020-2021, GoviEx conducted a 142-hole (6 354 metres) air-core drilling programme to test the gold potential associated predominantly with soil anomalies on the Madini licence area, which is part of the Faléa project. The assay results highlight some remarkable intercepts, which warrant follow-up exploration. During the first quarter of 2022, GoviEx undertook a diamond drilling programme that totalled 6 002 metres over 12 drill holes. Ten drill holes, totalling 5 202 metres were completed on the Faléa licence and 2 drill holes for 800 metres on the Bala licence. The drill programme was designed to target mineralisation in the Birimian rocks below the sedimentary mineralisation based on IP targets. Uranium results confirmed mineralisation in the Upper North and North Deep deposits. A strong correlation was observed between copper and uranium mineralisation within the sedimentary sequence.

Exploration permits.

As of 20 December 2021, four uranium exploration permits have been granted to two exploration companies in Mali. However, because of the rebellion in the northeastern part of the country, exploration activities are only being undertaken in the western part of the country.

Permits	Area (km^2)	Company	Location
Arafat-south	400	Singkind Mines Mali Sarl	Southern part
Bala	125	Delta Exploration Mali Sarl/GoviEx Uranium Inc.	Western part
Faléa	75		
Madini	67		

Uranium resources

Identified conventional resources

An updated NI 43-101 compliant resource estimate was reported for the Faléa project in October 2015 using a cut-off grade of 0.03% U_3O_8 (0.025% U) resulting in total indicated resources of 6.88 Mt at an average grade of 0.098% U, 0.161% Cu, 72.8 g/t Ag and inferred resources of 8.78 Mt at an average grade of 0.059% U, 0.20% Cu, 17.3 g/t Ag. Total in situ identified resources amounted to 11 846 tU, which includes 6 692 tU indicated and 5 154 tU inferred (no change compared to the 2022 edition of the Red Book).

Recent metallurgical test work and engineering have confirmed consistent recoveries of uranium, silver and copper, hence all these metals may be expected from mining. A pre-feasibility study has been initiated based on the results above, together with an enhanced understanding of the orebody and possible mining and metallurgical solutions.

Environmental activities and socio-cultural issues

On 26 April 2010, Rockgate announced that it had commissioned Golder Associates to conduct environmental and social baseline studies of the Faléa project. In January 2014, Denison took over Rockgate. In June 2016, GoviEx Exploration (Canada) acquired the Faléa project from Denison Mines.

Uranium exploration and development expenditures and drilling effort – domestic

(USD)

	2018	2019	2020	2021	2022
Industry exploration expenditures	354 000	298 000	30 000	1 157 000	1 220 000
Total expenditures	354 000	298 000	30 000	1 157 000	1 220 000

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	6 692	6 692	NA
Total	0	0	6 692	6 692	NA

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Unconformity*	0	0	6 692	6 692
Total	0	0	6 692	6 692

* Previously classified as a sandstone-type deposit.

Inferred conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified	0	0	5 154	5 154	NA
Total	0	0	5 154	5 154	NA

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Unconformity*	0	0	5 154	5 154
Total	0	0	5 154	5 154

* Previously classified as a sandstone-type deposit.

Mauritania*

Uranium exploration and mine development

Historical review

The first uranium exploration project in Mauritania was carried out in 1959 by France's Atomic Energy Commission in the Ogmane anticline.

In 1972, following the discovery of surficial-type uranium deposits in Western Australia, uranium exploration was initiated in the Reguibat Range by Total Compagnie Française de Pétrole (in a joint venture with the Société Mauritanienne de Recherches Minières, the French Atomic Energy Commission and Tokyo Uranium Development Company). The two exploration permits covered a total area of 164 000 km², divided into four blocks (Chami, Bir Hoghrein, Nouadhibou and Ghallamane). In 1975, the total area was reduced to five blocks totalling 41 000 km², and these joint ventures were modified after the founding of French Minatome SA and Compagnie Générale des Matières Nucléaires.

These joint ventures held the areas up to 1983. Work on the permits was carried out between 1972 and 1975 and again in 1981 and targeted the evaluation of surficial-type deposits (Reguibat Range), as well as occurrences in the Precambrian basement, where radioactive anomalies were found associated with syenites and granites (Bir En Nar, Tigismat, Tenebdar). In 1983, all uranium exploration activities were suspended.

In 2006, Mauritania's Ministry of Petroleum, Energy, and Mines began to implement a project, *Projet de Renforcement Institutionnel du Secteur Minier (PRISM-II)*, with the US Geological Survey to define the mineral resource potential of the country. It included delineation of areas permissive for calcrete-hosted, granite-hosted vein/shear, alkaline intrusive-hosted, unconformity-related, quartz pebble conglomerate-hosted, phosphate, sandstone-hosted and red bed-type uranium deposits. The results were published in 2013 (USGS Open-File Report 2013-1280).

In November 2006, the United Kingdom's Alba Mineral Resources, along with Mauritania Ventures Limited, started to investigate the uranium potential of areas located in northeast Mauritania. The area is considered prospective for unconformity-type uranium mineralisation. The permits cover significant areas of an unconformable contact between Early Proterozoic reworked granitic terrain and overlying sediments of Late Proterozoic to Carboniferous age. Airborne geophysics, flown on behalf of the Mauritanian government, revealed radiometric anomalies within a mapped, organic-rich unit near the base of this sedimentary sequence, and coincident with its intersection with large, deep penetrating crustal shear structures. Uranium mineralisation is known in the north and northwest part of the permit area, hosted in granites and rhyolites cut by these shear structures. On 3 November 2010, Alba Mineral Resources was notified that the mining authorities in Mauritania had withdrawn the licence, citing a lack of additional exploration activity.

In December 2007, Australia's Forte Energy NL (Forte) completed its first drilling programme in Mauritania, a 4 006 m reverse circulation programme of 41 holes of 50-150 m depth. The drilling was carried out in the Bir En Nar area of the Zednes region and followed up on high-grade results previously obtained. Downhole radiometric logging results indicated numerous high-grade uranium intersections, including 1.55 m at 18 280 ppm U (1.83% U). The results of

* Report prepared by the NEA/IAEA, based on previous Red Books and company reports.

drilling a second group of 21 holes yielded up to 6 310 ppm U (0.63% U) over 1 m, and 576 ppm U (0.058% U) over 19 m.

Forte held several uranium exploration licences in Mauritania, including for the A 238 and Bir En Ar areas. The A 238 and Bir En Ar uranium prospects are associated with granites near Bir Moghrein in the north of Mauritania. At the A 238 prospect, the main zone of mineralisation extends over a strike length of 1.75 km with mineralisation extending down to over 250 m from the surface with widths of over 60 m within 50 m of the surface. Following the positive results of the 2009/10 reverse circulation (RC) drilling, a further RC drilling programme of around 11 300 m commenced in October 2010, focusing initially on anomaly A 238. Preliminary results from A 238 indicated the potential for a shallow, large-volume, medium-grade deposit. A total of approximately 10 450 m of RC and diamond core drilling has been carried out, resulting in an announcement in June 2011 of initial JORC code-compliant U resources for A 238 of 26.5 Mt at 217 ppm U (0.0217% U) for 5 730 tU (85 ppm U cut-off; 0.0085% U). After completing a further 63 holes (8 567 m) of RC drilling in 2011/12, an updated JORC resource was announced in April 2012 for A 238. The deposit remains open along strike. In 2015, Forte was delisted and its leases in Mauritania expired.

Indicated and inferred resources – A 238 and Bir En Ar uranium prospects (2012)

Deposit	Resource category	Average grade (ppm U)	Tonnes of U
A 328	Inferred	199 (0.02% U)	9 000
Bir En Nar	Indicated Inferred	751 (0.0751% U) 488 (0.0488% U)	385 385
Total	Indicated Inferred	751 (0.0751% U)* 204 (0.0204% U)*	385 9 385

* Weighted-average grade by proportional amount of tU.

Australia's Aura Energy (Aura) owns the Tiris project (previously known as the Reguibat project), which comprises several laterally extensive developments of calcrete uranium mineralisation in northern Mauritania. Between November 2010 and February 2011, Aura completed a drilling programme that covered all of Aura's wholly owned permits, as well as its joint venture permits, which totalled over 9 100 m in 2 022 holes. A JORC code-compliant uranium resource estimate, based on these drilling results, was released in 2012, with total Tiris project resources (85 ppm U cut-off) of 18 847 tU at 283 ppm U (770 tU indicated resources at 254 ppm U, and 18 077 tU inferred resources at 284 tU).

In 2014, Aura conducted a scoping study that confirmed that Reguibat could be a robust project with shallow mineralisation that could be upgraded through simple beneficiation to high-grade leach feed. The study indicated that some 4 200 tU could be produced over an initial mine life of 15 years, using only 20% of the project's total 2012 mineral resource estimate. The project would require a capital investment of about USD 50 million, would have an operating cost of USD 30/lb U_3O_8 (USD 78/kgU), and a mine life average production rate of 290 tU/yr.

Additionally, extensive radiometric surveys allowed Aura to estimate an exploration target of an additional 19 000 tU, inferring a total mineral resource target of around 38 000 tU at Reguibat.

In 2015-2016, Aura continued to conduct test work and validation work aimed at defining optimal methods for the recovery of uranium. Additional verification/validation programmes were completed, including downhole gamma logging, disequilibrium test work, trenching of the mineralisation and detailed ground radiometric surveying.

Aura highlighted the very fine-grained nature of the uranium-bearing mineral, carnotite. This fine-grained character, together with the high, short-range grade, presents challenges in sampling. Carnotite tends to occur as small lenses, nuggets and coatings in or on the calcrete. Its distribution varies from deposit to deposit. This variability requires understanding and management in upgrading resources to measured and indicated status. In general, variability reduces as sample size increases, and for that reason, the 2015 drilling employed a larger diameter drill bit than that used in the earlier resource drilling programmes, resulting in a 50% greater sample size. However, even with the larger sample size, grade variability has still been relatively high. To test the effectiveness of gamma logging at Tiris, 63 holes that had been drilled and cased in 2015 were gamma logged. The results of this work were positive, and Aura is now using downhole gamma logging for its resource upgrade work.

In 2016, the Tiris project progressed to the feasibility study stage. In 2017, Aura continued the Tiris feasibility study, including the following activities: mining lease application, resource definition, geophysics and drilling for the definition of water resources, metallurgical test work, simulation and flowsheet development, early-stage engineering, completion of an Environmental and Social Impact Assessment (ESIA), and a community consultation process.

In 2017, a programme of ground radiometric surveying was carried out over all Tiris uranium resource zones as well as priority exploration targets, such as Hippolyte South. The surveys were conducted on lines spaced 20 m apart. A programme to increase the proportion of measured and indicated resources commenced in May 2017. This involved an extensive drilling programme on a 50 m x 50 m pattern with each hole being gamma logged. A proportion of the holes have been drilled by large diameter triple tube diamond drilling and the core was chemically assayed to validate the downhole gamma logging and to obtain density data throughout the zones drilled.

The Environmental and Social Impact Assessment was completed in 2017 by Earth Systems. The ESIA pays attention to issues of radiation exposure and the security of the yellowcake product. Best practice guidelines from the International Atomic Energy Agency (IAEA) and the International Commission on Radiological Protection (ICRP) have been used, complementing the applicable Mauritanian regulations and guidelines. The ESIA was approved by the Mauritanian government on 5 October 2017.

Recent and ongoing uranium exploration and mine development activities

In April 2018, Aura undertook a programme of trenching within the Lazare North and Lazare South deposits (part of the Tiris East deposit group). A total of 11 trenches were completed, with 8 in the Lazare South and 3 in the Lazare North deposits. Trenches were dug to a depth of 4 m. The focus of this programme was to collect representative samples for detailed test work.

On 27 August 2021, Aura released the results of a new resources estimate of the Tiris East deposits, that incorporated drill holes in the Sadi South Zone, not included in earlier resource estimates. This resulted in a total Tiris East resource estimate of 17 037 tU (2 038 tU measured resources at 200 ppm U, 5 461 tU indicated resources at 188 ppm U, and 9 538 tU inferred resources at 213 ppm U), a 2 080 tU increase compared to the 2011 estimate.

In 2021-2022, Aura completed a 10 000 m in-fill drilling programme with the objective of increasing confidence in the resource estimate. A new resource estimate of the Tiris project was completed in 2022. A reserve estimate, based on measured and indicated resources, using a uranium price of USD 65 /kgU and a cut-off of 110 ppm U_30_8 and including mining dilution, was released in 2023. Proven and probable reserves amount to 40.3 Mt of ore at an average grade of 0.0215 % U (8 680 tU). An estimate of the vanadium resource was also completed.

Tiris East Resources (85 ppm U cut-off – 2021 estimate)

Deposit	Category	Ore (Mt)	Grade (%U)	U (tU)
Hippolyte	Measured Indicated Inferred	5.7 6.5 7.4	0.0191 0.0184 0.0238	1 077 1 192 1 769
Hippolyte South	Indicated Inferred	4.8 3.1	0.0163 0.0149	769 462
Hippolyte West	Inferred	6.3	0.0254	1 615
Lazare North	Measured Indicated Inferred	1.1 10.6 3.9	0.0241 0.0194 0.0178	269 2 077 692
Lazare South	Measured Indicated Inferred	3.4 2.6 9.1	0.0203 0.0186 0.0181	692 500 1 654
Sadi	Indicated Inferred	4.5 14.9	0.0204 0.0226	923 3 346
Total Tiris East	Measured Indicated Inferred	10.2 29.0 44.7	0.0200 0.0188 0.0213	2 038 5 461 9 538

Tiris East Resources (85 ppm U cut-off – 2022 estimate)

Deposit	Category	Ore (Mt)	Grade (%U)	U (tU)
Hippolyte North	Measured Indicated Inferred	8.0 5.8 4.7	0.0200 0.0184 0.0180	1 615 1 077 846
Hippolyte South	Indicated Inferred	4.6 2.7	0.0163 0.0149	769 423
Hippolyte Marie & West	Inferred	8.2	0.0263	2 154
Lazare North	Measured Indicated Inferred	1.0 10.1 3.7	0.0239 0.0194 0.0178	231 1 962 654
Lazare South	Measured Indicated Inferred	8.6 5.2 4.8	0.0197 0.0192 0.0188	1 692 1 000 885
Sadi	Measured Indicated Inferred	11.5 7.4 10.3	0.0160 0.0170 0.0194	1 846 1 231 2 000
Total Tiris East	Measured Indicated Inferred Total	29.1 33.1 34.4 96.6	0.0185 0.0182 0.0202 0.0190	5 384 6 039 6 962 18 385

Tiris West Resources (85 ppm U cut-off – 2022 estimate)

Deposit	Category	Ore (Mt)	Grade (%U)	U (tU)
Oum Ferkik	Inferred	16.4	0.0259	4 308

During the same period, Aura conducted metallurgical studies, including beneficiation pilot plant tests on the ore to upgrade the uranium concentration into a small fraction of the mined feed. Results from a simple wet screening circuit indicated an increase in uranium grade by 550%, with a mass reduction of 80% of the mined material and 90% recovery of uranium. In 2023, Aura is planning exploration drilling on new targets in extension of the known mineralisation.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

In 2012, Forte released a JORC code-compliant resource estimation for the A 328 and Bin En Ar deposits. Based on an 85 ppm U cut-off (0.0085% U), global resources for the A 328 and Bin Ar deposits totalled 385 tU in the indicated category, and 9 385 tU in the inferred category (in situ resources).

In 2023, Aura released a new JORC code-compliant resource estimation for the Tiris project, including the Tiris East deposit group (Hippolyte – North, Marie and West, South, Lazare – North, South, and Sadi deposits) and the Tiris West (Oum Ferkik) deposits. Based on an 85 ppm U cut-off (0.0085% U), global resources for the Tiris project total 11 423 tU in the measured and indicated categories, and 11 270 tU in the inferred category (in situ resources).

As of 1 January 2023, Mauritania's total identified resources (in situ) amount to 32 463 tU, an increase of 886 tU compared to 1 January 2021.

Undiscovered conventional resources (prognosticated and speculative resources)

Strong radiometric anomalies exist in Mauritania, similar to anomalies occurring with the known resources at Tiris. Aura's exploration has largely focused on radiometric anomalies defined by regional airborne radiometric surveys. In 2016, Aura estimated an additional potential of 19 000 tU in the Reguibat area.

Uranium production

In 2014, Aura completed the Reguibat scoping study.

Mineralisation occurs largely within 3-4 m of the land surface, in gravels and weathered granite. Most of the mineralisation occurs as single sheets with little or no cover. The material is largely unconsolidated and can be readily excavated by diggers or scrapers without blasting. The overlying waste consists of loose windblown sand. The strip ratio is anticipated to be approximately 0.25:1.

Simple washing and screening tests on the ore yielded encouraging results. Wet screening at 75 µm resulted in the rejection of 80% by weight with the retention of 91% of the uranium into the screen undersize. This represents a sevenfold upgrade factor from the 334 ppm U (0.0334% U) resource grade. These results may be explained by the extremely fine size and ready liberation of the uranium mineral, carnotite, and the large difference in particle size distribution between the carnotite and the bulk of the host rock minerals. Following a series of encouraging small-scale preliminary tests, a standard leach test on -300 µm beneficiated material confirmed earlier results, with 92% uranium extraction within 4 hours and 95% after 8 hours.

The total estimated initial capital cost for engineering, procurement, construction, commissioning, start-up, and the owner's activities for the project is AUD 50 million. The life of mine unit operating cost estimate for the Reguibat project is estimated to be USD 30.3/lb U_3O_8 (USD 11.65/kgU). The planned operation will produce approximately 385 tU per year in years 2 and 3, followed by 250 tU for years 4-11, and 270 tU in years 12-15. The total uranium produced under these assumptions is approximately 3 850 tU over the 15-year mine life.

A feasibility study was undertaken in 2015, with a view to a simple truck and shovel mine on the eastern deposit, feeding an AUD 50 million plant, and production at about 400 tU/yr.

On 29 July 2019, Aura released the results of the Definitive Feasibility Study, which confirmed that the Tiris uranium project is a low-cost development. The project is designed to support an open-pit mine, a 1.25 million tonnes of ore per year processing plant, and supporting infrastructure. The uranium mineralisation lies largely within 3 to 5 m of the surface in a relatively soft, free-digging material containing patchy calcrete. Based on trenching and metallurgical test work to date, the mineralisation does not require blasting before mining or crushing before beneficiation.

Three mining areas can be developed in a practical sequence to produce 310-425 tU per year through the processing plant for 15 years. The processing facility will consist of three main sections: the beneficiation circuit, the uranium extraction circuit (alkaline leach – solid/liquid separation – ion exchange), and the uranium purification and precipitation circuit. Uranium recovery is expected to be 86.1%. Vanadium could be recovered as vanadium pentoxide (V_2O_5) through a standard precipitation and purification process. Target production is 115 t V_2O_5 per year. The cost to develop and operate the mine for ten years has been estimated at USD 66 million, or USD 2.24 per tonne of material mined. The total operating cash cost is estimated to be USD 25.43/lb U_3O_8 (USD 66.1/kgU). The all-in sustaining cost (inclusive of royalties, LOM sustaining capital, insurance and product transport) is estimated at USD 29.81/lb U_3O_8 (USD 77.5/kgU).

Two exploitation licences covering 390 km^2 were granted to Tiris Resources SA, a Mauritanian registered subsidiary of Aura Energy Limited, on 8 February 2019. The two licences cover the Eastern Tiris resources at Oued El Foule and Ain Sder. An application for a 38 km^2 exploitation licence remains pending over the smaller Western Tiris resource at Oum Ferkik.

In 2021-2022, Aura completed an Enhanced Definitive Feasibility Study of the Tiris uranium project. Compared to the 2019 study, projected annual production increased by 150% from 0.8 Mlbs U_3O_8 (310 tU) to 2.0 Mlbs U_3O_8 (770 tU). Total operating cost, including AISC, is estimated at USD 28.77/lb U_3O_8 (USD 75/kgU). Aura expects to reach a final investment decision on the project by the end of 2023 and begin commercial production in 2025.

Uranium production centre technical details

(as of 1 January 2023)

	Centre #1
Name of production centre	Tiris
Production centre classification	Prospective
Date of first production (year)	NA
Source of ore:	
Deposit name(s)	Lazare N and S, Hippolyte
Deposit type(s)	Calcrete
Recoverable resources (tU)	11 375
Grade (% U)	0.0183
Mining operation:	
Type (OP/UG/ISL)	OP
Size (tonnes ore/year)	4.18 Mtpa
Average mining recovery (%)	90
Processing plant:	
Acid/alkaline	Alkaline
Type (IX/SX)	IX
Size (tonnes ore/day)	NA
Average process recovery (%)	88
Nominal production capacity (tU/year)	770

Ownership structure

The project is 100% owned by Tiris Ressources SARL, which is 85% owned by Aura Energy Ltd and 15% by the Mauritanian Government's Agence Nationale de Recherches Géologiques et du Patrimoine Minier (ANARPAM).

Reasonably assured conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	9 140	9 140	80
Unknown	0	0	0	290	75
Total	0	0	9 140	9 430	80

Reasonably assured conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	0	0	9 140	9 140	80
Unknown	0	0	0	290	75
Total	0	0	9 140	9 430	80

Reasonably assured conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Granite-related	0	0	0	290
Calcrete	0	0	9 140	9 140
Total	0	0	9 140	9 430

Inferred conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	9 020	9 020	80
Unknown	0	0	0	7 040	75
Total	0	0	9 020	16 060	78

Inferred conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	0	0	9 020	9 020	80
Unknown	0	0	0	7 040	75
Total	0	0	9 020	16 060	78

Inferred conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Granite-related	0	0	0	7 040
Calcrete	0	0	9 020	9 020
Total	0	0	9 020	16 060

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
NA	NA	19 000

Mid-term production projections (tonnes U/year)

2025	2030	2035	2040	2045	2050
0	770	770	770	NA	NA

Mexico

Uranium exploration and mine development

Historical review

Uranium exploration began in 1957, using both ground and aerial prospecting with geological and radiometric methods. Limited technical and financial resources initially hampered national exploration efforts, but these problems were alleviated by government support, particularly from 1972 to 1980.

Until 1979, exploration was performed by the National Institute of Nuclear Energy. In 1979, the responsibility for exploration was vested in Uranio Mexicano (URAMEX). The areas explored, in order of importance, were in the states of Chihuahua, Nuevo León, Tamaulipas, Coahuila, Zacatecas, Queretaro and Puebla. Uranium exploration was stopped in May 1983 and URAMEX was dissolved in February 1985.

In 2009, the Mexican Geological Survey reactivated radioactive exploration in Mexico, to validate and re-evaluate the resources reported by URAMEX according to international standards. This involved the analysis of the preliminary information available, as well as complementary studies of geology, geochemistry, geophysics and drilling, simultaneously exploring new locations with uranium potential.

To gain a better knowledge of the uranium resources located in Peña Blanca (Chihuahua State), Los Amoles (Sonora State) and La Coma area (Nuevo León State), exploration and assessment works were continued through drilling programmes. During the period 2009-2018, a total of 17 361 metres were drilled in 154 holes.

Recent and ongoing uranium exploration and mine development activities

Within the period 2019-2020, a total of 3 200 metres were drilled in 56 holes with core recovery. All drill holes were logged using calliper, resistivity and gamma-ray spectrometry probes. From 2020-2022 regional exploration, campaigns were carried out in Sonora, Chihuahua and Durango states.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Past evaluation of projects by URAMEX in the early 1980s do not fulfil the current international standards of evaluation. Potential was demonstrated, however, and the Mexican Geological Survey (SGM) began a programme to evaluate resources following international standards. Data reported in Red Book 2022 have been reviewed and updated considering resource estimates derived from SGM studies. The results of this programme are presented here.

Undiscovered conventional resources (prognosticated and speculative resources)

There are 80 localities with potential occurrences of radioactive minerals in Mexico; 39 are considered to have geological potential to carry out further exploration works.

Unconventional resources and other materials

Geochemical soil data suggest average thorium anomalies ranging from 6 ppm to 17 ppm in the soil horizon C at North-Northwest Mexico.

Projects	Tonnes U (in situ)
Las Margaritas, Chihuahua State	520
El Puerto III, Chihuahua State	150
El Nopal I, Chihuahua State	380
Los Amoles, Sonora State	370
La Coma, Nuevo León State	1 350
Buenavista, Nuevo León State	1 065
El Chapote, Nuevo León State	715
La Diana, Nuevo León State	690
Peñoles, Nuevo León State	350
La Presita, Nuevo León State	150
Trancas, Nuevo León State	110
Dos Estados, Nuevo León State	143*
Santa Fe, Nuevo León State	76*
El Chapeño	150
La Osca	350
Huizachitos	190
Total	6 759

* Uramex estimated.

Uranium production

Historical review

From 1969 to 1971, the Mining Development Commission operated a plant in Villa Aldama, Chihuahua State. The facility recovered molybdenum and by-product uranium from ores mined in the Sierra de Gomez, Domitilia (Peña Blanca) deposits and other occurrences. A total of 49 tU was produced. At present, there are no plans for additional uranium production.

Uranium requirements

As of 1 January 2023, two boiling water reactors with a total net installed capacity of 1.6 GW were in operation at the Laguna Verde Nuclear Power Plant. These two units have been in operation since 1990 and 1995, respectively, together supplying about 3.1% of the country's electricity.

In 2015, an application for a licence renewal of both Laguna Verde units was submitted to the Mexican regulatory authority to allow their operation for an additional 30 years.

In 2020, Mexico's Secretariat of Energy (SENER) authorised the renewal of the operating licence for unit 1 of the Laguna Verde Nuclear Power Plant for an additional 30 years to 2050. In 2022, Mexico's Secretariat of Energy (SENER) authorised the renewal of the operating licence for unit 2 of the Laguna Verde Nuclear Power Plant for an additional 30 years to 2055.

The Laguna Verde Nuclear Power Plant annual uranium requirement is on average 200 tonnes U.

Supply and procurement strategy

An open bid system for uranium purchases is under study for three reloads (2022-2025).

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

The 1984 Act on Nuclear activities, adopted pursuant to Article 27 of the Constitution, entered into force on 5 February 1985. It specifies that the exploration, exploitation, and benefits of radioactive minerals are the exclusive domain of the government of Mexico. Exploration activities are exclusively delegated to the Mexican Geological Survey since 1985.

Uranium stocks

Uranium stocks are maintained at minimum levels to reduce costs.

Uranium exploration and development expenditures and drilling effort – domestic

In American dollar (USD)

	2020*	2021*	2022	2023 (expected)
Government exploration expenditures	660 000	810 000	630 000	1 000 000
Total expenditures	660 000	810 000	630 000	1 000 000
Government exploration drilling (metres)	1 257	1 943	0	NA

* Previous Red Book data reviewed and updated.

Reasonably assured conventional resources by production method

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Other or unspecified	0	0	3 321	3 321	NA
Total	0	0	3 321	3 321	

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Other or unspecified	0	0	3 321	3 321	NA
Total	0	0	3 321	3 321	

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	1 901	1 901
Volcanic-related	0	0	1 420	1 420
Total	0	0	3 321	3 321

Inferred conventional resources by production method

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Other or unspecified	0	715	2 723	3 438	NA
Total	0	715	2 723	3 438	

Inferred conventional resources by processing method

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Other or unspecified	0	715	2 723	3 438	NA
Total	0	715	2 723	3 438	

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	715	2 723	3 438
Total	0	715	2 723	3 438

Net nuclear electricity generation*

	2021	2022
Nuclear electricity generated (TWh net)	11.6	10.5

* Data based on NEA *Nuclear Energy Data* reports.

Installed nuclear generating capacity to 2050*

(MWe net)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
1 608	1 608	1 608	1 608	1 608	1 608	1 608	1 608	1 608	1 758	1 608	1 758	1 608	1 758

* Data based on PRODESEN 2023-2037 SENER.

Annual reactor-related uranium requirements* to 2050 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
NA	412	408	NA	205	NA	203	NA	408	NA	205	NA	203	NA

* Refers to natural uranium acquisitions, not necessarily consumption during the calendar year.

Mongolia

Uranium exploration and mine development

Historical review

The history of uranium exploration in Mongolia can be divided into three phases. The first phase started immediately after World War II, with investigations directed at the search for uranium contained in other, non-uranium deposits. During the period 1945-1960, numerous uranium occurrences were discovered in the brown coal deposits of eastern Mongolia.

The second phase of exploration covered the period between 1970 and 1990. Under a bilateral agreement between Mongolia and the former Soviet Union, specialised geological surveys were conducted by the Geological Reconnaissance Expedition of the Soviet Ministry of Geology with a result of 1 600 radioactive anomalies and hundreds of radioactive occurrences identified by the joint expedition. Full airborne gamma-ray spectrometric surveys at a scale of 1:25 000 and 1:50 000 were conducted over 420 000 km^2, covering about 27% of Mongolian territory; at a scale of 1:200 000 over 450 000 km^2, covering about 28% of the territory; and at a scale of 1:1 000 000 over 224 000 km^2 in the Altai, Khangai mountains and Gobi Desert, covering about 14% of the Mongolian territory. The territory along the border with the People's Republic of China and the central Mongolian mountain area – about 30% of the country – was not included in these surveys.

Metallogenic investigations at the scale of 1:500 000 over a 500 000 km^2 area, and more detailed geological mapping and exploration at the scale of 1:200 000-1:50 000 over 50 000 km^2 of territory in Mongolia, were also completed. This work included 2 684 000 m of surface drilling, 3 179 000 m^3 of surface trenching, and 20 800 m of underground exploration.

The third phase of exploration started in the 1990s with private stakeholder engagements including local and foreign entities. As a result of the depressed uranium market, exploration strategies changed globally towards the exploration for low-cost uranium deposits, especially sandstone-type deposits. Uranium exploration was focused on Mesozoic and Cenozoic basins in southeast Mongolia. The "uranium" state-owned manufacturing enterprise, in co-operation with the International Atomic Energy Agency (IAEA), assessed the uranium potential of Mongolia in two phases between 1993 and 2001. The studies that were completed focused on identifying the potential for uranium mineralisation in sedimentary and metasomatised settings.

Based on these surveys, the territory of Mongolia was classified into four uranium-bearing metallogenic provinces: Mongol-Priargun, Gobi-Tamsag, Khentei-Daur and Northern Mongolia. Each of these provinces has a different geology and hosts different deposit types. Mineral associations and ages of mineralisation also vary. Within these provinces, 13 uranium deposits, about 100 uranium occurrences, and 1 400 showings and radioactive anomalies were identified.

The Mongol-Priargun metallogenic province is located in eastern Mongolia, coinciding with a 70 to 250 km wide continental volcanic belt that can be traced over some 1 200 km, from the Mongolian Altai to the Lower-Priargun region. This territory includes deposits and occurrences with fluorite-molybdenum-uranium associations resulting from volcano-tectonic events. Distinct uranium mineralisation districts of the Northern Choibalsan, Berkh, eastern and central Gobi are included in this area. The Dornod ore field of Northern Choibalsan includes the uranium deposits of Dornod, Gurvanbulag, Mardaingol, Nemer and Ulaan, as well as other polymetallic and fluorite associations. The Choir and Gurvansaikhan Basins of the eastern and central Gobi uranium mineralisation district include the Kharaat and Khairkhan uranium deposits, among others.

The Gobi-Tamsag metallogenic province covers a territory 1 400 km long by 60 to 180 km wide in southern Mongolia. It is characterised by numerous uranium occurrences in terrigenous sediments. The district includes a prospective uranium deposit in the south, near the Dulaanuul and Nars deposits, and numerous other occurrences, as well as other prospective uranium-bearing sedimentary basins, such as the Tamsag, Sainshand and Zuunbayan Basins, among others.

The Henter-Daur metallogenic province (700 km long by 250 km wide) includes the Khangai and Khentii mountains. In this area, uranium occurrences in granite can be found, such as the Janchivlan ore field, which shows some promise of becoming a deposit of economic interest.

The Northern Mongolian metallogenic province is the largest (1 500 km long by 450 km wide) of the four metallogenic provinces. The northwestern part of Mongolia is characterised by a variety of minerals such as uranium, thorium, and rare earth elements related to alkaline mineralisation, and uranium and thorium in metasomatites, pegmatite, magmatic, and quartz schist host rocks.

Recent and ongoing uranium exploration and mine development activities

There are two types of uranium exploration activities in Mongolia: prospecting aimed at the discovery of new deposits and the exploration of previously discovered deposits to increase resource endowments.

Four companies are conducting exploration activities in Mongolia. From 2022, most of the uranium prospecting was performed in the south Mongolian sedimentary basins to identify sandstone-type uranium mineralisation that is amenable to in situ leach (ISL) mining.

Badrakh Energy conducted major exploration and development activities during 2019-2020 at the Zuuvch Ovoo and Dulaan Uul uranium deposits in Dornogobi province in southeastern Mongolia. As a result, the uranium resources of the Zuuvch Ovoo deposit were increased to 93 291 tU and a technical report was submitted to the Mongolian Professional Committee of Resources in February 2020. The deposit will be mined by ISL methods using sulphuric acid. The test mining will be conducted on two hexagonal cells located 470 m from each other, each of which will consist of six injection wells and one production well. Fifteen groundwater monitoring wells were drilled and equipped outside and inside of each cell and at different aquifer horizons along the direction of groundwater flow. In 2021, after receipt of all required authorisations from Mongolian governmental authorities, including the validation of a Detailed Environmental Impact Assessment and Environmental Management Plan 2021, Badrakh Energy started the ISL pilot test at the North ISL cell. On 10 August 2021, the pilot test successfully produced its first kilogram of uranium concentrate. The North and South ISL wells continued to operate until December 2022. As a result, key technical and economic parameters for future ISL commercial production were obtained. The pilot test results confirmed the economic and environmental feasibility of the project. The Feasibility Study is being finalised and is being discussed with the Mineral Resources Professional Council of Mongolia

As of January 2023, feasibility studies for eight deposits have been completed and approved by the Mineral Resources Professional Council of Mongolia.

Gurvansaikhan LLC holds licences for the Kharaat, Khairkhan, Ulziit and Gurvansaikhan uranium deposits in the Middle Gobi province in south Mongolia. Major exploration activities were conducted during 1998-2012 and resources equalling 23 021 tU were accepted by the Mongolian Professional Committee of Resources. In 2022 the company restarted activities and conducted an additional 40 662 m of exploration drilling. Gurvansaikhan LLC is working on a technical report to confirm its resources according to JORC standards based on exploration results.

Uranium exploration expenditures amounted to MNT 197 million (Mongolian Tugrik) in 2020, MNT 209 million in 2021, and increased significantly to MNT 13 208 million in 2022. No exploration drilling was carried out in 2020 and 2021, compared with 40 662 m reported in 2022.

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2023, Mongolia's total identified conventional recoverable resources amounted to 144 620 tU, while in situ resources comprised 192 241 tU. Recoverable conventional resources include 66 234 tU of reasonably assured resources (RAR) and 78 386 tU in the inferred category. All resources are recoverable at <USD 130/kgU, and 16 884 tU are recoverable at a cost of <USD 80/kgU by the acid ISL method.

Undiscovered conventional resources (prognosticated and speculative resources)

As of 1 January 2023, prognosticated resources amount to 13 300 tU and speculative resources totalled 1 319 000 tU.

Unconventional resources and other materials

No unconventional resources have been identified.

Uranium production

Historical review

Uranium production in Mongolia started with the operation of the Dornod open-pit mine in the Mardai-gol district in 1989, based on the known uranium resources at the Dornod and Gurvanbulag deposits. With an ore grade of 0.12% U, mining production was 2 400 tU/year. Mongolia has no processing facilities. The ores mined in the Mardai-gol district were transported 484 km by rail to the Priargunsky mining and processing facility in Krasnokamensk, Russia, for processing. Because of political and economic changes in Mongolia and neighbouring areas of Russia, uranium production at Erdes was terminated in 1995.

Status of production facilities, production capability, recent and ongoing activities and other issues

Currently, no uranium is being produced in Mongolia. However, several mines are in the planning stage of development.

Secondary sources of uranium

Production and/or use of mixed oxide fuels

Mongolia has not produced or used mixed oxide fuels.

Production and/or use of re-enriched tails

Mongolia currently does not have a uranium enrichment industry. Re-enriched tails are not used or produced.

Production and/or use of reprocessed uranium

There is no production or use of reprocessed uranium.

Status of production facilities, production capability, recent and ongoing activities and other issues (including information on uranium recovery methods)

Experimental production by the in situ leaching method is being conducted and the results are being reviewed. Feasibility studies are being developed for the Zoovch Ovoo, and Dulaan Uul deposits, and they are being reviewed by the Mineral Resources Professional Council of Mongolia.

Uranium production centre technical details

(as of 1 January 2023)

	Centre #1	Centre #2					Centre #3	
Name of production centre	Emeelt mines	Gurvansaihan					Badrakh energy	
Production centre classification	Planned	Planned					Planned	
Date of first production (year)	NA	NA					NA	
Source of ore:								
Deposit name(s)	Gurvanbulag	Kharaat	Khairkhan	Gurvansaikhan	Ulziit	Dulaan uul	Zuuvch ovoo
Deposit type(s)	Volcanic	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone
In situ resources (tU)	13 058	7 288	8 407	4 250	3 076	4 045*	73 741*
Grade (% U)	0.152	0.026	0.071	0.034	0.036	0.022	0.022
Mining operation:							
Type (OP/UG/ISL)	UG	ISL	ISL	ISL	ISL	ISL	ISL
Size (tonnes ore/day)	NA	NA	NA	NA	NA	NA	NA
Average mining recovery (%)	NA	NA	NA	NA	NA	NA	NA
Processing plan							
Acid/alkaline	Acid	Acid	Acid	Acid	Acid	Acid	Acid
Type (IX/SX)	IX	IX	IX	IX	IX	IX	IX
Size (tonnes ore/day)	NA	NA	NA	NA	NA	NA	NA
Average process recovery (%)	NA	NA	NA	NA	NA	NA	NA
Nominal production capacity (tU/year)	NA	NA	NA	NA	NA	NA	NA
Plans for expansion	No	No	No	No	No	No	No

* Orano 2022 Annual Activity Report.

Ownership structure of the uranium industry

The Nuclear Energy Law of Mongolia defines the ownership of radioactive minerals and state participation in the exploitation of radioactive minerals. Article 5 states that:

5.1: Radioactive minerals occurring in the subsoil of Mongolia shall be the property of the state.

5.2: Provided that the radioactive mineral deposit, for which exploration and reserves determination was conducted by state budget financing, and is jointly exploited with others, the state shall directly possess free of charge no less than 51% of shares of the company that will be set up jointly.

5.3: The state shall directly possess free of charge no less than 34% of shares of the company holding a special licence for exploitation of the radioactive mineral deposit, for which exploration and reserves determination were conducted without state budget involvement and was recorded in the state integrated register.

5.4: Provided the state owns shares exceeding the percentages specified in the clauses 5.2 and 5.3 of this law, the State Great Khural shall fix this share by presentation of the government in view of the size of investment made or to be made by the state.

National policies relating to uranium

The Mongolian government considers the mining of uranium deposits an important national interest as it can positively influence and improve the national economy. As a result, the government has developed a special programme on uranium and is committed to implementing it.

The programme covers the following policies and guidelines:

- Geological exploration and mining of uranium deposits, processing and marketing of uranium ores in Mongolia. The purpose is to reduce Mongolian government investment and to encourage foreign investment.
- Developing intensive and effective co-operation with international organisations involved in the prospecting, mining and sale of uranium and other raw materials for nuclear energy.
- Developing all of the necessary regulations, instructions and recommendations for activities related to uranium mining.
- Studying possibilities of recovering uranium from phosphate and brown coal deposits and developing alternative extraction techniques.
- Training national personnel for uranium studies and production and introducing advanced technology, instruments and tools of high precision.
- Setting up a government enterprise responsible for monitoring and co-ordinating uranium exploration and production, as well as developing and implementing government policy and strategies in the field of uranium exploration based on mobilising efforts of national uranium specialists.

Uranium exploration and development expenditures and drilling effort – domestic

(Mongolian tugrik millions)

	2020	2021	2022
Industry* exploration expenditures	197	209	13 208
Government development expenditures	0	0	0
Total expenditures	197	209	13 208
Industry* exploration drilling (m)	0	0	40 662
Subtotal exploration drilling (m)	0	0	40 662
Total drilling (m)	0	0	40 662

* Non-government.

Reasonably assured conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	0	20 744	20 744	75
Open-pit mining (OP)	0	0	1 762	1 762	80
In situ leaching acid	0	7 572	43 728	43 728	75
Total	0	7 572	66 234	66 234	

Reasonably assured conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	0	20 744	20 744	75
Conventional from OP	0	0	1 762	1 762	80
In situ leaching acid	0	7 572	43 728	43 728	75
Total	0	7 572	66 234	66 234	

Reasonably assured conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	7 572	43 728	43 728
Volcanic-related	0	0	22 506	22 506
Total	0	7 572	66 234	66 234

Inferred conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	0	15 582	15 582	75
Open-pit mining (OP)	0	0	5 263	5 263	80
In situ leaching acid	0	9 311	57 541	57 541	75
Total	0	9 311	78 386	78 386	

Inferred conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	0	15 582	15 582	75
Conventional from OP	0	0	5 263	5 263	80
In situ leaching acid	0	9 311	57 541	57 541	75
Total	0	9 311	78 386	78 386	

Inferred conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	9 311	57 541	57 541
Volcanic-related	0	0	20 845	20 845
Total	0	9 311	78 386	78 386

Prognosticated conventional resources
(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
13 300	13 300	13 300

Speculative conventional resources
(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
1 319 000	1 319 000	NA

Historical uranium production by production method
(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Open-pit mining	535	0	0	535	0
Total	535	0	0	535	0

Historical uranium production by deposit type
(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Volcanic-related	535	0	0	535	0
Total	535	0	0	535	0

Short-term production capability
(tonnes U/year)

2025				2030			
A-I	A-I	B-I	A-II	B-II	B-I	A-II	B-II
NA	NA	NA	NA	NA	NA	NA	NA

2035				2040			
A-I	A-I	B-I	A-II	B-II	B-I	A-II	B-II
NA	NA	NA	NA	NA	NA	NA	NA

Namibia*

Uranium exploration and mine development

Historical review

Uranium was first discovered in the Namib Desert in 1928 in the vicinity of the Rössing Mountains, but it was not until the late 1950s that the Anglo American Corporation of South Africa prospected the area by drilling and conducting limited underground exploration. As a result of erratic uranium prices, lack of demand, and limited economic prospects for uranium at that time, Anglo American abandoned its work.

With the upswing in the uranium market demand and prices, extensive uranium exploration started in Namibia in the late 1960s. Several airborne radiometric surveys were conducted, and numerous anomalies were identified. In 1966, after discovering uranium occurrences, Rio Tinto acquired the rights to the low-grade Rössing deposit, located 65 km inland from the town of Swakopmund on the Atlantic coast. Trekkopje, a near-surface calcrete deposit just north of Rössing and Langer Heinrich, another calcrete deposit situated 50 km southeast of Rössing, were also discovered during this period.

Mining commenced in 1976 at Rössing and exploration intensified as uranium prices increased sharply. However, in the early 1980s, the sharp decline in uranium prices caused a rapid curtailment of exploration and mine development efforts.

Beginning in 2003, rising uranium prices once again stimulated extensive exploration activity, mainly in the Namib Desert. Based on earlier successes, two major types of deposits were targeted: intrusive-type associated with alaskite, as at Rössing, and surficial calcrete-type deposits, as at Langer Heinrich.

In 2002, Paladin Energy bought the Langer Heinrich tenement. The Langer Heinrich Uranium deposit is situated approximately 85 km east northeast of the major Walvis Bay seaport. The ore occurs over 15 km in a paleochannel system approximately 50 m deep. An exploration prospecting licence covered the western extension of the mineralised Langer Heinrich paleochannel. In 2005, this prospecting licence was converted into a mining licence. Construction at the Langer Heinrich project commenced in September 2005 and staged commissioning of the plant began in August 2006. Mining commenced in 2007 with a proposed 25-year life. However, due to sustained low uranium prices, Langer Heinrich was placed on care and maintenance in August 2018.

In 2005 French state-owned Orano (at that time Areva) purchased Trekkopje from the Canadian company UraMin and began construction of an alkaline heap leach mine in 2008, as well as an associated seawater desalination plant. The Trekkopje Project, located approximately 65 km northeast of the coastal town of Swakopmund, embodies the Klein Trekkopje and Trekkopje surficial uranium deposits, with 80% of the mineralisation contained in the top 15 m of strata below the surface. Hosted in calcrete sediments, the basal channels in the Trekkopje area follow the northeast trending structural grain of the underlying basement rocks. The mine was developed in a staged process, with Phase 1 "Mini" designed to validate the chemistry of the heap leach process successfully completed in 2009. Phase 2 "Midi" treated 3 million tonnes of ore to prove the commercial process before scaling up to full production. Phase 3 "Maxi" represented the full production stage of the mine, which was expected to produce about 3 000 tU

* Report prepared by the NEA/IAEA and Namibian Uranium Institute.

per annum. However, due to the depressed uranium market, the mine was put on care and maintenance at the end of 2012.

Other uranium projects that were issued mining licences during this period of active exploration activity, but have not commenced construction, are the Norasa (original name Valencia) and the Zhonge projects.

Discovery holes for the Husab (initially known as Rössing South) uranium deposit were drilled by Extract Resources in late 2007 and chemical assay results were released in February 2008. The main part of the Husab orebody lies approximately 5 km south of the Rössing mine. Extract Resources and the current owner Swakop Uranium Limited had in total completed over 800 000 m of combined reverse circulation and diamond core drilling since the drilling programme began in 2006.

Since 2006, exploration efforts have continued, but low uranium prices since 2011 have slowed activity. Nonetheless, substantial growth in uranium exploration took place in the Erongo area of west-central Namibia, focused mainly on previously known deposits with considerable historical data.

Bannerman Mining Resources Pty Ltd progressed the Etango Project from an initial scoping study (2007) and pre-feasibility study (2009) to a definitive feasibility study in 2012. In total, over 300 000 m of exploration drilling has been completed in the Etango Project area. In 2015, Bannerman commissioned a heap leach demonstration plant to demonstrate the proposed metallurgical process. Following this metallurgical test work, the flowsheet was changed from a heap leach/solvent extraction process to a heap leach/ion-exchange process followed by nano-filtration. In 2018, Bannerman decided to develop the Etango Mine in a staged process – initially with a throughput of 22 000 t of ore per day. This re-scaled Etango Mine was taken through the scoping study, pre-feasibility study and definitive feasibility study stages between 2019 and 2022.

For the Rössing mine, since 2010, the main exploration focus has been on the southern Z20 deposit that extends across the lease boundary into the adjacent lease held by Husab. A total of 24 000 m of drilling was completed on Z20 from three phases of drilling by August 2013. Infill drilling of the eastern extension of the SJ orebody outside the current open pit was undertaken in 2015 and 2021-2022 as part of the SJ Phase 4 pushback Pre-Feasibility studies.

The Reptile Mineral Resources and Exploration (Pty) Ltd (RMR) is a wholly owned Namibian registered subsidiary of the Australian public company Deep Yellow Limited (DYL). Active in Namibia since 2006, RMR holds three exclusive prospecting licences including the Omahola, Tubas, Tumas and Aussinanis deposits. Deposits are hosted in leucogranites, also referred to as alaskites, and in surficial palaeochannel sediments. The Tumas palaeochannel system extends over more than 100 km. It contains secondary uranium mineralisation (carnotite) in fluviatile grit, calcrete and gravel sequences. The Tubas Sand Project consists primarily of low-grade secondary uranium mineralisation (carnotite) in well-sorted aeolian sediments. The Aussinanis deposit forms a shallower palaeochannel system, also with carnotite-rich calcrete. RMR is also the manager of the Nova Joint Venture (NJV), which includes Tumas North and Chungochoab exclusive prospecting licences (EPLs).

Over 60 exploration licences were issued until early 2007, when a moratorium on new licences was imposed by the Namibian government pending development of new policies and legislation, primarily in response to concerns about water and energy requirements of uranium mining. In January 2017, the Namibian government lifted the 10-year moratorium on new applications for exploration licences for nuclear fuel minerals.

Recent and ongoing uranium exploration and mine development activities

Rössing

A revision of the pricing outlook and detailed financial analysis resulted in the removal of the Z20 deposit from the 2016 JORC compliant resource declaration and were reclassified to mineralised inventory. Since 2020, the SJ Phase 4 pushback has been included in the Rössing resource declarations. However, the resources contained within the Phase 2 and 3 pushbacks currently being mined continue to demonstrate value. In February 2023, a bankable feasibility study was approved on the Phase 4 pushback, and the Phase 4 material moved into reserves.

Exploration drilling resumed on the mining licence in 2022 to the east of the Z20 deposit at the Z17 deposit and about 12 500 m of diamond drilling was completed by the end of 2022. A further 7 500 m of exploration drilling was planned for 2023.

Langer Heinrich

A restart PFS was completed in June 2020 followed by a value study in October 2021. Restart activities, including extensive refurbishment coupled with process upgrades, have been underway since July 2022, with first production targeted for quarter one 2024. The restart production schedule has a ramp up period of 4 years with a maximum production target of 2 300 tU/y (6.0 Mlbs U_3O_8). Production will resume by reclaiming stockpiled material for the first 18 months after which mining and in-licence exploration activities will resume. The life of mine is planned for 17 years.

Trekkopje

While the operation is under care and maintenance, Orano has conducted research to improve uranium recovery. An optimised process was developed that enhances permeability in the heap by adding cement at the agglomeration stage and recovery of a substantial part of the reagents used is accomplished through membrane technology. The desalination plant built in association with the mine continues to supply sufficient water to meet the demand of other uranium mines and other users in the coastal area. Water production capacity was boosted to 1 million m^3/month to meet increased demand when the Husab Mine began production.

Husab

Swakop Uranium holds tenure over a Mining License (ML) and two Exclusive Prospecting Licenses (EPLs). It is a wholly owned subsidiary of Taurus Minerals Ltd., which is an entity of China General Nuclear Power Group (CGN) and the China-Africa Development Fund. Infill and development drilling was conducted to better delineate and improve confidence in resources planned to be mined over the short-to-medium term within the ML. The adjacent EPL offers reasonable prospects for exploration and the discovery of additional uranium resources.

Holland's Dome and Garnet Valley deposits offer the best prospects for future mine development within the EPL, reflecting the significant investment made in the past to assess their potential. Based on current assessments, significant scope still exists to further improve upon the resource inventory of these deposits and thereby further increase their potential economic viability for mining.

During 2021 and 2022, drilling activities were conducted at Holland's Dome prospect area to test open-ended uranium mineralisation to the west of historic exploration. Noteworthy mineralisation was intercepted to significantly increase the resource inventory of the deposit. An independently verified resource update for this deposit will be commissioned in due course. Further drilling is planned at this deposit during 2023, with a focus to identify additional resources to the west of the current drill grid in the southern sector of the deposit. Holland's Dome provides a compelling exploration opportunity, with potential to develop a Husab-scale operation should sufficient resources be delineated.

Recent work has also demonstrated the presence of uranium resources at the Pizzaro deposit that requires further attention in the future. This coupled with the newly identified geophysical target areas located throughout EPL 3439, significantly increases prospectivity and has the potential for the discovery of new resources.

Exploration activities on EPL 3138 have been directed towards the assessment of the uraniferous alaskites within the Damara metasediments and the Abbabis Metamorphic basement. The completed work is a combination of geophysical surveys, geological mapping and modelling, drilling, and resource evaluation. Mineralisation continuity at Ida Central

Deposit has been established northwards of the previous drill grid. The mineralisation is hosted in oxidised alaskites. Future exploration activities at this EPL will focus on areas such as Ida Central and Zone 6 deposits, where additional drilling is required to improve confidence in identified resources as well as to further expand upon these resources.

Etango

Bannerman Resources' Etango Project consists of three prospects: Anomaly A, Oshiveli and Onkelo. These prospects contain uraniferous sheeted leucogranite alaskite bodies, very similar to those at Rössing and Husab Mine. Although extensions continue to 400 m below the surface, two-thirds of the resource base is located less than 200 m below the surface. Total identified in situ uranium resources amount to about 82 400 tU, including 57 850 tU RAR. The Etango Mine has all environmental approvals in place for a mine that could produce 2 770 tU/y. Following extensive metallurgical test work at its demonstration plant, Bannerman Resources has decided to develop the mine at a reduced scale with an annual production of 1 350 tU/y for 15 years. Following the approval of the Mining License (that was expected in Q3 2023), construction of the mine could commence early in 2024. Should uranium prices continue to rise, the decision to expand and invest additional capital into the Etango Mine could then be taken to increase the annual production to 2 770 tU.

Reptile Mineral Resources and Exploration (RMR) Projects

Total identified in situ resources amount to about 109 900 tU, 48 000 tU of which occur at the Omahola Project, including the Ongolo and MS7 alaskite as well as the Inca skarn deposits, and 61 900 tU are contained in the Tumas, Tubas and Aussinanis surficial calcrete deposits.

The definitive feasibility study (DFS) for the Tumas Project commenced in February 2021 with a key focus on enhancing and further optimising the results from the previously completed PFS. In support of the DFS, an infill drilling programme was undertaken at the Tumas 3 and Tumas 1 East deposits to define sufficient indicated and measured resources outlined as being required by the PFS. Nearly 1 500 holes totalling approximately 25 000 m were drilled between February and August 2021. This resource infill drilling delivered more than 100% direct conversion of existing inferred mineral resources to indicated mineral resource category. The combined mineral resource for the Tumas paleochannel deposits includes 51 120 tU (132.9 Mlb U_3O_8) at 211 ppm U.

In addition, a geotechnical diamond drilling was undertaken at Tumas 3 aiming at collecting samples for geotechnical test work. Six water production test holes totalling approximately 600 m were drilled, installed and developed to establish groundwater quality and quantity available for the construction of the Tumas Project.

In November 2020, RMR commenced an environmental impact assessment (EIA) for the Tumas Project. A mining licence application was submitted to Ministry of Mines and Energy in July 2021 and the company received the notification "Intention to Grant" in August 2022, subject to EIA approval and issue of environmental clearance certificate. The environmental impact assessment (EIA) was submitted to the Environmental Commissioner for consideration in April 2023. The environmental approvals for the project and the 20-year mining licence were granted in September 2023.

The Tumas DFS results were released to the market in February 2023. A key feature of the DFS, compared to the PFS outcome, is the increased production capacity of the plant from 1 150 tU/y to 1 400 tU/y. In 2023, the company focused on detailed Front-End Engineering and Design (FEED), project financing, and product offtakes ahead of a Final Investment Decision the first half of 2024.

Exploration drilling at the Omahola Project resumed in 2021. During 2021 and 2022, 340 holes were drilled. The drilling targeted alaskites under cover along a lithostratigraphic-structural zone, which is host to the mineralisation at Ongolo, MS7 and Inca. Thick and stacked mineralised alaskites, which require further exploration, were discovered west of the MS7 deposit.

RMR is also manager of the Nova JV, which is exploring two greenfield prospecting licences. Exploration undertaken between 2017 and 2020 identified several uranium prospects, but in situ resources are yet to be identified. The most prospective target is Barking Gecko, where uranium mineralisation is hosted by alaskitic sheets. In 2020, drilling delineated two prospective zones, namely Barking Gecko North and Barking Gecko South. Exploration of the Barking Gecko North prospect continued in 2021 and 2022. Thirty-seven holes confirmed prospectivity and delineated further potential.

Elevate Uranium

Elevate Uranium Ltd (former Marenica Energy) owns the Marenica uranium deposit under a Mineral Deposit Retention License and a number of Exclusive Prospecting Licenses, which make them the largest uranium tenement holder in Namibia. The Marenica Project includes the calcrete-hosted uranium deposits of Marenica and MA7 located in the same palaeochannel system that hosts Orano's Trekkopje uranium deposit, which has similar mineralogical characteristics to Marenica. The Marenica Project has identified mineral resources of 23 577 tU (61.3 Mlb U_3O_8) at 0.008% U (93 ppm U_3O_8), including 2 462 tU in the indicated category.

From 2015 to 2020 the company suspended all drilling activities due to depressed market conditions and focused on metallurgical testing of the so-called "U-pgrade™" beneficiation processes to increase the grade of mined ore prior to leaching. Feed grade can be elevated by over 50 times to approximately 5 000 ppm U_3O_8 (4 200 ppm U). Calcite rejection has also enabled the proposed leach circuit to be changed from an alkali leach (with higher operating temperatures and slower kinetics) to acid (at ambient temperature and rapid kinetics), thereby reducing expected capital expenses and operating costs.

In mid-2020, Elevate Uranium announced a new uranium discovery at EPL 7278 ("Hirabeb"). Exploration on the tenement identified a massive palaeochannel system that extends over 36 kilometres. The primary palaeochannel is mineralised over most of its length with the potential to host a significant uranium deposit. An airborne EM survey, flown in April 2021, covered the Hirabeb tenement and is expected to expand on the palaeochannel system. Furthermore, Elevate announced the discovery of a new palaeochannel system at EPL 7662 (Namib IV) extending over a length of 19 km and is 6 km wide at its widest point.

In total, Elevate Uranium has made four uranium discoveries in Namibia during 2020-2022, and increased its JORC compliant uranium resources to 31 385 tU (81.6 Mlb U_3O_8), after announcing in 2022 an initial 7 808 tU (20.3 Mlb U_3O_8) of inferred resource at its Koppies project. Subsequent resource drilling at Koppies has discovered extensions of the mineralisation in the northeast and south and has determined that Koppies 1, 2, 3 and 4 are a continuous zone of mineralisation over 20 km in length and less than 20 m in depth. In November 2023, Elevate Uranium reported Koppies inferred resources increased to 18 462 tU (48 Mlb U_3O_8). Koppies is one of the shallowest uranium resources globally, with 95% of the resource within approximately 15 metres of the surface and 50% of the resource within 6 metres of the surface.

Happy Valley

Located approximately 110 km northeast of Swakopmund and east of Rössing, the Happy Valley Project area was granted to Zhonghe Resources on 1 August 2006. Zhonghe is a Namibian registered company founded in 2008 by the China National Uranium Corporation (CNUC; 58%), a wholly owned subsidiary of the China National Nuclear Corporation (CNNC), and co-owned by two private companies, China Mineral Resources Investment and Development P/L Nam-China (21%), and Springbok Investment Ltd (21%).

Exploration work started in the area in 2007 and JORC compliant in situ resources amounting to 40 730 tU at 0.016% U were defined. A feasibility study was undertaken from 2013 to 2018 while Zhonge Resources continued to focus on resource evaluation and economic reassessment. Since CNUC has taken over Rössing Uranium Limited, the Zhonge Resources project could present further opportunity for Rössing Uranium Ltd.

A diamond drilling programme started in August 2022, and a series of geological and geophysical surveys were carried out on some anomalies in 2021-2022. The parent company CNNC implemented a 20 000 m drilling programme on both the neighbouring Rössing mining licence area and Zhonghe’s mining licence area.

Forsys

Forsys holds a mining licence for its Valencia uranium deposit, valid until 2033. It also owns the neighbouring Namibplaas uranium resource, for which it also submitted a mining licence application. The two projects together are known as the Norasa Uranium Project, for which environmental clearance is in place. The company is conducting studies to update and improve on its 2015 Definitive Feasibility Study. Forsys sees potential to improve project economics by optimising pit parameters and examining the potential of using heap leaching in mineral processing. The work programme started in 2023, and includes drilling, geotechnical optimisation of pit parameters, evaluation of alternative metallurgical processes including heap leaching, and a critical review of all linear infrastructure and utilities. An updated DFS on the project is anticipated to be completed in Q3 2024.

Wings

In southeastern Namibia, Russian owned Uranium One, through its Namibian subsidiary, Headspring Investments Pty., conducted ground geophysical and geochemical surveys during 2016-2017, completed metallurgical test studies of core with uranium mineralisation in 2018, and began systematic intensive exploration drilling in 2019. Exploration drilling volumes increased from 9 430 m in 2019 to 34 818 m in 2020 and further to 40 715 m in 2021. As a result of intensive 2019-2021 drilling activities (504 core drill holes), a new sandstone type uranium deposit, Wings, has been discovered with resources confirmed by a JORC compliant technical report amounting to 18 536 tU of measured and indicated resources (RAR), 22 977 tU of inferred resources and exploration potential of 30 000 tU. The total in situ resource base is 41 513 tU, equivalent to 33 210 tU of recoverable resources.

Based on 2020-2021 exploration, metallurgical and hydrogeological tests results, resources are potentially amenable for development by ISL method. A PFS completed in 2021 has confirmed positive economics for the ISL mining method. During 2022-2023, the company made preparations for the ISL pilot test. The pilot plant and well field construction was completed in 2022 and the pilot production start is subject to permission to be issued by Namibian regulators. This is the first time that sandstone type mineralisation potentially amenable for ISL recovery has been discovered in Namibia.

Identified conventional resources (reasonably assured and inferred resources)

Total identified in situ conventional resources in Namibia amounted to 688 456 tU as of 1 January 2023, while recoverable known resources amounted to 550 765 tU, including 337 620 tU in the reasonably assured and 213 145 tU in the inferred resource categories. The average overall recovery factor for all mining and processing methods is 80%. Deposits in Namibia are typically large and low grade. About 90% of the recoverable identified uranium resources are classified in the <USD 130/kgU cost category. Namibia reports also 33 210 tU of recoverable resources in the <USD 80 kg/U category that belong to the Wings sandstone type deposit potentially amenable for ISL mining.

Compared with data as of 1 January 2021, there has been an increase of 51 540 tU in situ conventional resources and 41 232 tU of total recoverable known resources. This is the result of additional resources identified at Tumas by RMR, at Wings by Headspring Investments and at Koppies by Elevate Resources. In addition, it accounts for decreases due to 2021 and 2022 mining depletion at the Husab and Rössing mines.

Undiscovered conventional resources (prognosticated and speculative resources)

Undiscovered resources are estimated in areas adjacent to deposits with identified resources in Happy Valley, Etango, Tumas, Husab and Wings. As of 1 January 2023, prognosticated resources amounted to 57 000 tU and speculative resources totalled 150 700 tU, the same amount as in the previous report.

Uranium production

Historical review

Rössing Uranium Limited was formed in 1970 to develop the Rössing deposit. Rio Tinto was the leading shareholder, initially with 51.3% of the equity of Rössing, and subsequently increasing its stake to 69%. In 2019, Rio Tinto sold its majority stake in Rössing to the Chinese state-owned company CNUC/CNNC. Mine development commenced in 1974 and initial production began in July 1976, but full design capacity of 3 816 tU/yr (5 000 short tons of U_3O_8/yr) was not achieved because of the highly abrasive nature of the ore, an aspect not identified during the pilot plant testing stage. The production target was reached in 1979 after plant design changes were implemented. From the date of first production in July 1976 to the end of 2022 a cumulative total of over 123 475 tU had been produced at Rössing.

Paladin Energy Ltd. acquired the Langer Heinrich project from Aztec Resources Ltd (formerly Acclaim Uranium NL) in August 2002. Construction of the Langer Heinrich project commenced in September 2005 and staged commissioning of the plant began in August 2006. Mining commenced in 2007 with a proposed 25-year life to 2030. The initial planned production level of 1 040 tU/yr was achieved in 2008. This was followed by the Stage 2 expansion to 1 350 tU/yr in 2010. Stage 3 expansion to 2 030 tU/yr was completed in 2012. In July 2014, Paladin Energy sold a 25% interest in the mine to CNNC Overseas Uranium Holding Limited, a wholly owned subsidiary of CNNC. A Stage 4 expansion feasibility study and environmental impact assessment were submitted to government, but subsequently the project was put on hold. Due to sustained low uranium prices, Langer Heinrich Mine (LHM) was placed in care and maintenance in August 2018.

The Husab Mine, developed and constructed by Swakop Uranium, is located approximately 5 km south of the Rössing mine and 45 km northeast of the Walvis Bay port. In 2011, the project received an environmental clearance certificate and a mining licence. Construction of the Husab Mine began in April 2013, and in December 2016, the first uranium oxide was drummed. Throughout the construction phase, the project created over 6 000 temporary jobs, contributing to local employment and economic development. Initially, Swakop Uranium was a fully owned subsidiary of Australian public company Extract Resources. However, in March 2012, the Chinese state-owned China Guangdong Nuclear Power Corporation (CGNPC) acquired Swakop Uranium. In November 2012, an agreement was finalised between Swakop Uranium and Epangelo, the Namibian state-owned mining company. Under this agreement, Epangelo obtained a 10% stake in Swakop Uranium, solidifying Namibian participation and ownership in the project.

Status of production facilities, production capability, recent and ongoing activities

Total uranium production in Namibia declined from 3 246 tU in 2014 to 2 992 tU in 2015 but rebounded to 3 593 tU in 2016. Production continued to increase to 4 221 tU in 2017 and 5 520 tU in 2018. Start-up of the Husab Mine is the main reason for national production increases since 2016. Uranium production in Namibia amounted to 5 754 tU (3 310 tU was produced at Husab and 2 444 tU at Rössing) in 2021, and to 5 612 tU in 2022 (3 357 tU at Husab and 2 255 tU at Rössing). In 2023, uranium production increased by 25% compared to 2022 and reached 6 985 tU (4 509 tU at Husab and 2 476 tU at Rössing), which is a historical record for Namibia. Namibia has good potential for further production ramp up, considering planned developments at existing mines and the Langer Heinrich mine restart in 2024.

Rössing

Rössing Uranium is one of the largest and longest operating uranium open cast mines in the world. Rössing Uranium produced 2 444 tU in 2021, representing a 16% increase compared to 2020. Production in 2022 amounted to 2 255 tU, about 7.7% less than in 2022. The main reason for the lower production compared to 2021 is related to lower ore feed grade. However, in 2023 Rössing increased production by about 10% to 2 476 tU.

Original mine plans foresaw a cessation of Rössing production at the end of 2026. A feasibility study to extend the life of mine production to 2037 is under way and the Ministry of Mines and Energy has already extended the mining licence to 2036. Based on the study, new investment may be considered from Q3 2023 onwards and contemplate several aspects such as pit and tailing storage facility extensions, plant refurbishment and infrastructure upgrades.

Langer Heinrich

From the date of first production in March 2007 to the end of 2018, a cumulative total of 16 449 tU was produced at LHM. Due to sustained low uranium spot prices, the operations at LHM were suspended in August 2018 and the mine was placed in care and maintenance. There were no production or development activities since 2018. In June 2020, Paladin released the Mine Restart Plan setting a pathway to transition back into reliable production.

On 19 July 2022, a Final Investment Decision was announced confirming the return of LHM to optimal operational status with first production targeted for the first quarter of 2024. Since the decision, the Langer Heinrich Mine Restart Project has progressed activities focused on, inter alia, general repairs and refurbishment to return the existing process plant to operational readiness. The Restart Plan has confirmed a 17-year project life with peak production of up to 6 Mlb U_3O_8 (~2 300 tU) per annum for the targeted 7 years of mining.

Trekkopje

Following Phase 1 trial mining with 250 000 t of ore and processing operations, Phase 2 pilot tests, heap leach trials (using a sodium carbonate/bicarbonate leach process) and construction of the main production pad in 2010, a final production level of 2 545 tU/yr (3 000 t U_3O_8/yr) was envisaged. However, production levels were limited to 251 tU and 186 tU in 2012 and 2013, respectively. As a direct consequence of low uranium prices, the project was placed in care and maintenance in mid-2013. The mine is expected to remain under care and maintenance until the uranium price makes it economical to restart production, since 80% of the investments to develop the mine have already been made, and the advanced processing knowledge acquired through metallurgical testing has realised further potential for efficiency improvements.

Husab

Husab is today one of the largest operating open-pit uranium mines in the world with a nameplate capacity of 5 700 tU/yr (15 Mlb U_3O_8/yr). The mining fleet at Husab is designed to transport 15 million tonnes of ore per year from two open pits to the processing plant, with a total capacity of 120 million tonnes per year for both ore and waste rock transportation.

Mining started in March 2014, and the processing operation started towards the end of 2016. Since then, Husab Mine has been ramping up its operations and production reached 3 310 tU in 2021 and 3 357 tU in 2022. The 2022 uranium production was negatively impacted primarily due to 39 production days lost on account of water shortages. Husab increased uranium production to 4 509 tU in 2023 and plans further production ramp up.

In August 2023, Swakop Uranium reported that it expects to construct a pilot heap leach plant at Husab, which will explore the economic feasibility of processing lower-grade uranium ore. Heap leach tests will be concluded by the end of 2025, after which further decision will be made if found to be economically feasible.

Future production centres

Etango

In 2020, Bannerman Resources updated a scoping study, and in August 2021 the company completed a new pre-feasibility study (PFS) for an 8 million tonnes ore per annum development of its flagship Etango Project. The environmental clearance certificate for the proposed Etango Uranium Mine was renewed by the Ministry of Environment, Forestry and Tourism during 2021.

In December 2022, Bannerman Mining Resources Namibia released the results from the definitive feasibility study completed on its Etango-8 uranium project. It confirms technical and economic viability of a conventional open-pit mining and heap leach processing operation with a throughput of 8 million tonnes per annum that is expected to deliver over 3.5 Mlb U_3O_8 (1 350 tU) per annum over an initial operating life of 15 years. In 2023, Bannerman progressed to the Front-End Engineering and Design phase of the project. A mining licence application was launched with the Ministry of Mines and Energy in August 2022.

Norasa

With estimated annual production of about 2 000 tU over a 15-year mine life, at costs of USD 86/kgU (USD 32.96/lb U_3O_8) over the first 5 years of production, and USD 90/kgU (USD 34.72/lb U_3O_8) over the mine life, the project is expected to start when uranium prices reach required levels. Environmental approval for an open-pit mine was granted in June 2008 and a 25-year mining licence was granted in August 2008 to Valencia Uranium P/L (a wholly owned subsidiary of Forsys). In situ indicated resources of 44 235 tU and inferred resources of 6 538 tU at a cut-off grade of 0.01% U have been delineated.

Tumas

After completing a definitive feasibility study in February 2023, Deep Yellow Ltd (with its wholly owned subsidiary Reptile Mineral Resources and Exploration (Pty) Ltd) confirmed the viability of the project with a long-term uranium price of about USD 65/lb U_3O_8 with pre-production capital costs estimated at USD 372 million. The mining operation has a production capacity of 3.6 Mlb U_3O_8 (1 400 tU) and 1.15 Mlb V_2O_5 (500 tV_2O_5) per annum.

Employment in the uranium industry

According to the Namibian Chamber of Mines annual reports, employment in the uranium industry remained relatively stable: 2 754 employees at the end of 2021, 2 716 in 2022 and 2 788 in 2023. These numbers include permanent, temporary and expatriate employees and exclude employed contractors. Approximately 60% of total 2023 numbers related to Swakop Uranium and 31% to Rössing Uranium.

The number of employed contractors increased from 1 729 in 2021 to 3 066 in 2022, mainly due to increases at Husab from 1 100 in 2021 to 2 175 in 2022. Rössing Uranium increased employed contractors from 784 in 2022 to 1 336 in 2023.

Langer Heinrich and Trekkopje were under care and maintenance and the number of employees in 2022 was 22 and 16 accordingly; however, Langer Heinrich started preparation for mine relaunch and increased its employment to 265 persons in 2023.

Uranium production centre technical details
(as of 1 January 2023)

	Centre #1	Centre #2	Centre #3	Centre #4	Centre #5	Centre #6	Centre #7
Name of production centre	Rössing	Langer Heinrich	Husab	Trekkopje	Norasa	Etango	Tumas
Production centre classification	Existing	Idled	Existing	Idled	Prospective	Prospective	Prospective
Date of first production (year)	1976	2007	2016	2013	NA	NA	NA
Source of ore:							
Deposit name(s)	Rössing SJ, SK,	Langer Heinrich	Husab Zones 1 and 2	Trekkopje, Klein Trekkopje	Valencia and Namibplaas	Etango	Tumas, Tubas
Deposit type(s)	Intrusive	Calcrete	Intrusive	Calcrete	Intrusive	Intrusive	Calcrete
Recoverable resources (tU)	23 568	36 831	147 096	20 034	40 618	65 942	24 500
Grade (% U)	0.025	0.045	0.033	0.012	0.017	0.016	0.035
Mining operation:							
Type (OP/UG/ISL)	OP	OP	OP	OP	OP	OP	OP
Size (tonnes ore/day)	26 000	N/A	42 000	30 800	33 000	55 000	11 400
Average mining recovery (%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Processing plant:							
Acid/alkaline	Acid	Alkaline	Acid	Alkaline	Acid	Acid	Alkaline
Type (IX/SX)	IX/SX	IX	IX/SX	HL/IX	IX/SX	HL/IX/NF	NA
Size (tonnes ore/day)	26 000	N/A	40 000	100 000	30 000	55 000	11 400
Average process recovery (%)	85	90	87	80	90	90	80
Nominal production capacity (tU/year)	2 000	2 000	5 700	3 000	2 000	1 350	1 400
Plans for expansion (yes/no)	No	Yes	Yes	No	No	No	Yes

Uranium production centre ownership structure

Project	Rössing	Langer Heinrich	Husab	Trekkopje	Norasa	Etango	Tumas
Company	Rössing Uranium Ltd	Langer Heinrich Uranium	Swakop Uranium	Orano Mining Namibia	Forsys Metals	Bannerman Resources	Reptile Uranium Namibia
Owners	68.6% CNUC (China)	75% Paladin Energy (Australia)	90% CGN Mining (China)	100% Orano (France)	100% Forsys Metals Corp. (Canada)	100% Bannerman Energy (Australia)	100% Deep Yellow Ltd. (Australia)
	28% other interests, 3.4% Namibian Government	25% CNNC (China)	10% Epangelo Mining (Namibia)				

Environmental activities and socio-cultural issues

Namibia's "Vision 2030" spells out the country's development programmes and strategies to achieve national objectives. It focuses on eight themes to realise the country's long-term vision. Uranium mining and exploration companies actively support these government objectives. Moreover, as the Namibian uranium exploration and mining sector operates in the environmentally sensitive Namib Desert and partly in National Parks, environmental best practice is absolutely high on the agenda of the industry.

The Namibian Uranium Association

The Namibian Uranium Association (NUA) is an advocacy body for the uranium industry, assisting senior executives in shaping the context in which their industry operates. It supports policies that allow uranium to compete on its merits as a source for low-carbon energy appropriate for modern society through research, information and advocacy. Members of NUA span all Namibian uranium mining operations, most of Namibia's leading uranium exploration companies, and associated contractors.

NUA is the leading point of contact for government, media, stakeholders, and the general public interested in the position and policies of the Namibian uranium industry. NUA promotes industry adherence to sustainable development performance, product stewardship, and compliance within the Namibian legislative framework. A key mission of the association's uranium stewardship programme is to "earn public trust for the global nuclear fuel cycle through the continued replacement of standard practice with best practice".

As part of its stewardship mission, NUA established the Namibian Uranium Institute (NUI). NUI is guided by respected independent scientists who serve on its Scientific Committee. The main purpose of the NUI is to act as a communication hub for the industry in Namibia, and to promote knowledge and capacity building in specialised skills in the fields of environmental management, radiation safety and health. NUI therefore provides an opportunity for NUA members to collectively improve safety and health performance through the identification of world-class leading practices and their implementation. As such, NUI is working closely with the Namibian government and state agencies, as well as maintaining close ties to the Namibian University of Science and Technology.

Environmental Management Act, Act No. 7 of 2007

Namibia committed itself to sound environmental management, as reflected in the Environmental Management Act, Act No. 7 of 2007 and Regulations, gazetted on 6 February 2012. The objective of the act is prevention and mitigation, following environmental management principles that:

- ensure that the significant effects of activities on the environment are considered in time and with care;
- ensure that there are opportunities for timely participation of interested and affected parties through the assessment process, and that the findings of an assessment are considered before any decision is made with respect to the activities.

The Strategic Environmental Assessment and the Strategic Environmental Management Plan

Most of the Namibian uranium exploration and mining activities occur in the Central Namib, an ecologically sensitive area containing parts of the Namib Naukluft and Dorob National Parks. Mining and associated developments are vital for Namibian economic growth, and the country strives to reconcile development objectives and mineral exploitation with environmental protection to foster long-term socio-economic growth and stability. An integrated approach is required so that development of one resource will not jeopardise the potential of another.

The need for proper environmental planning in the framework of a comprehensive environmental assessment was therefore realised at an early stage when rising uranium prices in the mid-2000s caused a uranium exploration rush. Apart from forming the uranium stewardship committee, a proposal was made for a strategic environmental assessment (SEA) that was subsequently carried out by the Geological Survey of Namibia. The Uranium-SEA, as it has become known, dealt with a variety of topics, such as water, energy, air quality, radiation, health, transport, tourism, biodiversity, heritage, economics, education and governance. Following an independent assessment by the International Institute for Environment and Development, a Strategic Environmental Management Plan (SEMP) was created from the SEA findings and is being implemented by the Ministry of Mines and Energy. The Namibian uranium industry has supported the SEA process and is an active partner of government in the implementation of the SEMP.

Positive impacts noted in the SEA include stimulating the Namibian economy, as well as developing skills and infrastructure. Constraints to development, such as possible water shortages, lack of skills, capacity of physical infrastructure and environmental protection, were also identified. The SEA noted that a uranium rush could impact natural physical resources, biodiversity, health, infrastructure and tourism. Good governance will be critical in minimising these impacts.

The SEMP sets out several environmental quality objectives related to socio-economic development, employment, infrastructure, water, air quality and radiation, health, tourism, ecological integrity, education, governance, heritage and future developments, closure and land use, which are to be continuously monitored as a collective proxy for measuring the degree to which uranium mine development activities are moving the Erongo Region towards a desired future state. An office has been established to administer the SEMP programme.

One of the key aspects identified in the SEMP is water. Since 2010, water has been supplied to Trekkopje from a coastal desalination plant built by Areva (now Orano) capable of supplying 20 million m^3/yr and requiring 16 MWe from the grid. Desalinated water is also supplied via the Namibian Water Corporation to Rössing, Langer Heinrich and Husab. The SEMP stated that uranium mining, mine development and exploration have not compromised community access to water supplies of acceptable quality.

Environmental monitoring

Uranium mining operations, in co-operation with the Environmental Affairs Department of the Ministry of Environment, Forestry and Tourism, continue to actively monitor environmental issues of concern. Best practices and sharing experiences are encouraged through participatory environmental planning and management and promoting effective waste management. In addition to the SEMP, Namibian Uranium Association members carry out additional environmental monitoring, verified by government, to ensure that the mining footprint is as small as possible. Stringent water-saving measures, air quality and biodiversity monitoring, as well as the implementation of mitigation measures for adverse impacts and environmental training of staff are examples of these efforts. Well-established environmental monitoring programmes approved under the environmental clearance certificate granted by the Ministry of Environment and Tourism continue.

Rössing works to continuously improve environmental management programmes to maximise benefits and minimise negative impacts. Key environmental management programmes include energy efficiency and greenhouse gas emissions, air quality control (including emissions of dust and other impurities, as well as noise and vibration), water use, waste management (both mineral and non-mineral), chemical substance management and land use management (including biodiversity, rehabilitation and closure).

The mineral waste generated by Rössing Uranium in 2022 amounted to a total of 16.33 million tonnes (8.97 million tonnes of tailings and 7.36 million tonnes of waste rock). Tailings were deposited in the existing tailings storage facility. Waste rock was deposited in existing rock dumps close to the open pit with no extension of the footprint. The total mineral waste inventory generated by Rössing over the last 46 years amounts to roughly 1.50 billion tonnes covering a total footprint of 1 488 ha.

Since 1980, Rössing has been recycling 60 to 70% of its water annually. The 2022 Rössing operating plan set and achieved a target for desalinated freshwater usage of 2.8 million m^3 supplied by NamWater. Abstraction of saline groundwater from the Khan River aquifer used for haul road dust suppression amounted to only 0.55% of the permitted volume in 2022.

Langer Heinrich Uranium remained fully permitted during care and maintenance, regularly submitting compliance reports as stipulated under various permitting and licensing conditions. Well-established environmental monitoring programmes approved under the environmental clearance certificate (ECC) granted by the Ministry of Environment, Forestry and Tourism continued during this reporting period.

The Husab Mine continued to prioritise environmental activities, ensuring compliance and monitoring various aspects of the operation. Routine audits, inspections, and management of permit conditions were conducted to maintain regulatory requirements. Bio-physical monitoring, including surface and groundwater assessments, air quality evaluations, environmental radiation measurements, and biodiversity studies, were regularly carried out. The mine has made notable progress in the social component of its rehabilitation, restoration and closure plan, demonstrating its commitment to responsible mining practices. Water requirements are met through agreements with NamWater and Orano, utilising desalinated water supply. In addition, Husab has applied for a permit from the Ministry of Agriculture, Water, and Land Reform to use water from pit dewatering for dust suppression purposes. To minimise water consumption, the Husab processing plant operates a closed-loop circuit that enables continual water recycling. The treated effluent from the sewage treatment plant is effectively utilised for dust suppression. Furthermore, Husab implements wastewater recycling from the tailings dam to the processing plant, reducing the reliance on raw water sources and promoting sustainable water management practices.

The environmental management plan (EMP) for Husab Mine and its associated linear infrastructure was compiled and approved as part of the environmental clearance certificate. Through the environmental impact assessment (EIA) Amendment process conducted in 2021, specific to the Heap Leach Facility and its related infrastructure, new environmental management measures have been identified. As a result of these findings, the approved EMP has been updated, and now includes all additional and amended management and mitigation measures that are associated with the proposed changes to the mine. This ensures that the environmental impacts of the new developments are adequately addressed and managed in accordance with environmental regulations and best practices. The EMP serves as a comprehensive plan to guide environmental management and mitigation activities at Husab Mine and its associated linear infrastructure, taking into account any modifications or expansions that have been made.

An EIA for the Tumas Project mining licence application was completed and submitted to the relevant ministries and authorities in early 2023. Environmental monitoring includes groundwater and dust sampling, the collection of weather data, and monitoring of native flora.

Site rehabilitation

All Namibian uranium operators adhere to the Mine Closure Framework of the Chamber of Mines of Namibia. The framework provides guidance to the mining industry on developing relevant, practical and cost-effective closure plans and establishes minimum requirements for members bound by the Chamber's Code of Conduct and Ethics.

The Rössing Environmental Rehabilitation Fund, established to provide for the mine's closure costs, complies with statutory obligations and stipulated requirements of the government. The Fund requires an annual contribution by the mining company to provide for the total cost of the eventual closure of the mine, expected currently in 2036.

Corporate social responsibility

Members of the Namibian Uranium Association have undertaken corporate social responsibility projects for more than three decades, with over 20 ongoing to address themes such as economic advancement, social progression, education and training, hunger and poverty, water supply, sanitation, and youth employment.

Rössing promotes healthy, safe and environmentally responsible lifestyles among neighbouring communities, and makes direct contributions to initiatives targeting biodiversity protection, conservation education, health and safety (including HIV/Aids), and waste management. Total investment in these corporate social activities in the year 2022 amounted to NAD 29 million (USD 1.8 million).

Langer Heinrich (LHU) remains committed to addressing social aspects such as local procurement, recruitment, employee development and involvement in the community. During this reporting period, LHU made donations to the Namib Anti-Poaching Unit, for use in the Namib Naukluft National Park. The provision of fuel to this organisation assists them in continuing critical conservation work.

Swakop Uranium places a high value on corporate social responsibility (CSR) and endeavours to contribute to community projects that potentially have a long-lasting and positive impact on their host community, as well as the larger Namibian demographic landscape. Swakop Uranium continues to make good progress in terms of aligning its CSR targets with those outlined in the National Development Plans and the UN Global Sustainable Development Goals (SDGs). The years 2020 and 2021 were of an unprecedented nature with the emergence of a global health crisis that saw governments and industries come up with urgent measures to preserve life. Swakop Uranium responded to the call of government for support from the business community during the first and second COVID-19 waves and more so when the third wave collapsed the healthcare system in Namibia, causing a shortage of oxygen supply for life support and hospital beds countrywide.

Orano engages with stakeholders at local, regional and national levels in the areas of economic development, education, culture and sport.

Bannerman Resources, even at an early stage of mine development, has focused on education and tourism as part of its social programme, for example by supporting over 2 000 disadvantaged primary school children in the Erongo Region and other regions in Namibia.

RMR's CSR activities are aligned with the United Nations SDGs and the National Development Plans of Namibia, i.e. the Fifth National Development Plan (NDP5) and the Harambee Prosperity Plan, and are focused on early childhood development, empowering people and communities through sports and promoting a sustainable environment.

Regulatory regime

Namibia has been hosting uranium exploration and mining for more than 47 years. The sector is governed by a range of comprehensive pieces of legislation, starting with the Namibian Constitution, which provides for the protection of the environment and the welfare of people. Uranium mining is regulated by the Minerals (Prospecting and Mining) Act 33 of 1992. Section 2 of this Act vests all rights with respect of minerals in the state. Environmental issues are regulated by the Minister of Environment, Forestry and Tourism. The Minister of Mines and Energy may not issue a mineral licence before the applicant has obtained an environmental clearance certificate.

Furthermore, the Minerals (Prospecting and Mining) Act 33 sets the terms and conditions for granting exploration and mining licences. Section 102 of this Act prohibits the processing, import, export or possession of source material without the Minister's written authorisation. Health and safety aspects relating to the minerals industry are administered in terms of the Mines, Works and Minerals Ordinance 20 of 1968.

Namibia's Environmental Management Act underlines the importance of consultation with interested and affected parties. It promotes sustainable environmental management and use of natural resources by establishing principles for decision-making and environmental impact assessment regulations.

The Atomic Energy and Radiation Protection Act (Act No.5 of 2005) was gazetted on 16 January 2012. Administered by the National Radiation Protection Authority, it provides for the regulation of all activities associated with radiation sources, radioactive or nuclear material. The primary purposes of the act are to protect people against the harmful effects of radiation, minimise environmental pollution that may be caused by radiological contamination, ensure the safety of facilities and radiation sources, and guarantee that Namibia meets its obligations within the context of international legal instruments in the sector of radiation or nuclear technologies.

Namibia is party to the Nuclear Non-Proliferation Treaty and has concluded a comprehensive safeguards agreement in force since 1998, and in 2000 signed and ratified the Additional Protocol.

Epangelo Mining

In July 2008, the Epangelo Mining Company was established by the government to participate in the mining sector, and as per the provisions of the Minerals (Prospecting and Mining) Act, to acquire mining rights and equity by concluding joint ventures with existing companies. The Namibian government is the sole shareholder of Epangelo. Namibia has identified uranium as a strategic mineral and potential source of energy, expressing its desire to enhance economic development through potential local fuel cycle facilities and by considering nuclear power to augment its energy needs.

Uranium requirements

At present, Namibia has no nuclear power generating facilities. Namibia produces power locally and imports about half its electricity through the Southern African Power Pool.

National policies relating to uranium

The government has designated its uranium resources as a strategic and controlled mineral that must be treated differently from other minerals because of, among other reasons, the risk of proliferation, radiological risks, and its use as fuel for generating electricity.

Given its special nature and the radiological and fissile properties of uranium, the government has developed responsive regulatory frameworks to address health, safety, research and development applicable to the nuclear fuel cycle. Because Namibia is considering the development of commercial nuclear power to promote energy security and meet its increasing energy needs without increasing greenhouse gas emissions, it has developed a Nuclear Fuel Cycle Policy to examine the potential of further value addition to the production of yellowcake.

Uranium exploration and development expenditures and drilling effort – domestic

(NAD – Namibian dollars, thousands)

	2021	2022	2023 (expected)
Industry* exploration expenditures	342 236	293 288	241 599
Industry* development expenditures	18 452	1 087 760	1 139 600
Total expenditures	360 688	1 381 048	1 381 199
Industry* exploration drilling (m)	67 453	77 262	75 085
Industry* exploration holes drilled	1 564	2 378	2 523
Industry* development drilling (m)	32 861	19 083	12 950
Industry* development holes drilled	1 612	133	138
Total drilling (m)	100 314	96 345	88 035
Total number of holes drilled	3 176	2 511	2 661

* Non-governmental expenditure.

Reasonably assured conventional resources by production method
(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	307 130	322 791	80
In situ leaching	0	14 829	14 829	14 829	80
Total	0	14 829	321 959	337 620	80

Reasonably assured conventional resources by processing method
(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	0	0	260 849	268 172	80
Heap leaching* from OP	0	0	46 281	54 619	80
In situ leaching	0	14 829	14 829	14 829	80
Total	0	14 829	321 959	337 620	80

* A subset of open-pit and underground mining, since it is used in conjunction with them.

Reasonably assured conventional resources by deposit type
(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Intrusive	0	0	237 104	244 426
Surficial	0	0	70 026	78 365
Sandstone	0	14 829	14 829	14 829
Total	0	14 829	321 959	337 620

Inferred conventional resources by production method
(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	157 540	194 763	80
In situ leaching	0	18 382	18 382	18 382	80
Total	0	18 382	175 922	213 145	80

Inferred conventional resources by processing method
(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	0	0	139 970	165 498	80
Heap leaching* from OP	0	0	17 570	29 266	80
In situ leaching	0	18 382	18 382	18 382	80
Total	0	18 382	175 922	213 145	80

* A subset of open-pit and underground mining, since it is used in conjunction with them.

Inferred conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Intrusive	0	0	116 114	141 642
Surficial	0	0	41 426	53 121
Sandstone	0	18 382	18 382	18 382
Total	0	18 382	175 922	213 145

Prognosticated conventional resources

(in situ tonnes U)

Cost ranges		
<USD80/kgU	<USD 130/kgU	<USD 260/kgU
0	0	57 000

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	0	150 700

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Open-pit mining*	147 633	5 754	5 612	158 999	6 985
Total	147 633	5 754	5 612	158 999	6 985

* Pre-2018 totals may include uranium recovered by heap and in-place leaching.

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Conventional	147 196	5 754	5 612	158 562	6 985
Heap leaching	437	0	0	437	0
Total	147 633	5 754	5 612	158 999	6 985

Historical uranium production by deposit type

(tonnes U in concentrate)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Intrusive	131 184	5 754	5 612	142 550	6 985
Surficial	16 449	0	0	16 449	0
Total	147 633	5 754	5 612	158 999	6 985

Ownership of uranium production in 2022

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
412	7	0	0	5 143	92	56	1	5 612	100

Uranium industry employment at existing production centres

(Person-years)*

	2021	2022	2023
Employment directly related to uranium production	2 754	2 716	2 788

Includes permanent, temporary and expatriate employees and excludes employed contractors.

Short-term production capability

(tonnes U/yr.)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	0	7 200	7 200	0	0	7 200	7 200

2035				2040			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	0	7 200	9 800	0	0	7 200	9 800

* Report prepared by the NEA/IAEA, based on company reports and government data.

Nepal

Uranium exploration and mine development

Historical review

Since 1972, the Department of Mines and Geology (DMG) has been engaged in the exploration of uranium resources in Nepal through ground radiometric and spectrometric surveys.

A ground radiometric survey was initiated in 1972 over part of the Palung and Ipa granites of the Makawanpur and Lalitpur districts.

Systematic ground exploration for uranium in sedimentary rocks, using scintillation counters, was launched in 1981. From 1981 to 1987, radiometric surveys covered about 8 000 km² of the Siwalik Range.

In 1982, radiometric surveys were carried out in the Thumki-Jagat and Kakani-Panchmane areas, north of the Kathmandu valley. Several anomalies were identified during these reconnaissance surveys. Based on this work, a follow-up ground radiometric survey covering about 1 200 km² was carried out between the Kamala River and Narayani River from 1988 to 1990 in the Siwalik range. Uranium mineralisation was observed in the Tinbhangale area of Makawanpur district, where uranium grades of up to 0.13% U were recorded.

From 1992 to 1994, preliminary and follow-up ground radiometric exploration was carried out over part of the Baitadi, Bajhang and Darchula districts. Exploration covering an area of about 150 km² was conducted between the Mahakali River and the Jamari Gad area of the Baitadi and Darchula districts. Uranium contents of up to 0.92% U were observed in bedrock and float.

By 2011, the DMG had identified 24 uranium occurrences in Nepal, mainly within the Siwalik sandstone, and in quartzites and pegmatites/granites. A subeconomic uranium occurrence was identified at the Tinbhangale (Makawanpur) locality estimated at 35 tU.

From 2012 to 2015, uranium and thorium exploration, sponsored by a Technical Cooperation project between the DMG and the International Atomic Energy Agency, was completed in Tinbhangale area.

From 2014 to 2015, prospecting was completed in sericitic white quartzite injected with quartz veins and basic rocks in the Bangabagar-Baggoth area and ferruginous quartzite in the Gorang area of the Baitadi district.

From 2016 to 2017, U and Th exploration and radiation hazard mapping was completed in the Shivpuri gneiss zone area and nearby Kathmandu valley sediments.

An extensive radioactive anomaly was discovered in the Lomanthang area of the Upper Mustang region in 2014 as a part of a Departmental programme. From 2014 to 2017, radioactivity anomalies were prospected and identified in sandstones.

In 2018, U and Th prospecting was carried out in the Ampipal area of the Gorkha District as part of a geological mapping programme. Follow-up prospecting was carried out in 2019 and identified radioactive anomalies in nepheline syenite injected with magnetite veins.

Uranium potential in sandstones (tabular sandstone and roll-front sandstone-type)

There is potential for Nepal to host economic uranium deposits, and the most promising targets are sandstone-type deposits. However, the challenges associated with access, remoteness, environmental concerns and protected areas are significant.

Tinbhangale uranium prospect

Small and irregular uranium mineralised showings have been discovered in the upper parts of the Middle Siwalik and the basal part of the Upper Siwalik Formations in Central Nepal. Coarse-grained sandstones that may have high permeability, and the presence of reductants, are favourable for the occurrence of sandstone-type uranium deposits. The Siwalik Group was deposited from the Mid-Miocene to the Lower Pleistocene. The Group is composed of shale, claystone, mudstone, sandstone and conglomerates, mainly of fluviatile origin. Plants, as well as invertebrate and vertebrate fossils and coalified plant remains (fossil wood, lignite layers, etc.) are common. The Palung two-mica peraluminous granite complex located to the north of the mineralised areas may have represented a major uranium source for these deposits. The uranium is associated with coal material in gritty to pebbly arkosic sandstone. The mineralised sections are 1-5 m in thickness and 500 m long at the Tinbhangale locality. Uranium contents from 10-1 308 ppm (0.001-0.13% U) have been measured in chip and channel samples. Uranium minerals are tyuyamunite in the oxidised zone and uraninite and coffinite in the unoxidised zone.

From 2012-2015, geological and ground radiometric surveys for uranium and thorium in the Tinbhangale, Makwanpur district, were carried out over an area of 10 km^2. The Tinbhangale and Apdamar Khola prospects were identified. The Tinbhangale prospect occurs within the Upper Middle Siwalik sediments and has a strike length of about 1 400 m and thickness up to 5 m. The mineralisation occurs in a sandstone host rock correlating with coal seams and black carbonaceous reworked shale/siltstone fragments. The highest radioactivity intensity value was detected at the Kalopani Khola right bank with 4 200 cps (929 ppm eU) (BGS-1S). The average value was 141 ppm eU and 17 ppm eTh from 29 measurements. Heavy mineral concentrate analysis identified uraninite. The yellow wall rock staining at places in the mineralised zone could be due to the presence of tyuyamunite (carnotite). The Apdamar Khola prospect has a strike length of about 200 m with a thickness of 10 cm in a sandstone host rock.

The Tinbhangale prospect has a relatively low uranium concentration in the ridge area and a higher concentration in the river valley section, implying remobilisation during diagenesis and tectonic activity. The oxidised outer rim of the coal seams and lenses in the sandstone host rocks and the concentration pattern of radioactive mineralisation in ridge and valley sections could be regarded as evidence of small sandstone-hosted roll-front type deposits warranting further prospecting and exploration. A speculative resource of 48 tU and 6 tTh is estimated.

Lomanthang uranium prospect

The Lomanthang U prospect was discovered in 2014. From 2014 to 2017, exploration in the remote Lomangthang area, Upper Mustang region, identified an extensive area of anomalous radioactivity, possibly associated with tabular or roll-front sandstone-type deposits. The radioactivity occurs within young (8-2 Ma), poorly consolidated interbedded sandstones and siltstones that occur close to U-rich Mustang granite source rocks. The sandstones also appear to contain organic material that could act as reductants for uranium deposition. Carbonaceous siltstone with coal lenses up to 1 m thick also occur in the uppermost radioactive beds. Speculative resources of U and Th are estimated at 12 000 tU and 1 500 tTh, respectively, from the upper, intermediate and lower U beds. Further exploration is warranted.

The initial study area was geologically and radiometrically mapped over a 100 km^2 area from Kagbeni to Lomanthang. Geologically, it is a part of the Tethys sediments that unconformably overly Thakkhola graben sediments. The Tethys sediments form the basement geology of the graben fill sediments. The Paleozoic and Mesozoic sediments form the parts of the basement geology. The Thakkhola graben fill sediments consist of Late Miocene to Holocene sediments deposited on an extensional half graben. The graben sediments consist of the Tetang Formation, Thakkhola Formation, Samagaon Formation, Marpha Formation and Kaligandaki Formation from bottom to top, over a stratigraphic thickness of more than 800 m.

The radioactive beds lie within the upper parts of Thakkhola Formation, consisting of predominantly siltstone over sandstone and muddy conglomerate. The beds are more or less horizontal but at places the oxidised sandstone beds are dipping due northwest, with a dip angle of six degrees. The anomalous radioactive beds consist of black carbonaceous siltstone and mudstone at the Kimatin Khola section. A reconnaissance ground radiometric survey was carried out using both a gamma ray spectrometer and a scintillation counter. Three prospects were identified. The geological maps and sections were prepared and interpreted. The lithological and structural data were plotted and a lithological description was recorded in each location.

Prospect-1 is located to the north of the Lomanthang area. The upper bed is approximately 40 m thick. The intermediate uranium bed averages 5 m thickness. The lower bed has an average thickness of 20 m. The strike length of these beds is significant, ranging from 2-2.5 km. The upper bed has the highest concentration of 5 155 ppm eU. The lower bed has a maximum recorded value of 1 927 ppm eU. Prospect-2 is located near Sunda Chhorten, on the way to Charan from Lomanthang. Radioactivity intensity values of up to 300 cps were recorded over grey siltstone beds. Prospect-3, located near the Sangboche spur, yielded values up to 400 cps in grey siltstone and sandstone beds. Chemical analysis results are still pending.

Uranium potential related to sodium metasomatism (Na-Metasomatite Type)

Chhuling Khola uranium prospect

In 1982, a radioactivity showing (>3 000 cps) a few hundred metres above the Main Central Thrust was identified along the Chhuling Khola River. The mineralisation is represented by brannerite disseminated in an albitised rock. These features are typical of uranium deposits associated with Na metasomatism which may present large uranium resources. This prospect was under investigation by the DMG in 2023.

Ampipal U/Th prospect

The "Gorkha radioactivity occurrence" is associated with a large (~10 km by ~2 km) saprolite-weathered nepheline syenite body. Scintillometer radioactivity (>5 000 cps BGS-1SL) was discovered during a regional scale field-mapping programme conducted by the DMG. Subsequent spectrometer surveys identified up to ~475 ppm eU and up to ~730 ppm eTh at the locality. The nepheline syenite body has high background radioactivity throughout and is well foliated (schistose to gneissic). The surface of the body and edge/contact with phyllites/country rocks are associated with anomalous radioactivity and appear to be important exploration targets. A saprolite-weathered nepheline syenite body has anomalous radioactivity relative to the background. Weathered material is not competent (no longer considered rock) and it is verging on becoming soil. "Fresh" (weak to no alteration) nepheline syenite also appears to be associated with anomalous radioactivity. New road cuts and roadwork helped uncover new rocks and outcrops.

Altered nepheline syenite rock has anomalous radioactivity relative to the background. The highest radioactivity observed was in altered nepheline syenite coincident with fractures (>20 times that of "normal" syenite). If the entire radioactivity is attributed to uranium, one fractured sample would have 900-1 000 ppm eU. Radioactive fractures are magnetic and associated with iron oxides and hydroxides (magnetite ± hematite ± limonite). Near this fracturing, the nepheline syenite is altered, but still competent and un-weathered. Albite/feldspars are converted to white clays and sericite (saussuritisation). Mafic minerals ± nepheline have been converted to chlorite. This is not interpreted to represent a low-temperature alteration system and is most likely the result of hydrothermal alteration processes. Field observations suggest that either a metasomatite or granite-hosted uranium deposit model may be valid for the Gorkha radioactive occurrence.

A follow-up ground radiometric survey for U/Th prospection and REE assessment in the Ampipal area of the Gorkha district covered 25 km^2, using gamma ray spectrometry (RS-125) and scintillometry (BGS-1). The phyllite and quartzite in the lower stratigraphic level is intruded with nepheline syenite. The dip direction of the host rocks diverges away from the pluton. About 204 instrument readings show maximum U concentrations of 476 ppm eU and 1 011 ppm eTh. The Ampipal area has magnetite veins in nepheline syenite fracture zones, with recorded values up to 1 000 ppm eU. The Phalamedada area hosts a magnetite bearing body injected in the phyllite country rocks and shows concentrations up to 1 011 ppm eTh. The mean eTh concentration is 115 ppm which is representative of mainly saprolites and nepheline syenite bodies injected with magnetite veins. REE assessment shows that the area has anomalous concentration of Sr, K, Rb, Ba, Ta, Nb, Zr, Y.

Uranium potential of the Banku quartzite ("vein-type")

Uraninite and autunite mineralisation has been discovered in outcrops over the Banku quartzite in West Nepal over a strike length of 1 500 m with a thickness of 1.5-8 m. Uranium oxides occurring in millimetre thick veinlets indicate the presence of a hydrothermal system that was able to leach and concentrate uranium in the form of uranium oxide. Surface radiometry has yielded total counts of 3 500-10 000 cps (GAD 6). Outcrop sample analyses have given uranium contents of 137-9 213 ppm U (0.04-0.9% U). This area is considered as prospective for the discovery of "vein-type" uranium mineralisation associated with quartzites.

The Bangabagar-Baggoth-Gorang prospect lies within the Banku Quartzite of Lesser Himalaya metamorphics. The Banku quartzite consists of sericitic white quartzite and phyllite partings quartzite with cross cutting and parallel quartz veins and boudins. The beds are mostly dipping due northeast. The competent beds are shattered due to oblique faults. The Bangabagar Thrust separates foot wall Lesser Himalayan metasedimentary rocks like Malekhu Limestone in the study area. Spectrometer data suggests that the Bangabagar-Baggoth section has low concentration and Sarmauli section has high concentration of uranium, whereas it is reversed for Th concentration. A concentration of 1 052 ppm eU has been recorded in the Sarmauli section, and a maximum concentration of 184 ppm eTh from the Bangabagar section. The U/Th mineralised bed has a strike length of about 2 000 m and thickness up to 6.7 m. The host rock is sericitic white quartzite, with phyllite partings with Au concentrations. The chemical analysis results are pending. The Bangabagar-Baggoth prospect has a speculative resource of about 212 tU and 86 tTh. Field observation suggests that it could be a metasomatic type of deposit model.

The Gorang prospect spectrometer data suggests that the Pari Gorang, Prospect-1 section has a high concentration of uranium with a maximum of 1 482 ppm eU recorded in the ferruginous quartzite. The maximum thorium concentration is 192 ppm eTh from the Wari Gorang, Prospect-2 section. The U/Th mineralised bed has a strike length of about 200 m including both prospects and thickness of up to 5 m. The host rock is sericitic white quartzite, and ferruginous quartzite having Au concentrations. The chemical analysis results are pending. The Gorang prospect has a speculative resource of about 13 tU and 3 tTh.

Uranium potential from unconventional resources (phosphate, lignite-coal, black shale types)

The most important phosphate occurrence in Nepal has been identified in the Baitadi carbonate formation in the Lesser Himalaya of Far East Nepal, of the middle Proterozoic age (1 200 to 1 000 Ma). The phosphate-rich horizon is confined in the stromatolitic Massive Cherty Dolomite member among seven lithological members. It extends laterally over more than 25 km. Its thickness varies from a few metres to 18 m. The P_2O_5 content varies from 10 to 32 wt.%. To evaluate the economic potential of the Baitadi Formation, it would be necessary to identify the average phosphate content.

In Nepal, coal occurs in four stratigraphic horizons: Quaternary lignite of the Kathmandu valley, Siwalik coal of the Sub Himalayan/Churia Range, Eocene coal of western and mid-western Nepal, and Gondwana coal. The uranium content of these horizons is unknown. The uranium content of the lignite horizon from the Kathmandu valley may have significant uranium contents owing to the presence of uranium showings in the gneissic muscovite-tourmaline granites and pegmatites occurring to the north of Kathmandu city, with drainage directed to the Kathmandu valley. Only the Quaternary lignite of the Kathmandu valley and the Eocene coal has been mined for domestic needs. The resources from the Quaternary lignite and the Eocene are quite limited and even if they were relatively rich in uranium, their recovery will not be of economic interest. However, due to the presence of uranium-rich othogneisses surrounding the Kathmandu depression, it is likely that these lignites are significantly enriched in uranium. As they are also used for domestic needs, they may also represent an environmental concern that could be evaluated.

Black shales also occur in various parts of Nepal, but they are generally metamorphosed and deformed, and their uranium content is not known. Therefore, the probability of having significant uranium resources in this type of lithology seems to be limited given the present state of knowledge.

Radiation hazard mapping in parts of Shivpuri area

In 2016-2017, geology and ground radiometric surveys for U/Th prospecting and radiation hazard mapping were conducted over parts of Shivpuri area, in the northern part of the Kathmandu area, and this has been completed using spectrometry. The data show maximum concentrations of 33 ppm eU and 295 ppm eTh in tourmaline granite and weathered gneiss from Sanla area. The tyuyamunite (carnotitie) was identified in weathered uraninite from the temple area of Dhrmasthali and Jagat known to host pegmatite vein-type U mineralisation. The radiation hazard based on the observed dose rate was assessed.

Recent and ongoing uranium exploration and mine development activities

Nepal is currently building its capacity to explore for uranium deposits and to analyse geological samples for U and Th. The IAEA continues to support Nepal through national and interregional technical co-operation projects on uranium exploration and production (2012-2023). These projects support national capacity building for the exploration and mining of U and Th resources, with a focus on training, equipment procurement and technology transfer. Priority exploration targets include the Tinbhangale and Upper Mustang Lomanthang sandstone-type uranium occurrences. The hard rock hosts like the Banku quartzite and nepheline syenite are also considered important for exploration.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Nepal has no known uranium resources.

Undiscovered conventional resources (prognosticated and speculative resources)

Resources are roughly estimated at 48 tU at Tinbhangale in the Siwalik region. The Lomanthang prospect is speculated to contain of approximately 12 000 tU and could reach up to 100 000 tU if explored in detail. The Bangabagar and Gorang prospects could have a speculative resource of 225 tU. A speculative resource for the Ampipal uranium prospect has not been completed, but exploration models have been identified. The radiation hazard in the northern part of the Kathmandu valley is minimum. The Chhuling Khola Na-metasomatic uranium prospect warrants further work.

Unconventional resources and other materials

No unconventional resources have been identified.

Uranium production

Historical review

No uranium production has occurred.

Status of production facilities, production capability, recent and ongoing activities and other issues

No uranium production is planned.

National policies relating to uranium

The regulations of the Mines and Mineral Act, 1985, guide the exploration of all minerals in Nepal. Uranium along with rare earth elements are treated as strategic minerals and exploration activity is conducted exclusively by the DMG. The Environmental Protection Act and regulations offer specific guidance for uranium exploration. The national mineral policy applicable for the development of uranium production states that uranium exploration, production and development is the responsibility of the central government. A specific environmental policy has not been established for the nuclear fuel cycle, but the overall environmental policy is guided by the Environmental Protection Act, 2019 and regulations, 2020. Safety and social development policies have been incorporated in nuclear act and regulations. The regulatory bodies include the DMG, the Department of the Environment, and the Nuclear Material Management Division. The "Radioactive Material (Uses and Regulation), Act 2020" provides direction for interactions among the regulatory bodies and acts as a co-ordination mechanism for the regulatory process, decision making and involvement of interested parties and stakeholders in Nepal and abroad.

Niger*

Uranium exploration and mine development

Historical review

Uranium exploration began in 1956 in the Arlit area of Niger within the Tim Mersoï sedimentary basin, and uranium was first discovered in sandstone at Azelik in 1957 by the French Bureau de Recherches Géologiques et Minières (BRGM). The French Atomic Energy Commission initiated further studies of the sandstone, which were taken over by the Compagnie Générale des Matières Nucléaires (COGEMA) and resulted in the discoveries of Abokurum (1959), Madaouela (1963), Arlette, Ariege, Artois and Taza (1965), Imouraren (1966) and Akouta (1967).

The Société des Mines de l'Aïr (Somaïr) was created in 1968 and started production from the Arlette deposit in 1971 by shallow (60 m depth) open-pit mining. From 1971 to 1988, acid heap leaching was used at Arlit, producing 200-600 tU/yr, for a total of 5 900 tU over this 17-year period. The uranium recovery rate achieved was low (50% or less) and from 1988 to 2009 more than 10 Mt of low-grade ore (0.08% U average grade) had been stockpiled. In 2009, after conducting tests over several years, Somaïr restarted heap leaching using an improved process to achieve recovery rates above 85%. Since the start of operations in 1971, about 70 000 tU were produced at the Somaïr mine. In 2017, due to tough uranium market conditions, Somaïr entered a plan to reduce annual production to 1 700 tU.

The Compagnie Minière d'Akouta (Cominak) was set up in 1974 and started production from the Akouta and Akola deposits, near the town of Akokan. This is an underground operation at a depth of about 250 m. Production has now switched to the deposit of Ebba/Afasto, south of Akouta and Akola. Since the start of operations in 1978, more than 70 000 tU were produced at Cominak mine.

In 2004, COGEMA and the government of Niger signed an agreement to undertake a major exploration programme. In subsequent years, both Somaïr and Cominak were involved in exploration solely for the purpose of better evaluating previously discovered deposits. Somaïr delineated the Taza Nord deposit, while Cominak evaluated a mineralised area south-east of the Akola deposit.

Development of the large Imouraren deposit about 80 km south of Arlit was confirmed in January 2008. In 2009, Areva SA (Orano SA as of January 2018) was awarded a mining licence and a joint venture agreement was signed to develop Imouraren, but it did not proceed because of unfavourable market conditions.

In 2006, the China National Nuclear Corporation (CNNC) signed an agreement to develop the Azelik-Abokurum deposit and a new company, Société des Mines d'Azelik (Somina), was created in 2007 for this purpose. About 670 tU were produced up to 2014, when the mine was put in care and maintenance.

All uranium deposits in Niger are located within the Tim Mersoï Basin, a sub-basin of the Illemmenden Basin. The Tim Mersoï Basin is close to the main Arlit-In Azaoua fault. Uranium is mined close to the twin mining towns of Arlit and Akokan, 900 km north-east of the capital, Niamey (more than 1 200 km by road), near the southern border of the Sahara Desert and the western range of the Aïr Mountains. The concentrates are trucked to ports in Benin and the majority are exported to the Malvési conversion facility in France.

Uranium exploration in Niger was revitalised in 2007 as the price of uranium increased. Six new exploration permits were granted that year and by 2011 uranium exploration activities were being carried out on 160 concessions by foreign companies. From 2001 to 2016, 356 uranium exploration permits were registered. However, since 2011, there have been increasing geopolitical tensions in the region, resulting in foreign companies like Paladin and URU Metals ceasing exploration activities in Niger.

Following a 2006 agreement in which Areva agreed to increase royalty payments to the government by 50%, development of the Imouraren deposit, about 80 km south of Arlit and 160 km north of Agadez, was announced in January 2008. In January 2009, Areva was awarded a mining licence. The Imouraren SA mining company was established, with Areva NC Expansion (86.5% Areva, 13.5% KEPCO) holding a 66.65% interest and Sopamin of Niger holding the remaining 33.35%. Production was expected to be 5 000 tU/yr for 35 years. The deposit covers 8 km by 2.5 km. Orano reports 213 722 tU of probable reserves at 0.072% U plus 62 584 tU of indicated and 2 879 tU of inferred resources. Average depth is 110 m and maximum thickness 60 m. At full production, the project's heap leaching facility will process 20 000 tonnes of ore per day with an expected 85% rate of recovery. Excavation of the first pit started in mid-2012. In May 2014, as uranium prices were not sufficient for profitable mining of the deposit, the Nigerien government and Areva agreed to suspend development and set up a joint strategic committee that will determine when mining should start.

In 2008, GoviEx Uranium held two exploration properties of 2 300 km^2: one near the Arlit mine, including the Madaouela deposit, as well as 2 000 km^2 near Agadez. In August 2008, Cameco bought an 11% share in the company for USD 28 million, with an option to increase its share to 48%. The government of Niger has the right to hold a 10% carried interest and the option to purchase a further 30% share when the Nigerien mining company is incorporated. The GoviEx drilling programme commenced in August 2008. The work programme was based on three objectives: i) resource delineation drilling of the Marianne and Marilyn deposits; ii) exploration and resource definition drilling on the Madaouela South deposit area; and iii) exploratory drilling between the known deposits. As of February 2010, a project-wide total of 584 000 m had been drilled by GoviEx.

Global Atomic Fuels Corp. (GAFC), a private Canadian company, has six exploration permits (728.8 km^2) located in the north of Agadez, four at Tin Negouran (the "TN permits") and two at Adrar Emoles (the "AE permits"). The Adrar Emoles permit hosts the Dasa deposit, a sandstone basal-channel type deposit. From 2010 to 2014, GAFC drilled 969 holes (867 rotary drill holes and 102 diamond drill holes), for a total of >120 000 m and in January 2014 released an initial inferred resource estimate, which totalled 43 850 tU grading 0.054% U, using an 0.0085% U cut-off. In June 2014, GAFC announced internal resource estimates ranging from 64 600 tU at 0.049% U (0.0085% U cut-off), to 29 600 tU grading 0.29% U (0.127% U cut-off). The base case appeared to be 36 500 tU grading at 0.222% U (0.085% U cut-off).

URU Metals Limited reported a South African Mineral Resource Committee (SAMREC) compliant inferred resource of 1 654 tU on the In Gall deposit and in 2011 continued to drill the Aboye, Akenzigui and Fagochia targets within their Irhazer and In Gall permits. Project commitments elsewhere caused URU Metals to take steps to terminate activities in Niger by 2014.

In December 2010, Paladin completed the takeover of NGM Resources Ltd, the owner of the local company Indo Energy Ltd that held concessions in the Agadez region. NGM Resources had announced an inferred mineral resource of 4 320 tU. In early 2011, Paladin carried out a drilling programme that further defined targets for follow-up and information from the drilling was used to plan a 15 000 m drilling campaign. However, this was put on hold because of security concerns. All fieldwork has ceased, and *force majeure* was requested from the government authorities for an indefinite suspension of further expenditures.

In 2011, GazPromBank Niger Minerals SARL, a Russian company, was granted two uranium licences (Toulouk) located in the Tim Mersoï Basin. In March 2017, the company submitted a pre-feasibility study through which it declared JORC compliant inferred resources of sandstone-type tabular mineralisation with 29 630 tU at a grade of 0.016%, a roll-front type deposit containing 17 000 tU with grades varying from 0.04% to 0.06% and a surficial sandstone-type deposit containing 8 237 tU at a grade of 0.025% U.

On 20 September 2013, Pan African Minerals Ltd was granted four uranium licences (Ouricha 1 and 2 and Tegmert 1 and 2) located in the Agadez area. Pan African Minerals planned to invest at least USD 20 million in exploration activities during the next three years.

Recent and ongoing uranium exploration and mine development activities

Dasa project

In 2017-2018, Global Atomic Corporation (GAC; formerly GAFC) commenced a new drilling programme targeting various areas of the Dasa project and a total of 59 holes amounting to 26 479 m were completed. This delineated higher-grade mineralisation within 300 m of the surface. The drilling was focused on areas of faulting associated with a graben structure and results improved understanding of the distribution of mineralisation within the deposit and confidence in the geological model. This resulted in an upgraded classification of resources from inferred to indicated.

The Dasa project mineral resources were first estimated and reported by CSA Global in April 2017, then updated in June 2018 and June 2019. Mineral resources were reported in two parts; those that have potential for extraction by open pit, and the deeper, higher-grade material outside of the open pit that may be amenable to underground mining. The open-pit mineral resources are the parts of the deposit above a cut-off of 320 ppm equivalent-U_3O_8 (eU_3O_8). Higher-grade material above a cut-off grade of 1 200 ppm eU_3O_8 outside of the optimised pit shell was considered for underground mining. Some areas could also be considered for ISL.

Dasa mineral resources as at 1 June 2019

(NI 43-101 compliant)

Category	Ore (Mt)	Grade (% eU)	Uranium (t)
Indicated OP	25.59	0.145	37 118
Indicated UG	0.71	0.275	1 962
Total indicated	26.30	0.148	39 080
Inferred OP	18.93	0.115	21 771
Inferred UG	3.38	0.352	11 924
Total inferred	22.31	0.151	33 695

In May 2020, GAC completed a preliminary economic assessment (PEA) using a base case uranium price of USD 35/lb (USD 91/kgU) to mine the flank zone of the Dasa deposit. GAC planned to use conventional underground mining and proven processing technology that is currently being used at existing uranium mines in Niger, targeting an initial production of 44 Mlb U_3O_8 (16 900 tU) with an average processed grade of 0.46 %U. The PEA cash costs amounted to USD 16.72/lb U_3O_8 (USD 43.47/kgU), including corporate and all other off-site costs, and an all-in sustaining cost of USD 18.39/lb U_3O_8 (USD 47.81/kgU).

An environmental impact statement (EIS) was completed and filed with the Niger government in July 2020. The Dasa project site hydrogeology drilling and water flow test work was completed and a tender for final geotechnical diamond drilling for the feasibility study was issued. Public hearings regarding the EIS were organised, one in the Dasa project area and one in the capital city of Niamey.

In August 2020, pilot plant tests were initiated at the Ortech process research facility in Canada to confirm and optimise the processing plant flow sheet. The tests demonstrated the viability of the uranium recovery process detailed in the May 2020 PEA.

On 25 September 2020, GAC announced that it had applied for a mining permit for the Dasa project. In December 2020, a presidential decree granting the mining permit was approved by the Council of Ministers for the project. GAC also received three-year permit extensions for each of its six exploration properties in Niger. These include the Adrar Emoles 3 permit hosting the Dasa and Dajy deposits (6 540 tU), the Adrar Emoles 4 permit, hosting the Isakanan deposit (13 080 tU) and the Tin Negouran 1, 2, 3 and 4 permits, hosting the Tin Negouran deposit (3 850 tU).

In September 2021, GAC started a 15 000 m drilling programme of both in-fill and step-out drilling to increase phase 1 resources and upgrade phase 2 resources. Based on the positive results, the programme was extended in 2022 by a further 1 000 m.

A feasibility study (FS) focused solely on phase 1, primarily comprised of the Flank zone (less than 20% of the Dasa deposit total mineralisation), was completed in November 2021. The study, representing the initial 12 years and production of 17 460 tU, confirmed that the project is economically compelling at a price of USD 35/lb U_3O_8 (USD 91/kgU), and formed the basis for the Board of Director's decision to proceed with production at the Dasa project.

A new mineral resources estimate was released in May 2023. It was calculated incorporating drill, probe and chemical assay data from the 2021-2022 drill programme (16 000 m), and geotechnical data derived from drill core were incorporated into the geological model. Unlike the 2019 estimate, the new estimate focused solely on an underground mine model and excluded near-surface mineralisation that could be mined by open-pit method. On January 2023, GAC released an update of the phase 1 feasibility study based on the results of the new mineral resources estimate.

Dasa mineral resources as 12 May 2023*

Category	Ore (Mt)	Grade (% eU)	Uranium (t)
Indicated UG	10.09	0.417	42 040
Inferred UG	4.45	0.445	19 770

* Mineral resources are based on CIM Definitions. A cut-off grade of 1 480 ppm U_3O_8 (1 255 ppm U) and a bulk density of 2.36 t/m^3 have been applied. GAC intends to update the Dasa mine plan and feasibility study by the end of 2023, using the results of the new resources estimate, actual mining costs and capital costs for the processing plant.

In 2021, exploration expenditures amounted to CAD 9 453 000. Expenditures for 2022 are not available.

In addition to Dasa, two other deposits are located on the Adrar Emoles permits, Dajy and Isakanan. The Dajy deposit is located along the major northeast-southwest trending Azouza Fault that hosts the Azelik and Dasa deposits, some 30 km SE of Imouraren. Whereas Dasa can be traced to the surface, Dajy occurs at depth. Dajy uranium mineralisation is hosted in three sandstone units over a 3.5 km long and 400 m wide area. The Dajy deposit contains 6 540 tU grading 0.058 U (inferred resources). The Isakanan deposit, located 15 km south of the Dasa and Dajy deposits, hosts 13 080 tU grading 0.076% U (inferred resources). The Tin Negouran permits host the Tagadamat deposit, where mineralisation occurs within surface paleochannels along a 3-km strike, with potential for open-pit mining and heap leach processing. The Tagadamat deposit hosts 3 850 tU grading 0.015% U (inferred resources). An environmental baseline study was completed in 2009, but the project was put on hold.

Madaouela project

In March 2017, GoviEx began a drilling programme focused on expanding shallow near-surface uranium mineralisation associated with the Miriam deposit. The 4 000 m drilling programme was conducted on a 100 m grid at Madaouela to an expected average depth of approximately 100 m (40 drill holes). However, the drilling did not result in additional resources. On 15 November 2017, GoviEx was granted an exploration permit for Agaliouk, which is adjacent to the Madaouela deposit. The Agaliouk exploration permit adds 4 488 tU of mineral resources in the measured and indicated categories and 3 596 tU in the inferred category.

GoviEx developed an NI 43-101 compliant integrated development plan for five deposits (Marianne, Marilyn, Miriam, Madaouela South North East [MSNE] and Maryvonne). The plan is based on detailed pre-feasibility studies that considered metallurgical testing and processing options, mine design, infrastructure, rock mechanics, tailings and heap leach and hydrogeological and environmental impacts. As of November 2017, NI 43-101 compliant resources at Madaouela totalled 42 603 tU of measured and indicated resources and 10 647 tU of inferred resources. An open-pit mine on at least part of the deposit, followed by underground room and pillar mining with conventional processing, is expected to produce 1 030 tU/yr over 21 years, with potential for expanding the resource. Production was expected to begin by 2022. The environmental and social impact assessment for the project was filed with the Nigerien government in March 2015 and a mining licence was obtained in January 2016.

In 2018, GoviEx reviewed the ore process design of the Madaouela project and determined that the inclusion of membrane separation in the process design could potentially reduce operating and capital costs, which may in turn improve project economics. On 19 September 2018, GoviEx announced the appointment of SRK Consulting (UK) Ltd and SGS Bateman (Pty) Ltd as the consultants to complete a feasibility study for the Madaouela project.

In September 2019, Niger approved the revision to the shape of the Madaouela mining permit to include 1 550 tU in the measured and indicated categories associated with the Miriam uranium deposit as well as 6 880 tU in the measured and indicated categories associated with the Madaouela South North East deposit, both previously situated within the Agaliouk exploration permit.

In 2020, GoviEx decided to complete an updated preliminary feasibility study and announced the results in February 2021. Open-pit mining was planned to be based on standard truck and shovel operations for the Miriam deposit at a planned rate of 1 Mt per year of ore feed to the process plant. Mining operating and capital costs were updated with a high degree of confidence as they were based on the current supplier quotes to define owner-operator operating costs of USD 2.30/tonne mined. The Marianne-Marilyn and MNSE-Maryvonne deposits would be mined by underground methods. Ore mining was designed to be undertaken at a rate of approximately 1.4 Mt per year with run-of-mine (ROM) ore to be sorted by X-ray fluorescence to remove waste dilution. The sorted ore would be trucked to the process plant at a rate of 1.0 Mt per year.

On 18 February 2021, GoviEx released the results of a mineral reserves estimate. The estimate is based on the mineral resources classified as measured and indicated (as of 2 March 2016) and incorporates technical and economic studies that justify economic extraction. All mineral reserves are classified as probable in accordance with the CIM NI 43-101 code.

Open-pit mineral reserves are reported within a designed pit shell at a cut-off grade of 0.03% eU. Cut-off grades are based on a price of USD 50 /lb U_3O_8 (USD 130/kgU) and uranium recovery of 93%, without considering revenues from other metals. Underground mineral reserves for Marianne-Marilyn and MSNE-Maryvonne are reported at a cut-off grade of 0.06% eU. Cut-off grades are based on a price of USD 50 /lb U_3O_8 (USD 130/kgU) and uranium recoveries of 89.3%, without considering revenues from other metals. A 20-year project life is forecast, producing an estimated total of 19 100 tU, averaging 950 tU per annum. For the first four years of operation, the expected cash operating costs, excluding royalties and including credits for molybdenum, is USD 47.6 per kgU, with a life of mine cost of USD 57.7 per kgU.

In 2021, GoviEx carried out a diamond drilling programme over the Miriam and Marianne deposits in order to obtain samples for chemical assay to enable the modelling of molybdenum resources as well as confirming eU grades derived from downhole radiometric surveys. In addition to the diamond drilling programme, 6 holes were completed for geotechnical purposes within the proposed Miriam open-pit area, 14 short diamond holes were also completed for the civil engineering of the process plant area, and a further 5 mud rotary holes were drilled over the planned process plant area for sterilisation purposes. No significant mineralisation was found in the sterilisation holes. Total 2021 drilling amounted to 15 906 m.

On 1 July 2022, GoviEx released the results of a new uranium and molybdenum mineral resources estimate. For the open-pit resources, volumes are defined by the optimised pit shell above an eU cut-off of 0.22 kgU/t (0.022% U). The underground resources are constrained within an optimised underground mining shape constructed assuming economic extraction at a uranium price of USD 70/lb U_3O_8 (USD 182 kg/U) and a cut-off of 0.40 kgU/t (0.04% U). Molybdenum resources at the Marianne/Marilyn and Miriam deposits are estimated within the same volume as for uranium resources.

Madaouela uranium resources as of 1 July 2022

(NI 43-101 compliant)

Deposit	Classification	Ore (Mt)	Grade (%eU)	eU (t)
Marianne/Marilyn	Measured	3.00	0.150	4 458
	Indicated	14.00	0.119	16 728
	Inferred	3.10	0.096	2 949
Miriam	Measured	10.70	0.067	7 110
	Indicated	0.50	0.046	238
MSNE	Indicated	5.05	0.137	6 878
	Inferred	0.10	0.114	111
Maryvonne	Indicated	1.23	0.152	1 861
	Inferred	0.42	0.141	596
MSCE	Inferred	1.16	0.115	1 332
MSEE	Inferred	1.95	0.131	2 547
	Total measured	13.70	0.085	11 568
	Total indicated	20.78	0.124	25 705
	Total inferred	6.73	0.112	7 535

Madaouela molybdenum resources as of 1 July 2022

Deposit	Classification	Ore (Mt)	Grade (ppm Mo)	Mo (t)
Marianne/Marilyn	Indicated	1.90	486	914
	Inferred	4.90	388	1 897
Miriam	Measured	10.70	101	1 076
	Indicated	0.50	38	20
	Total measured	10.70	101	1 076
	Total indicated	2.40	393	9 34
	Total inferred	4.90	388	1 897

The mineral reserves for the Madaouela project consist of open-pit mineral reserves at Miriam, and underground mineral reserves at M&M, MSNE and Maryvonne.

Uranium reserves for Miriam open pit deposit as of 1 July 2022

Deposit	Classification	Ore (kt)	Grade (%U)	U (t)
Miriam	Proven Probable	5 344 55	0.088 0.040	4 696 22
	Total	5 399	0.087	4 718

Uranium reserves for the M&M, MSNE, Maryvonne underground deposits as of 1 July 2022

Deposit	Classification	Ore (kt)	Grade (%U)	U (t)
M&M	Proven Probable	3 149 10 602	0.106 0.081	3 353 8 629
MSNE + Maryvonne	Proven Probable	- 6 652	- 0.079	- 5 273
	Total proven	3 149	0.106	3 353
	Total probable	17 254	0.081	13 902
	Total	20 403	0.085	17 255

In November 2022, GoviEx released a feasibility study for the Miriam open-pit project, process plant and associated infrastructure. Additional work and mine modelling has been carried out on the two underground mines, updating previous pre-feasibility studies.

The Miriam open-pit operation will be a conventional drill, blast, truck and shovel operation. Pit optimisation was undertaken based on a USD 55/lb U_3O_8 price (USD 143/kgU). The pit design was divided into six stages resulting in 5.4 Mt of ROM ore at 0.87 kgU/t (0.087% U) and 123 ppm molybdenum with 50 Mt of waste, for a strip ratio of 9.3. The inventory is based on a cut-off grade of 0.28 kgU/t (0.028% U) and includes 2% dilution and 0% mining loss.

The M&M and MSNE-Maryvonne deposits are planned to be mined as two independent underground room and pillar operations. M&M is to be mined first following completion of the Miriam open-pit operation. The project also includes a series of other deposits, not included in the 2022 FS, that are anticipated to be mined by either open-pit or underground method.

In 2021 and 2022, exploration and evaluation expenditures amounted to USD 5 076 000 and USD 3 527 000, respectively.

Cominak, Somair and Arlit

In 2021-2022, Orano continued exploration and development activities in the Somaïr mines perimeters and in the Arlit concession. As a result of an increase in the level of resources and reserves and the optimisation of its production costs, Somaïr now has more than ten years of production viability.

On 31 March 2021, the Akouta mine in Niger operated by Cominak ceased production after more than 40 years of operation and 75 000 tU extracted. Remediation of the site began immediately after production ceased and is expected to last about ten years, followed by a period of environmental monitoring of at least 5 years.

In 2022, as part of optimisation studies for the Imouraren open-pit mining project, a mineral resource update was carried out with the use of a deterministic ore envelope model that is more restrictive and conservative than the probabilistic models used previously, in order to improve the robustness of the project. The work has led to a decrease in mineable mineral resources and economic reserves recognised in Orano's specifications, accompanied by an increase in the average grade of the ore and an improvement in its classification. Geological studies and work to determine the technical and environmental feasibility of mining using the ISR (in situ recovery) method are underway and aim to minimise the environmental impact of the operation and improve the economics of the deposit.

Mineral reserves (in situ) reported by Orano as of 31 December 2022*

Deposit	Classification	Ore (Kt)	Grade (%U)	U (t)
Imouraren	Proven	36 682	0.09	34 404
	Probable	174 868	0.08	136 932
Somaïr	Proven	167	0.07	110
	Probable	29 920	0.12	36 590
Total	Proven	36 849	0.094	34 514
	Probable	204 788	0.085	173 522

* Does not include mineral resources. Recovery factors: Imouraren (85%), Somaïr (86.3%).

Mineral resources (in situ) reported by Orano as of 31 December 2022*

Deposit	Classification	Ore (kt)	Grade (%U)	U (t)
Imouraren	Indicated	32 512	0.07	22 368
	Inferred	9 926	0.07	6 475
Somaïr	Indicated	18 512	0.11	21 115
	Inferred	21 807	0.14	30 311
Total	Indicated	51 024	0.085	43 483
	Inferred	31 733	0.118	36 786

* Does not include mineral reserves. Recovery factors: Imouraren (85%), Somaïr (86.3%).

Takardeit project

The Takardeit project is located about 40 km northwest of the city of Agadez.

First exploration activities in the Takardeit area were completed in 1972-1973 by COGEMA and ONAREM (Office National des resources Minières, now SOPAMIN).

In 2009-2010, NGM Resources Ltd completed 241 drill holes (9 464 m) over an area defined by geophysical studies. Inferred resources were estimated to amount to 23 Mt of ore at an average grade of 210 ppm eU_3O_8, resulting in 11 Mlbs U_3O_8 (4 230 tU).

The Takardeit project was acquired in 2011 by Paladin Energy Ltd, then by ENRG Elements in 2021. ENRG Elements acquired historical information including geological and geophysical data, surveys, drill logs and assays results.

In 2022, ENRG Elements completed an exploration programme including 5 340 m of rotary mud drilling and 160 m of diamond core drilling, in conjunction with a surface sampling programme. The drilling programme confirmed the mineralisation from surface to about 40 m depth and extending beyond the previous mineral resource estimate area.

In March 2023, ENRG Elements released the results of a new mineral resource estimate, completed according to the JORC 2012 standards. At a cut-off of 175 ppm, inferred resources amount to 31.1 Mt of ore at an average grade of 315 ppm eU_3O_8, resulting in 21.5 Mlbs U_3O_8 (8 270 tU).

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

The total recoverable identified conventional resources for Niger, as of 1 January 2023, amounted to 453 965 tU (561 133 tU in situ), compared to 468 048 tU as of the end of 2020. Recoverable reasonably assured resources (RAR) amount to 315 170 tU; inferred recoverable resources total 138 795 tU. The decrease of total recoverable resources (14 083 tU) is mainly associated with a decrease of Imouraren deposit resources, following a new resources estimate (-58 780 tU), partially offset by an increase of resources for underground mining at the Dasa deposit (+17 750 tU) and new resources associated with the Takardeit project (6 300 tU). Mining production in 2021 and 2022 amounted to 4 268 tU and is taken into consideration in the resource figures.

In the <USD 130/kgU cost category, recoverable RAR amount to 273 136 tU (87% of total RAR), and inferred recoverable resources amount to 62 818 tU (45% of total inferred resources).

All uranium deposits in Niger are sandstone-hosted, with average grades of 0.02 to 0.45% U, with 69% of total identified resources in the RAR category and 84% of these amenable to open-pit mining.

Undiscovered conventional resources (prognosticated and speculative resources)

Total speculative and prognosticated resources in Niger, as of 1 January 2023, amounted to 64 900 tU (unchanged from 2017).

Uranium production

Historical review

Uranium has been produced from sandstone deposits in Niger since 1971 by Somaïr at the Arlit mine, since 1978 by Cominak at the Akouta mine (Akouta, Akola and Ebba deposits) and since 2010 by Somina at the Azelik mine.

The Société des Mines d’Azelik SA (Somina) was established in 2007 to mine the Azelik/Teguidda deposits. Azelik was developed by the China National Nuclear Corporation (CNNC) and came into production at the end of 2010, with the aim of ramping up to 700 tU/yr. It is an open-pit and underground operation using alkaline leach. In August 2014, CNNC announced that Azelik had experienced prolonged project delays, overruns in its construction budget, and low production. In February 2015, CNNC announced that the mine would be closed and put in care and maintenance because of “tight cash flow”.

Somaïr and Cominak were licensed to the end of 2013, and in mid-December 2013, both were shut down for maintenance, pending resolution of negotiations on licence renewals. The mines resumed operation at the end of January 2014 under the terms of a government decree. In May 2014, the government and Areva signed a new five-year agreement for the two mines based on the 2006 mining law and expressing what both sides said was a balanced partnership.

In 2015, production recorded for Niger amounted to 4 116 tU, then decreased to 3 478 tU in 2016, 3 484 tU in 2017 and 2 878 tU in 2018, and increased slightly to 2 982 in 2019 and 2 991 tU in 2020.

Uranium production centre technical details

(as of 1 January 2023)

	Centre #1		Centre #2	Centre #3	Centre #4	Centre #5
Name of production centre	Arlit (Somaïr)		Azelik (Somina)	Imouraren	Madaouela (Comima)	Dasa (Somida)
Production centre classification	Existing		Care and maintenance	Planned	Planned	Committed
Date of first production	1971	2009	2010	NA	NA	2025
Deposit name(s)	Tamou, Artois, Tamgak	Low-grade stockpiles	Azelik, Teguidda, Abolorum	Imouraren	Miriam, Marianne, Marilyn, MSNE, Maryvonne	Dasa (Phase 1)
Deposit type(s)	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone
Recoverable resources (tU)	31 672	NA	9 684	145 636	11 539	17 460
Grade (%U)	0.12	0.08	0.142	0.08	0.085	0.417
Type (OP/UG/HL)	OP	OP/HL	OP/UG	OP/HL	OP/UG	UG
Size (tonnes ore/day)		1 800 kt/yr				
Acid/Alkaline	Acid	Acid	Alkaline	Acid	Acid	Acid
Type (IX/SX)	SX	SX		SX	SX	SX
Average process recovery (%)	86	Up to 85	85	85	82	95
Nominal production capacity (tU/year)	2 000	700	700	NA	950	1 400
Other remarks						

Status of production facilities, production capability, recent and ongoing activities and other issues

Production in 2021 amounted to 2 248 tU, 1 996 tU of which was produced by Somaïr at the Arlit open-pit mine and 252 tU by Cominak at the Akouta underground mine. Production in 2022 amounted to 2 020 tU, all from the Arlit mine.

On 31 March 2021, the Akouta mine in Niger operated by Cominak ceased production after more than 40 years of operation and 75 000 tU extracted.

In October 2022, a new heap leach area was commissioned at Somaïr. Heap leach allows for the processing of low-grade ore, helping to extend the life of the mine. It will account for nearly a third of Somaïr's annual capacity (500 to 700 tU/year).

In September 2023 Somaïr halted yellowcake production at the Arlit mine and brought forward plant maintenance initially planned for early 2024, due to political events that resulted in disruption of supplies of chemical products. Only mining operations continued.

On 25 September 2020, GAC submitted a mining permit application for the Dasa project and in December 2020, a presidential decree granting the mining permit was approved by the Council of Ministers. GAC has also received three-year permit extensions for each of its six exploration properties in Niger.

The excavation of a box cut for ramp access to the Dasa deposit was completed in 2022. Construction of the surface infrastructure started in 2022. Underground development of the mine started in November 2022. Dasa is fully permitted for production, with the company projecting that first uranium delivery to utilities will commence in 2025.

On 19 July 2019, GoviEx announced that it had finalised agreements with Niger that stipulate commercial terms to progress the Madaouela project. Under the terms of these agreements, a Nigerien operating company named Compagnie Minière Madaouela SA ("COMIMA") was incorporated by GoviEx, into which the Madaouela mining permit is to be transferred. GoviEx and the government of Niger own 80% and 20% shares in COMIMA, respectively.

Ownership structure of the uranium industry as of 1 January 2023

Uranium industry operations in Niger are each structured with a specific operating company established for the operation, which is jointly owned by the foreign uranium company (and any joint venture partners) and the State of Niger through the state-owned company Sopamin (Société du Patrimoine des Mines du Niger).

On 12 August 2012, the government of Niger and Global Atomic Corporation signed an agreement for the creation of the Société des Mines de DASA (SOMIDA S.A.). This new company with a share capital of two billion CFA francs is 80% owned by Global Atomic and 20% by the State of Niger.

The ownership structure of Niger's six uranium exploration and production companies are set out in the table below:

Somaïr	Cominak	Somina	Imouraren	Comima	Somida
36.6% Sopamin (Niger)	31% Sopamin (Niger)	33% Sopamin (Niger)	33.35% Sopamin (Niger)	20% Sopamin (Niger)	20% Sopamin (Niger)
63.4% Orano (France)	69% Orano (France)	37.2% CNUC (China)	66.65% Orano (France)	80% GoviEx (Canada)	80 % Global Atomic Corp (Canada)
		24.8% ZXJOY invest (China)			
		5% Trend Field Holdings SA (Hong Kong [China])			

Cominak is 69% owned by Orano Mining following the February 2021 acquisition of the 25% previously owned by the Japanese company OURD (Overseas Uranium Resources Development) and the December 2022 acquisition of the 10% previously owned by the Spanish company ENUSA (Enusa Industrias Avanzadas SA). OURD contributed 25% to the decommissioning and transition estimate when Orano bought out its share. The other remaining shareholder is SOPAMIN (Niger) with a 31% ownership share of Cominak.

Employment in the uranium industry

In 2022, Somaïr employed nearly 800 people and an equivalent number of subcontractors. It is reported that 99% of the workers are Nigerien.

At Cominak, following the closure of mining activities, part of the workforce has been kept on for remediation of the site. A plan has been rolled out dedicated to supporting employees and subcontractors affected by the closure, exceeding the requirements of the existing legal system. At the end of 2022, 87% of Cominak employees had a validated outplacement solution.

Development of new mines at Dasa and Madouela could again increase Niger uranium industry employment in the near future. At Dasa, the initial two years of underground development will be undertaken by a mining contractor, with a manpower of around 180 persons. After the initial 2 years of mine development, Global Atomic Corp plans to assume operational control of the mine. At Madaouela, it is estimated that around 800 skilled and semi-skilled jobs will be created during the life of operations with substantially more temporary positions during construction.

Future production centres

In May 2009, development of the Imouraren mine was launched with an initial investment of more than USD 1.9 billion. Once ramped-up to full capacity, production of 5 000 tU/yr for 35 years is expected. Production, originally scheduled to start mid-2015, remains delayed owing to poor market conditions. In 2023, geological studies and work to determine the technical and environmental feasibility of mining using the ISR (in situ recovery) method were underway with the aim of minimising the environmental impact of the operation and improving the economics of the deposit.

GoviEx has completed a PFS and proposed an open-pit/underground mine development for the Madaouela project, which could go into production after 2025 with a capacity to produce 950 tU/yr at the beginning and plans to reach 5 000 tU/yr when fully operational.

GAC is constructing its first mine at Dasa, targeting annual capacity of 1 400 tU/yr. In November 2021, GAC started with site infrastructure development, including road upgrades to connect the mine camp to the main highway, and new roads to the mine and mill sites. The portal area has been cleared for excavation to begin in January 2022. Underground development of the mine started in November 2022. Commercial uranium production is expected to begin in 2025.

Environmental activities and socio-cultural issues

Both mining operations at Somaïr and Cominak have maintained their ISO 14001 certification for environmental management for many years (certification is renewed every three years). Orano maintains that environmental issues, including water preservation, is fundamentally important to their operations. The mandate of the AMAN project, established in 2004, is to study the existing aquifers in the Arlit and Akokan areas to ensure an adequate supply of potable and industrial water is available and not being compromised. Ways to conserve and reduce water consumption have been implemented, and over the past 15 years, the annual consumption of water at the mines has been reduced by 35%, despite uranium production doubling at Somaïr in the past 10 years.

In April 2010, Areva (now Orano) and local authorities signed a series of protocols and procedures to implement multipartite radiological control of materials and equipment in the streets of Arlit and Akokan, including more stringent monitoring of used materials being taken from the industrial sites.

Somaïr and Cominak manage two hospitals in Arlit and Akokan with technical support centres. First created to provide medical care for the miners and their families, the centres are now largely open to the public free of charge. Imouraren also recently opened a medical centre that treats local residents for free.

As the country's largest private employer, Orano has been contributing to the improvement of living conditions in local communities. In 2010, Orano (then Areva) initiated a social policy and committed EUR 6 million per year (about USD 6.5 million) for the next five years for implementation. Mining activity has resulted in the construction of housing and a modern network of water distribution as well as contributing to the funding of public services and the construction of educational facilities (schools, libraries, lunchrooms, etc.).

In 2018, Orano invested EUR 2 million (about USD 2.2 million) in the Irhazer project to develop irrigation systems and agricultural activities in desert areas in the Agadez region. The objective of the project is to contribute to sustainable food safety against poverty.

As part of Orano's commitment to reduce its CO_2 emissions, Somaïr decided in 2022 to build an 8 MW solar power plant, expandable to 10 MW. It is scheduled to be commissioned by the end of 2024.

Studies for the remediation of the Cominak site began in 2002 with the collection of environmental data to inform the closure planning process. The remediation plans have been regularly updated over the subsequent years to include the results of additional data and technical studies, in order to fully inform the possible closure options.

A remediation plan that includes technical, social and community components has been defined in the Detailed Basic Design study to meet three major challenges:

- Technical: ensure lasting stability in terms of public health and safety, reduce as low as reasonably achievable (ALARA principle) the residual impacts as well as the surface area of land subject to use restrictions after the remediation.
- Employees: minimise the social impact of the closure of production activities and ensure fair and equitable treatment of all employees.
- Community: take into consideration and minimise the impacts of the closure on the community by ensuring a sustainable transition, adapted to the needs of the local populations and in keeping with the company's scope of responsibility.

In 2022, remediation work of the Cominak site is proceeding according to the planned schedule, with the deconstruction of the plant and part of the buildings in the industrial zone, the continuation of the reprofiling and capping tests of the tailings zone, as well as the permanent closure of the accesses to the underground mine.

At Dasa, according to the environmental and social impact assessment, the project involves the mining of uranium in an area (7 km around the project) that is sparsely inhabited with no permanent villages. Livestock grazing occurs to a limited extent within the area. The extended (15 km) area of influence includes two permanent villages located on the Agadez-Arlit road, and more extensive livelihood activities.

Uranium requirements

There are currently no uranium requirements in Niger. However, it has been reported that Niger has started consultations with the International Atomic Energy Agency and is considering the installation of two civilian nuclear reactors to meet domestic energy requirements and assist in national economic development.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

One of the main objectives of Niger's national uranium policy is to achieve a higher degree of international competitiveness in the industry. In July 2011, President Issoufou stated that he would seek a better price for the country's uranium exports to maximise their value to support economic and social development. About one-third of Niger's export revenue comes from uranium.

Each year's production is sold to joint venture partners, usually in proportion to their equity, at a set transfer price known as "prix Niger". The quantities not sold to joint venture partners, if any, are sold to trading companies at the prevailing spot prices.

Uranium prices

The price of uranium sold to joint venture partners (prix Niger) is proposed by mining companies to the Ministry of Mines, which ultimately decides on its level and duration of validity – usually equivalent to one year. This price is officially published in the *National Gazette* (*Journal Officiel de la République du Niger*) and posted on its website. In case the price determination is made during the year, it is retroactively applied to deliveries already made.

Reasonably assured conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	0	43 069	65 226	81
Open-pit mining (OP)	0	31 672	230 067	249 944	81
Total	0	31 672	273 136	315 170	81

Reasonably assured conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	0	43 069	65 226	81
Conventional from OP	0	31 672	84 431	85 296	81
Heap leaching from OP	0	0	145 636	164 648	81
Total	0	31 672	273 136	315 170	81

Reasonably assured conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	31 672	273 136	315 170
Total	0	31 672	273 136	315 170

Inferred conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	0	14 828	22 658	76
Open-pit mining (OP)	0	0	47 990	54 290	81
Unspecified	0	0	0	61 847	75
Total	0	0	62 818	138 795	77

Inferred conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	0	14 828	22 658	76
Conventional from OP	0	0	42 486	42 486	82
Heap leaching from OP	0	0	5 504	11 804	80
Unspecified	0	0	0	61 847	75
Total	0	0	62 818	138 795	77

Inferred conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	62 818	138 795
Total	0	0	62 818	138 795

Prognosticated conventional resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	13 600	13 600

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	51 300	0

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (actual)
Open-pit mining*	76 571	1 996	2 020	80 587	1 130
Underground mining*	75 541	252	0	75 793	0
Total	152 112	2 248	2 020	156 380	1 130

* Pre-2018 totals include uranium recovered by heap and in-place leaching.

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (actual)
Conventional	NA	2 248	2020	NA	NA
Heap leaching*	NA	0	0	NA	NA
Total	152 112	2 248	2 020	156 380	1 130

* A subset of open-pit and underground mining, since it is used in conjunction with them.

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (actual)
Sandstone	152 112	2 248	2 020	156 380	1 130
Total	152 112	2 248	2 020	156 380	1 130

Ownership of uranium production in 2022

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
739	36.6	0	0	1 281	63.4	0	0	2 020	100

Uranium industry employment at existing production centres

(person-years)

	2020	2021	2022
Total employment related to existing production centres	NA	NA	NA
Employment directly related to uranium production	NA	NA	NA

Mid-term production projections (tonnes U/year)

2025	2030	2035	2040	2045	2050
2 600	5 000	8 000	8 000	NA	NA

Mid-term production capability

(tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
2 000	2 000	2 600	2 600	2 000	2 000	4 000	5 500

2035				2040			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
2 000	2 000	4 000	8 000	2 000	2 000	4 000	8 000

Pakistan*

Uranium exploration and mine development

Historical review

Extensive uranium exploration has been conducted in Pakistan using techniques including surface prospecting through systematic geological and geophysical surveys. A wide variety of geologic environments have been investigated including the igneous and metamorphic rocks of northern Pakistan and the sedimentary Siwalik Group. The Siwalik Group extends across the country from Kashmir in the northeast to the Arabian Sea in the southwest. Igneous and metamorphic rocks of northern Pakistan have been evaluated including granites, graphitic metapelites and carbonatites. Extensive prospecting has been carried out over both the metapelites and granite terrain. Although a large number of radioactive anomalies have been discovered in these rocks, there has been little success in locating any significant uranium concentrations.

During routine prospecting activities some of the carbonatites have been found to be radioactive. The main source of radioactivity is the mineral pyrochlore. Preliminary analysis of one carbonatite body indicated the presence of uranium in the rock samples, which also contain rare metals, rare earths, phosphate and to a lesser degree magnetite. Geological investigations were undertaken to determine the trend and size of the radioactive zones in the carbonatite body and to evaluate its potential for exploitation as a multi-mineral prospect.

Pakistan's geographic (geologic) position is in a tectonically active collision zone where the Indo-Pakistan Plate, located to the south, is subducting under the Island Arc Assemblage along the Main Mantle Thrust, which in turn is subducting under the Eurasian Plate. This situation is of particular importance in northern Pakistan where the tectonic activity is responsible for both the very rugged terrain and the unstable geologic environment. The rugged topography makes exploration very difficult. In addition, the tectonically active conditions have left few stable areas to trap and preserve uranium deposits. The first uranium deposit in Pakistan was discovered in Sulaiman Range in 1959 in Dera Ghazi Khan district. Afterwards, small deposits have been discovered in different parts of the country.

Recent and ongoing uranium exploration and mine development activities

Uranium exploration activities are underway in continental sediments, granitic rocks of the Indian and Eurasian plates, surficial deposits (calcretes) in deserts and placers in northern Pakistan. The main areas of interest can be listed as follows:

Area	Host rock
Dera Ghazi Khan	Sandstone / shale
Pathwar	Sandstone
Bannu Basin	Sandstone
Manshhra, Chitral, etc.	Granite, sedimentary rocks, metasediments, carbonatite
Kirthar Range	Sandstone
Kohat Plateau	Sandstone, conglomerate, carbonaceous rock
Northern Areas	Placers

* Secretariat report based on Red Book 2022, information provided by the PAEC, UxC Weekly reports and the WNA website.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2023, the total identified in situ resources of Pakistan are 30 000 tU at the cost category <USD 260 /kgU.

Undiscovered conventional resources (prognosticated and speculative resources)

No prognosticated and speculative resources have been assessed.

Unconventional resources and other materials

As of 1 January 2023, the total unconventional in situ resources of Pakistan are between 1 100 and 4 400 tU at unassigned cost category.

Uranium production

Historical review

A major portion of the uranium deposits, at various locations in Sulaiman Range, have been mined out. The ore bodies discovered at Nangar Nai, Bannu Range, have been tested for mining using in situ leach (ISL) mining technology.

The uranium ore bodies outlined in Bannu Basin are hosted by poorly consolidated sandstones. Their exploitation through conventional mining methods was considered impracticable and hazardous due to bad ground conditions and the influx of large quantities of water. Alternatively, application of ISL technology was investigated, which was found to be feasible because the ore bodies are located below the water table in highly permeable sandstones. Some less favourable geologic characteristics in the area include a dipping, rather than horizontal sandstone host, and structural imperfections. Furthermore, confining shale is frequently not present below the ore bearing horizon.

Subsequently, ISL tests were conducted on several five spot patterns over a period of four years. Based on the test results, ISL parameters were established to plan for the start of semi-commercial scale operations in mid-1995. Research and development has continued at the site to fine-tune the operations with a view to improving recovery and reducing production costs.

The ISL mining technique employed both 5 and 7 spot well patterns. Ammonium bicarbonate and hydrogen peroxide were used, respectively, as the lixiviant and oxidant. They were injected at atmospheric pressure. The uranium bearing leach liquor was recovered using submersible pumps. The system operated at low pH to forestall mobilisation of calcium. The lateral excursion of the leaching fluids was controlled by maintaining a balance between injection and production. The wellfield was regularly monitored using monitor boreholes.

Status of production facilities, production capability, recent and ongoing activities and other issues

Small-scale mining is being carried out at selected sites. In 2021 and 2022, the production totalled 55 tU and 59 tU, respectively.

Ownership structure of the uranium industry

State-owned Pakistan Atomic Energy Commission (PAEC), established in 1957, is responsible for research work necessary for the promotion of peaceful uses of nuclear energy in the fields of agriculture, medicine, industry and nuclear power.

Pakistan Nuclear Regulatory Authority (PNRA) is working as an independent regulatory authority to ensure the safe operation of nuclear facilities and protect the workers, general public and environment from the harmful effects of radiation.

Production and/or use of mixed oxide fuels

Pakistan neither produces nor uses MOX fuel in its nuclear power plants.

Production and/or use of re-enriched tails

In Pakistan, there is no production or use of re-enriched tails.

Environmental activities and socio-cultural issues

Environmental issues

Regarding uranium production, environmental challenges include the protection of water reservoirs, the control of dust and contaminating gases, and the management of used resins that contain various impurities.

The main mitigation measures focus on improvement in the monitoring and design of ISL facilities, the use of appropriate scrubbers and the adequate characterisation and handling of waste.

Uranium requirements

As of 1 January 2023, the country has six PWR reactors in commercial operation: Karachi 2 (1 100 MWe), Karachi 3 (1 100 MWe), Chashma 1 (325 MWe), Chashma 2 (325 MWe), Chashma 3 (340 MWe) and Chashma 4 (340 MWe).

With a total installed capacity of 3 530 MWe (gross), nuclear power represents a 16% share in the national electricity matrix, with natural uranium requirements of approximately 560 tU per year.

In Pakistan, the expansion of the nuclear power network has been planned. In 2023, PAEC and the China National Nuclear Corporation (CNNC) signed the final contracts for the construction of a new reactor, Hualong One (1 210 MWe) at Chashma.

Supply and procurement strategy

Pakistan (PAEC) has an agreement with China (CNNC) for fuel supply for the reactors.

Identified conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Other or unspecified	0	0	0	30 000	NA
Total	0	0	0	30 000	NA

Identified conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Other or unspecified	0	0	0	30 000	NA
Total	0	0	0	30 000	NA

Identified conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Other or unspecified	0	0	0	30 000	NA
Total	0	0	0	30 000	NA

Prognosticated conventional resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	0	0

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	0	0

Historical uranium production by production method

(tonnes U in concentrate)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Unspecified	1 684	47	50	1 781	50*
Total	1 684	47	50	1 781	50*

* IAEA/NEA Secretariat estimate.

Historical uranium production by processing method

(tonnes U in concentrate)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Unspecified	1 684	47	50	1 781	50*
Total	1 684	47	50	1 781	50*

* IAEA/NEA Secretariat estimate.

Historical uranium production by deposit type

(tonnes U in concentrate)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Unspecified	1 684	47	50	1 781	50*
Total	1 684	47	50	1 781	50*

* IAEA/NEA Secretariat estimate.

Ownership of uranium production in 2022

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
59	100	0	0	0	0	0	0	59	100

Mid-term production projection

(tonnes U/year)

2025	2030	2035	2040	2045	2050
59	59	NA	NA	NA	NA

Mid-term production capability

(tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	0	59	59	0	0	59	59
2035				**2040**			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
NA	NA	NA	NA	NA	NA	NA	NA
2045				**2050**			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
NA	NA	NA	NA	NA	NA	NA	NA

Net nuclear electricity generation

	2021	2022
Nuclear electricity generated (TWh net)	15.8	22.2

Installed nuclear generating capacity to 2050

(MWe gross capacity)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
2 430	3 530	3 530	3 530	4 740	4 740	4 740	4 740	NA	NA	NA	NA	NA	NA

Annual reactor-related uranium requirements to 2050

(tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
385	560	560	560	750	750	750	750	NA	NA	NA	NA	NA	NA

Paraguay*

Uranium exploration and mine development

Historical review

Exploration for uranium in southeastern Paraguay was started in 1976 by the Anschutz Corporation (Anschutz) of Denver, Colorado, after signing of the Concession Agreement between the Government of Paraguay and Anschutz in December 1975. This agreement allowed Anschutz to explore for "all minerals, excluding oil, gas, and construction materials".

Previously, intermittent exploration had been carried out by international oil companies, with insignificant results. The region is known for its limited mining activities and production of high-grade iron ore, mineral pigments, clays, limestone, sandstone, sand and gravel by Indigenous people.

In early 1976, several reports by Anschutz consultants covered the geology of eastern Paraguay based on reconnaissance field trips made through the southern Precambrian area, the sedimentary section from north to south, and the alkalic intrusions in the north-central part of a large concession. From field examinations of various rock types and airborne radiometric data, it was concluded that the Anschutz Concession contained areas with good potential for uranium mineralisation. The regional correlation of stratigraphic horizons favourable for uranium mineralisation was shown in that report.

The initial uranium exploration by Anschutz in 1976 covered an exclusive exploration concession covering some 162 700 km^2, virtually the whole eastern half of Paraguay. This included geological mapping, water sampling, soil sampling and a broad reconnaissance track etch programme, with stations spaced 10 km apart. The station spacing for the track etch survey was subsequently reduced to 5 km in the southern part of the concession. The reconnaissance programme outlined large anomalous zones and Anschutz concluded that the concession in Paraguay constituted a new uranium province in an area underlain by granitic rocks and sandstones.

The initial reconnaissance programme by Anschutz was followed by a programme of airborne radiometric and magnetic surveys, a detailed track etch survey, with station spacing of 100 m to 200 m, geochemical stream sediment and soil sampling, and diamond drilling and rotary drilling over selected target areas. In total, some 75 000 m of drilling was completed from 1976 to 1983. Flight line spacing for the airborne radiometric survey was 5 km with a clearance of 100 m above the surface.

Anschutz carried out exploration on behalf of a Joint Venture with Korea Electric Power Corporation (Kepco) and Taiwan Power Company (Taiwan Power). Exploration works intersected uranium mineralisation in drill holes ranging from 0.017% eU (equivalent U) to 0.17% eU associated with layers of sub-horizontal sandstones, and higher-grade intersections ranging from 0.1% eU over 10.2 m to 0.3% eU over 0.3 m in sandstones and siltstones. Work was suspended in 1983 due to low uranium prices.

* Report prepared by the NEA/IAEA, based on previous Red Books, UNECE documents and company reports.

Since 2011-2012, the companies that have been working on uranium projects in Paraguay are Uranium Energy Corporation (UEC), through its Paraguayan subsidiaries Transandes Paraguay S.A. and Piedra Rica Mining S.A., and UrAmerica Limited (UrAmerica), through joint ventures with Ita Pora Mining S.A. and Minera Mbujapeju S.A.

In September 2015, UEC requested a 2-year suspension of activities due to low uranium prices. Because of this and other administration issues there was no exploration activity until 2019.

Historic exploration expenditures by the Anschutz/Taiwan Power/Korea Electric Power joint venture and by Cue Resources, plus more recent exploration by UEC totalled approximately USD 50 million.

Resulting from this work, all known uranium occurrences in Paraguay are found in the eastern part of the country, and most are situated in the sandstones in the western flank of the Parana Basin. The age of most major sandstone uranium deposits ranges from Paleozoic to Mesozoic.

Within southeastern Paraguay there is one uranium deposit close to the town of Yuty, and drilling indicates elongated, uranium bearing roll fronts. At least one other area with good potential for becoming a new uranium district is presently under investigation to the east and north of the city of Coronel Oviedo. Additional uranium potential in eastern Paraguay is also likely to exist in Upper Permian sandstone near the town of Curuguaty and within Silurian sandstone sequences east of the village of Eusebio Ayala.

Recent and ongoing uranium exploration and mining development activities

In the 2019-2021 period, exploration activities have been focused on the Coronel Oviedo area. Several radon emmanometry surveys and drilling exploration totalling approximately 1 000 m have been carried out. Total expenditures for the period are estimated at USD 750 000. No activities have been reported in the 2022-2023 period.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

In 2011, about 4 290 in situ tU of Canadian Securities Administrators (CSA) National Instrument 43-101 identified conventional resources have been reported from the Yuty Project by UEC, and these were comprised of reasonably assured resources of 3 430 tU at a grade of 0.044% U, and inferred resources of 860 tU at a grade of 0.04% U. In 2022, as a US domestic and domiciled company, UEC reported all mineral resources in accordance with Item 1302 of Regulation S-K ("S-K 1300").

The resource estimate is based on the development of a three dimensional geologic and resource model, using mainly the results of 256 drill holes totalling 31 000 metres of core and rotary drilling carried out between 2007 and 2011. Additionally, some 75 000 metres of drilling had been completed from 1976 to 1983.

Pumping testing indicates that the uranium bearing unit has aquifer characteristics that would support operational rates for ISL mining and that the aquifer properties determined from the test fall within the range of values determined at other uranium ISL projects located in the United States. Metallurgical test work indicates that a satisfactory rate of extraction can be obtained using a sulphuric acid lixiviant.

Adjacent to Yuty, UrAmerica owns the Parana Basin Project, which covers an extensive area of uranium mineralisation potential with several detected uranium anomalies and an inferred resource of 770 tU. This estimate is based on extensive regional exploration work and reconnaissance scale drilling by UrAmerica's predecessor, Wildhorse Explorations S.A., the Paraguayan branch of Wildhorse Energy Ltd.

Updated in situ uranium identified resources for the country total 5 060 tU at the production cost category <USD 130/kg.

Undiscovered conventional resources (prognosticated and speculative)

UEC has reported an NI 43-101 exploration target at Coronel Oviedo ranging from 8 900 to 21 500 tU at grades between 0.034 and 0.044% U, which can be categorised as prognosticated resources.

Estimates are based on a 10 000 metre drilling programme completed by UEC in 2012. A total of 35 holes were drilled, averaging 290 metres in depth.

Aquifer testing to date indicates that the uranium bearing unit has aquifer characteristics that would support operational rates for ISL mining and that the aquifer properties determined from the test fall within the range of values determined at other uranium ISL projects located in Wyoming, Texas and Nebraska. Determination of amenability to acid and alkaline leaching is still pending.

Uranium production

There has been no past production of uranium.

Uranium exploration and development expenditures and drilling effort – domestic

(USD)

	2020**	2021**	2022**	2023** (expected)
Private* exploration expenditures	250 000	250 000	0	0
Total expenditures	250 000	250 000	0	0
Private* exploration drilling (m)	330	330	0	0
Total drilling (m)	330	330	0	0

* Non-government.

** Average estimated figures have been considered.

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)*
In situ leaching acid	0	0	3 430	3 430	86
Total	0	0	3 430	3 430	86

* Based on column leaching test (NI 43-101 report).

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)*
In situ leaching acid	0	0	3 430	3 430	86
Total	0	0	3 430	3 430	86

* Based on column leaching test (NI 43-101 report).

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	3 430	3 430
Total	0	0	3 430	3 430

Inferred conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)*
In situ leaching acid	0	0	1 630	1 630	86
Total	0	0	1 630	1 630	86

* Based on column leaching test (NI 43-101 report).

Inferred conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)*
In situ leaching acid	0	0	1 630	1 630	86
Total	0	0	1 630	1 630	86

* Based on column leaching test (NI 43-101 report).

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	1 630	1 630
Total	0	0	1 630	1 630

Prognosticated conventional resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	8 900-21 500	8 900-21 500

Peru

Uranium exploration and mining development

Historical review

Macusani has been the most important uranium district, with uraniferous mineralisation found in acid volcanic Mio-Pliocene rocks in the Department of Puno in southeastern Peru.

Historically, original radiometric prospecting revealed over 40 uraniferous areas; the most important of them are Chapi, Chilcuno-VI, Pinocho, Cerro Concharrumio and Cerro Calvario, which are hosted almost entirely in the Macusani Formation.

Background (whole rock) uranium contents of the younger lava flows average 28 ppm U (0.003% U) and attain 120 ppm U (0.012% U) and 270 ppm U (0.027% U) in coeval hypabyssal intrusions and residual glasses (obsidian), respectively.

Considering all the surveyed areas, Chapi was selected as the most important site and detailed radiometry, trenching and gallery work, as well as diamond drilling, were carried out. The mineralisation is in sub-vertical fractures distributed in structural lineaments from 15 m to 150 m in width and 20 m to 30 m in thickness. Grades vary between 0.03% U and 0.75% U, with an average of 0.1% U. Therefore, based on the available geological and exploration results, a minimum potential of 10 000 tU was assigned to the Chapi site and 30 000 tU to the whole Macusani uraniferous district.

Since 2003, private companies restarted exploration in both the Macusani district and the Santa Lucia-Rio Blanco and Pampacolca areas (250 km from Macusani near Arequipa, in the south of Peru), which are also located in a Tertiary volcanic environment. In addition, the Peruvian Nuclear Energy Institute (IPEN), through its promotional activities, proposed highlighting new areas of interest such as the San Ramón Oxapampa and Corongo areas in the central region of the country, where some work had been conducted to identify potential uraniferous regions.

Several companies have focused on Macusani in an effort to further develop uranium resources through drilling different prospects in the district.

Between 2010 and 2013, resource estimates by mining exploration companies for different complexes of the Macusani district were reported.

As the uranium potential in other parts of Peru is considered significant, IPEN proposed to highlight other areas of potential interest. In 2012, IPEN subsequently discovered new uranium occurrences in the San Ramón Oxapampa region, where initial results had demonstrated significant uranium potential.

In 2015, Plateau Uranium Inc. reported an NI 43-101 compliant resource estimate for the Kihitian, Isivilla and Corani uranium complexes in the Puno district.

In 2016, an NI 43-103 preliminary economic assessment (PEA) of the Macusani project was prepared for Plateau Energy Metals (formerly Plateau Uranium Inc.). The PEA base case assessed the potential mining and processing of 109 Mt of ore with an average grade of 245 ppm U (0.0245% U) to be mined over 10 years at 10.9 Mt/a, resulting in average annual production of 2 340 tU, at a forecast production cost of USD 38/kg U.

In 2018, it was published that the properties controlled by Plateau Uranium Inc. in the Macusani district, southern Peru, contained mineral resources of 19 970 tU at 210 ppm U (0.0210% U) of measured and indicated resources and 27 740 tU at 212 ppm U (0.0212% U) of inferred resources.

Summing up the private interests, there have been several mining companies that have explored for uranium in the Puno, Arequipa and Junín regions, including Peruvian companies Minera Milpo and Macusani Yellowcake, Canadian companies Vena Resources, Cardero Resources, Solex Resources, Frontier Pacific Mining, Wealth Minerals, Strathmore Minerals and Plateau Energy Metals, and Australian companies Range Resources, Contact Uranium and Alara Uranium.

Recent and ongoing uranium exploration and mining development activities

The Macusani district continues to be the focus of uranium exploration activities in Peru. Uraniferous mineralisation in Macusani is hosted by young rhyolites of Upper Miocene age (8-6 Ma), where there are more than 70 radiometric anomalies depicted to date on the Macusani plateau, of which around 20 have been drilled.

In 2021, American Lithium Corp. acquired Plateau Energy Metals and its projects in the Macusani district that total about 93 000 hectares. Additionally, American Lithium acquired mining concessions that cover another 14 243 hectares in Puno. In addition to the uranium deposits from this acquisition, American Lithium subsequently discovered three new anomalies with grab samples that returned an average uranium content of 18 270 ppm U (1.8% U).

Also in 2021, the Canadian company Sulliden Mining Capital Inc., acquired 22 600 hectares of concessions in Puno, a region that hosts interesting uranium deposits.

Based on positive results from prospecting, mapping and sampling, American Lithium announced updated drilling plans (12 000 m; 70 holes) for the Macusani project to expand existing uranium resources and identify new deposits. The permitting process has been initiated, including development of an environmental impact assessment and community access agreements. Drilling is expected to start once an exploration permit is granted.

Azincourt Energy Corp. (Canada) reported interest in intensifying exploration activities at the Escalera Group uranium-lithium project located on the Picotani Plateau in southeastern Peru. The Escalera Group consists of three concessions (Lituania, Condorlit, Escalera) acquired by the company in 2020, covering a combined area of 7 400 hectares of prospective exploration targets for volcanic-hosted supergene/surficial uranium and lithium. Surface rock samples obtained in 2017-2018 from the Escalera project returned values of up to 3 560 ppm U (0.36% U) and 153 ppm Li, while historical samples have yielded values up to 6 812 ppm U (0.68% U).

Fission 3.0 Corp. (Canada) holds the rights to 9 claim blocks encompassing 5 100 ha, and surface rights over some of the areas with known uranium mineralisation. In 2016, the potential of these properties was demonstrated by a drilling programme that resulted in 13 of 16 holes striking mineralisation, with high-grade uranium values of up to 12 151 ppm U (1.2% U) over 0.5 m only 16 m from surface, and lithium of up to 533 ppm over 0.5 m.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

According to the NI 43-101 report originally prepared for Plateau Energy Metals, the identified conventional resources of the Macusani district total approximately 47 710 in situ tU, comprised of 19 970 tU reasonably assured resources and 27 740 tU inferred resources. Since 2021 the Macusani project has been under the control of American Lithium.

Identified conventional resources of Macusani district

(in situ tonnes U)

Prospect	RAR	IR	Total
Corachapi	1 930	730	2 660
Chilcuno	7 610	9 120	16 730
Quebrada Blanca	1 540	3 620	5 160
Tantamaco	1 410	6 150	7 560
Isivilla	1 350	2 180	3 530
Colibri II-III	5 650	1 580	7 230
Nuevo Corani	480	680	1 160
Tuturumani	0	480	480
Calvario I-Real	0	550	550
Puncopata	0	1 280	1 280
Tupurumani	0	1 370	1 370
Total	19 970	27 740	47 710

Undiscovered conventional resources (prognosticated and speculative resources)

Prognosticated conventional resources account for approximately 19 780 tU and occur in the following sectors of Macusani: Kihitian (10 440 tU), Tupurumani (5 600 tU), Corachapi (1 910 tU), Isivilla (1 330 tU) and Corani (500 tU).

In addition, there are some 45 360 tU of speculative resources, according to the information by private companies involved in uranium exploration projects in the Macusani district, notably American Lithium and Fission 3.0. As a result, speculative resource values have been updated from the amounts reported in Red Book 2018.

Unconventional resources and other materials

Unconventional/low-grade resources account for a minimum of 41 600 tU, which includes phosphates, granites and hydrothermal deposits. Only uranium resources related to phosphate have been estimated with a moderate degree of confidence.

Unconventional /low-grade resources

(in situ tonnes U)

Permo-triasic granites*	20 000 tU
Bayóvar phosphates**	16 000 tU
Thirty-nine locations***	5 600 tU
Total	41 600 tU

* Granites with radioactive anomalies and uranium occurrences located in the departments of Junín and Pasco, average 50-80 ppm U (0.005-0.008% U).

** Currently, only exploited rock phosphate concentrate; the evaluated content is 46 ppm U (0.005%U).

*** Others in the rest of the country, uranium deposits associated with hydrothermal deposits (Cu Pb-Ni-W).

In 2010, the Vale company (formerly Vale do Rio Doce) of Brazil started exploitation of the Bayóvar phosphate deposit through its local subsidiary, Miski Mayo SRL. Before the start of the operation, the company planned for the possibility of uranium recovery during phosphate production, but these plans have not yet been implemented.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Mining activities, formerly conducted by the government, entered a privatisation process in 1992 with the application of the Mining Investment Promotion Law. This legislation aims to provide stability and a guaranteed framework for long-term investments in mining, including uranium. In recent years, the reactivation of interest in uranium exploration has resulted in several foreign private companies conducting exploration and evaluation programmes.

The Peruvian state, by promoting investment in uranium mining, plans to evaluate the potential for uranium in the entire country.

The Law 28 028 regulates the use of ionising radiation sources (2003), while the nuclear regulatory body is the Peruvian Nuclear Energy Institute (IPEN).

Complementary regulations issued by IPEN are:

- Regulation of Radiological Safety (1997), based on IAEA International Basic Safety Standard No. 115;
- Regulation of Physical Protection for Nuclear Facilities and Materials (2002);
- Regulation of Law 28 028 (2008), which refers to the authorisations for different nuclear and radiological practices.

Peru does not yet have any specific regulations for uranium mining, but IPEN is working with the support of the IAEA on the development of a regulatory framework for this purpose. Under this initiative, mandatory technical standards and regulatory guides to inform applicants are being prepared.

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Open-pit mining (OP)	0	19 970	19 970	19 970
Total	0	19 970	19 970	19 970

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Heap leaching* from OP	0	19 970	19 970	19 970
Total	0	19 970	19 970	19 970

* A subset of open-pit and underground mining, since it is used in conjunction with them.

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Volcanic-related	0	19 970	19 970	19 970
Total	0	19 970	19 970	19 970

Inferred conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Open-pit mining (OP)	0	27 740	27 740	27 740
Total	0	27 740	27 740	27 740

Inferred conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Heap leaching* from OP	0	27 740	27 740	27 740
Total	0	27 740	27 740	27 740

* A subset of open-pit and underground mining, since it is used in conjunction with them.

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Volcanic-related	0	27 740	27 740	27 740
Total	0	27 740	27 740	27 740

Prognosticated conventional resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
6 610	19 780	19 780

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
45 360	45 360	0

Poland

Uranium exploration and mine development

Historical review

Prospecting for uranium in Poland began in 1948. An industrial plant in Kowary (Lower-Silesian Voivodeship) was established for the exploitation and processing of uranium from local deposits.

Research beginning in 1956 by the Polish Geological Institute involved the exploration of Carboniferous formations of the Upper Silesian Coal Basin, phosphorite formations and research in boreholes in the Polish Lowlands. As a result of this research, signs of uranium mineralisation were discovered in lower Ordovician formations of the Podlasie Depression (the "Rajsk" deposit) and in Triassic formations of the Perybaltic Syneclize and the Sudetes (Okrzeszyn, Grzmiąca, Wambierzyce).

In the Ladek and Snieznik Klodzki metamorphic formations, small occurrences of uranium mineralisation were discovered, including the Kopaliny-Kletno deposit. Approximately 20 tU was extracted from the Kopaliny-Kletno deposit.

In 2014, Poland completed geological and technological analyses and modelling of a process for uranium extraction from low-grade Ordovician Dictyonema shale (black shale-type). Analysis has shown that the costs of obtaining raw material required to produce 1 kg of uranium would be several times higher than the uranium market price at that time. In addition, resources of uranium in waste heaps from prospecting and extractive operations in the Sudety Mountains in the years 1948-1967 are estimated at 10 to 30 tU. Since 2015, geological exploration of uranium ore has not been conducted in Poland.

Recent and ongoing uranium exploration and mine development activities

There are no uranium deposits documented in Poland. However, there are some prospective indications of uranium and small prospects amenable for discovery of uranium that could potentially be economically exploited.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

The data presented in the table below summarises information from historic geological documentation that does not fulfil current requirements for resource reporting and the potential for mining under current economic conditions. Reinterpretation of geological data in 2009-2010 showed that Poland has no identified conventional uranium resources that could be classified according to the Red Book standards. Modelling of uranium extraction by underground mining from the Rajsk deposit related to the low-grade Ordovician Dictyonema shales (black shale-type) showed that the costs of obtaining raw material to produce 1 kg of uranium would be above USD 260 kgU. A comparison of these costs with market prices from the last 30 years implies that the extraction of uranium from those rocks will remain uneconomic for the foreseeable future.

Identified conventional resources*

(in situ tonnes U)

Region	Resources (tU)	Uranium content (% U)
Rajsk deposit (Podlasie Depression)	5 320	0.025
Okrzeszyn (Sudetes)	938	0.05-0.11
Grzmiąca (Sudetes)	792	0.05
Wambierzyce (Sudetes)	218	0.0236

* Note: These data represent historical geological resources that were reinterpreted in 2009-2010 and under present-day market conditions are subeconomic.

Undiscovered conventional resources (prognosticated and speculative resources)

Historical research also led to the identification of 20 000 tU of speculative resources. However, as with the identification of uranium occurrences noted above, the speculative resource estimate requires modern methods to confirm results.

Speculative conventional resources

(in situ tonnes U)

Region	Resources for depth to 1 000 m
Perybaltic Syneclise	20 000

Uranium production

Historical review

In 1948, a government-operated industrial plant was established in Kowary (Lower Silesia) to process ore mined from local uranium deposits. Exploitation of vein deposits in the Karkonosze-Izera Block and metamorphic deposits in the Ladek and Snieznik Klodzki Blocks continued until 1967. Total production amounted to 541.8 tU from deposits as presented below.

Exploitation of vein deposits in the Karkonosze-Izera Block (Wolnosc, Miedzianka, Podgorze, Rubezal, Mniszkow, Wiktoria, Majewo, Wolowa Gora, Radoniów, Wojcieszyce) and of metamorphic deposits in the Ladek and Snieznik Klodzki Blocks (where some small uranium occurrences and the Kopaliny-Kletno deposit were discovered) took place until 1967, at which time the deposits were almost completely depleted. In the Ladek and Snieznik Klodzki metamorphic rocks, a few occurrences of uranium mineralisation and the “Kopaliny-Kletno” deposit were discovered, from which approximately 20 tU was extracted.

During this period, all uranium produced was exported to the former Soviet Union. It is estimated that between 1948 and 1967 approximately 650 tU was mined in the Sudetes (southwest Poland). Chemical treatment of low-grade ores started in Kowary in 1969 and continued until 1972, producing a significant volume of waste that was left in a tailings pond.

Historical uranium production from selected deposits

(tonnes U)

Deposit name*	Initial resources**	Produced***
Wolnosc	94.0	94.0
Miedzianka	14.7	14.7
Podgorze	280.0	199.0
Rubezal	0.5	0.5
Mniszkow	4.5	4.5
Wiktoria	0.3	0.3
Wolowa Gora	2.5	2.5
Radoniów	345.0	214.0
Wojcieszyce	14.4	12.3
Total	755.9	541.8

* These are a subset of vein deposits from a larger group of deposits listed below.

** Resources not specified as either recoverable or in situ.

*** Production not specified, but assumed to be from concentrates.

Status of production capability and recent and ongoing activities

Currently, no licences for uranium production have been granted in Poland.

Secondary sources of uranium

There is no production of or demand for mixed-oxide fuel, re-enriched tails and reprocessed uranium in Poland.

Environmental activities and socio-cultural issues

All exploitation activities associated with uranium mining and processing in Poland were performed between 1948 and 1976. Although the companies associated with this activity no longer exist, there remains a need to remediate the environment in the area around the sites where the mines operated. The Geological and Mining Law stipulates that the State Treasury is accountable for liabilities from all past uranium production activities in Poland. Therefore, the government is responsible for funding the remediation, using either the national or the district Environmental Protection Fund.

The regional authorities of the voivodship (local administration area) and its special inspectorates or officers are responsible for different aspects of the remediation. The local authorities approve remediation plans and supervise their execution and impacts. The inspectorates of the Environmental Protection of a particular voivodship are responsible, in general, for environmental monitoring. Radiological monitoring is considered a part of this overall monitoring effort and it is being performed under the responsibility of the President of the National Atomic Energy Agency.

Since 1996, Poland has taken part in the PHARE Multi-country Environmental Sector Programme on “Remediation Concepts for the Uranium Mining Operations in Central and Eastern European Countries” (CEEC). In the framework of this programme, an inventory and a common database for the CEEC have been created. According to this inventory, the situation in Poland is characterised by a large number of small-scale liabilities from uranium exploration, localised over several places in the country and generally causing minor environmental impacts.

Only a limited number of issues related to mining and milling are considered to be causing serious impacts, with the most important being the tailings pond in Kowary. The 1.3 ha hydrological construction is closed on three sides by a dam that has been modified a number of times in the past. The dam itself is 300 m long (the sum of three sides) and has a maximum height of 12 m. As a result of uranium processing activities, the tailings pond has been filled with about 250 000 tonnes of fine-grained gneisses and schists with average uranium content of 30 ppm (0.003% U). In the early 1970s, the Wroclaw University of Technology (WUT) received, by governmental decision, the ownership of both the area and the facilities of the former uranium mining company. Subsequently, a company owned by the WUT has continued to use the existing chemical plant for various experimental processes on rare earth metals, chemical production and galvanic processes. As a result, about 300 tonnes of remnants of rare earth metal processing and 5 000 m^3 of post-galvanic fluids, with up to 30 tonnes of solids with a high content of aluminium, nickel, zinc and sodium sulphates, have been deposited in the pond.

The remediation programme of the tailings pond was prepared in 1997 by the WUT and successfully carried out under the PHARE programme until 2003. The specific objectives of this programme are related to the construction of drainage systems, the design and construction of the tailings pond cover and the final site reclamation.

Three abandoned uranium mines in the Sudetes Mountains of southwest Poland have been successfully adapted for use as tourist attractions and for educational purposes.

The National Atomic Energy Agency conducts regular monitoring of radiation. The monitoring covers the area degraded by extraction and processing of uranium ore in the Lower Silesia region. The monitoring programme consists of the following measurements:

- Total alpha and beta radioactivity in surface waters and groundwater.

  The water is sampled from the natural outflow of the former uranium mine workings, including surface watercourses and reservoirs, dug wells and natural springs discharge (a total of 30 sampling points).

- Total alpha and beta radioactivity in drinking water.

  The water is sampled from the surface and underground public drinking water intakes (a total of 37 sampling points).

- The level of gamma radiation on the surface.

  The measurements of gamma dose rate in the area of former mine workings: drifts, shafts, dumps and in their immediate surroundings (a total of 62 objects).

- Radon concentration in the atmosphere.

  The instantaneous radon Rn-222 concentration measurements (radon emanation) in the atmosphere in the open mine workings such as shafts and tunnels (a total of 22 objects).

- Radon concentration in water.

  The water is sampled from public drinking water intakes, natural outflow from former mine workings, springs and dug wells (a total of 58 objects).

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

In 2014, the Polish government introduced nuclear into the energy mix and the Council of Ministers adopted the Polish Nuclear Energy Programme. One of the topics covered is the potential mining of domestic uranium resources.

In 2020, the Council of Ministers approved an update of the Polish Nuclear Energy Programme. It reaffirmed the strategic plan of introducing the first nuclear power reactor with a capacity of 1.0 to 1.5 GWe by 2033 and five subsequent blocks, one every 2-3 years. As a result, it is expected that six reactors with a combined capacity of 6-9 GWe will be built in Poland. In terms of the institutional framework, there has been a substantial change as the Ministry of Energy was dissolved and its policymaking competences have been transferred to the newly created Ministry of Climate, which is now in charge of both energy and climate protection policies.

In 2022, the Polish government selected Westinghouse as a technology supplier for the construction of the first nuclear power plant in Poland.

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Open-pit mining	0	0	0	0	0
Underground mining	650	0	0	650	0
In situ leaching	0	0	0	0	0
Co-product/by-product	0	0	0	0	0
Total	650	0	0	650	0

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Granite-related	435	0	0	435	0
Metamorphite	215	0	0	215	0
Total	650	0	0	650	0

Installed nuclear generating capacity to 2050

(MWe net)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
0	0	0	0	0	0	1 000	3 000	3 000	9 000	6 000	12 000	9 000	15 000

Annual reactor-related uranium requirements to 2050 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
0	0	0	0	0	0	160	480	480	1 440	1 080	1 920	1 440	2 400

Portugal

Uranium exploration and mine development

Historical review

There has been no exploration and exploitation of uranium in Portugal since 2001, although unexploited uranium deposits exist in the southern part of the country.

In 2001, the Portuguese government launched the decree-law nº 198A/2001, which granted the state-owned mining company EDM - Empresa de Desenvolvimento Mineiro, S.A. (EDM) the concession for environmental rehabilitation of all abandoned and legacy mines (uranium and polymetallic). Since then, activities undertaken by EDM have prioritised safety and the environmental rehabilitation and remediation of legacy uranium mining sites.

Recent and ongoing uranium exploration and mine development activities

There has been no activity in the country or elsewhere.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

As previously reported (since the 2007 edition of the Red Book), Portugal hosts an estimated 4 500 tU of reasonably assured resources at a production cost of <USD 80/kgU and 6 000 tU of reasonably assured resources in situ at a production cost of <USD 130/kgU. Additionally, 1 000 tU are reported as in situ inferred resources at a production cost of <USD 130/kgU. No processing or mining loss recovery factors have been applied to the resource categories.

Undiscovered conventional resources (prognosticated and speculative resources)

As previously reported (since the 2007 edition of the Red Book), undiscovered conventional resources are estimated to include 1 500 tU of prognosticated resources. Speculative resources are not reported because only one outdated appraisal is available.

Uranium production

Historical review

Portugal's granite-related uranium deposits, located in the north-central area of the country, have been exploited from the beginning of the 20th century to 2001. Most of the uranium concentrates produced were exported.

In 1950-1951, a uranium mill facility processing 50 000 t/yr was built at Urgeiriça, and underground extraction continued until 1973, followed by in-place leaching from 1970 to 1991. The mine reached a depth of about 500 m and 1 600 m in length.

Between 1951 and 1962, Companhia Portuguesa de Radio (CPR) produced a total of 1 123 tU from 22 concessions, of which 1 058 tU were milled at the Urgeiriça plant and 65 tU at other mines by heap leaching. A low-grade concentrate was obtained by precipitation using magnesium oxide.

During the period 1962 to 1977, Junta de Energia Nuclear (JEN) took over the mining and milling activities from CPR, introducing organic solvent extraction in 1967 and expanding ore treatment capacity to 100 000 t/y to produce a rich ammonium uranate concentrate. In July 1985, a new capacity expansion to 200 000 t/yr was implemented. In total, 825 tU was produced under JEN management from the Urgeiriça plant and the pilot plant at Senhora das Fontes. Between 1977 and 2001, Empresa Nacional de Uranio, SA (ENU) produced 1 772 tU.

Of the total historical concentrate production, 25% came from the Urgeiriça mine. The Urgeiriça mill stopped conventional ore processing in 1999 and was decommissioned in March 2001. In this interim period, only charged ion-exchange resins from heap and in-place leaching plants, located in the Bica and Quinta do Bispo mines, were processed at the Urgeiriça plant for yellowcake production. Nationally, 57 ore bodies have been mined, 29 by underground methods, 24 by open pit, and 4 by mixed underground/open-pit methods. In 18 of these mines, local ore treatment was used, but only at Urgeiriça were uranium concentrates produced at an industrial scale. Two pilot treatment plants (Forte Velho and Senhora das Fontes) produced limited amounts of concentrates (sodium uranate).

Ownership of the Urgeiriça mill plant evolved over its operational history and after CPR concluded the agreement with the Portuguese government in 1962, JEN took over until 1977 when ENU, a publicly owned enterprise, acquired exclusive rights to uranium concentrate production and sales. In 1978, JEN exploration teams joined the Direcçao-Geral de Geologia e Minas. In 1992, ENU was integrated into the Portuguese state-owned mining company EDM. In March 2001, EDM decided to liquidate ENU by the end of 2004.

Status of production facilities, production capability, recent and ongoing activities, and other issues

Rehabilitation and remediation (environment and safety) are the only activities currently being developed by EDM.

Future production centres

No future production centres are planned.

Environmental activities and socio-cultural issues

EDM was granted the concession by the Portuguese government to deal with mining legacy sites, including remediation work at several uranium legacy sites. This work on legacy uranium and radium mine sites required expenditures of more than EUR 89.1 million (USD 95.6 million) between 2001 and 2022. As of 2022, from the 62 identified uranium mining and milling sites 45 have been remediated, including Urgeiriça, Bica, Cunha Baixa, Rosmaneira, Mondego Sul, Vale da Abrutiga, Barroco, Freixiosa, Prado Velho, Castelejo, Mortórios, Ribeira do Bôco, Canto do Lagar and Quinta do Bispo (1^{st} phase). In 2023, remediation work continued at 7 sites, comprising Picoto, Ferreiros, Reboleiro, Barrôco do Ouro, A-do-Cavalo, Quinta das Seixas and Lenteiros, with an additional estimated investment of EUR 6.8 million (USD 7.3 million).

Uranium requirements

Portugal has no uranium requirements.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

The recently published Ministerial Council Resolution No. 107/2019 approved the Roadmap for Carbon Neutrality 2050 (RNC 2050), adopting the commitment to achieve carbon neutrality in Portugal by 2050. Nuclear energy is not considered in Portugal's energy mix. A new energy strategy, PNEC 2030 (Climate and Energy National Plan), reaffirms the importance of renewable sources (mainly wind and hydropower) and increased efficiency as a means of reducing external energy dependence, as well as its associated impact on trade balance and meeting commitments made with respect to the Kyoto Protocols.

Uranium stocks

There have been no changes of stocks since the 2007 edition of the Red Book.

Reasonably assured conventional resources by production method

(tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	0	500	500	80
Open-pit mining (OP)	0	4 500	5 500	5 500	75
Total	0	4 500	6 000	6 000	

Reasonably assured conventional resources by processing method

(tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	0	500	500	80
Conventional from OP	0	4 500	5 500	5 500	75
Total	0	4 500	6 000	6 000	

Reasonably assured conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Granite-related	0	4 500	6 000	6 000
Total	0	4 500	6 000	6 000

Inferred conventional resources by production method

(tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	1 000	1 000	75
Total	0	0	1 000	1 000	

Inferred conventional resources by processing method
(tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	0	0	1 000	1 000	75
Total	0	0	1 000	1 000	

Inferred conventional resources by deposit type
(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Granite-related	0	0	1 000	1 000
Total	0	0	1 000	1 000

Prognosticated conventional resources
(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
1 000	1 500	1 500

Historical uranium production by production method
(tonnes U in concentrate)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Open-pit mining*	1 810	0	0	1 810	0
Underground mining*	1 326	0	0	1 326	0
Unspecified	584	0	0	584	0
Total	3 720	0	0	3 720	0

* Pre-2020 totals may include uranium recovered by heap and in-place leaching.

Historical uranium production by processing method
(tonnes U in concentrate)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Conventional	3 136	0	0	3 136	0
In-place leaching*	250	0	0	250	0
Heap leaching**	321	0	0	321	0
Other methods***	13	0	0	13	0
Total	3 720	0	0	3 720	0

* Also known as stope leaching or block leaching.

** A subset of open-pit and underground mining, since it is used in conjunction with them.

*** Includes mine water treatment and environmental restoration.

Historical uranium production by deposit type

(tonnes U in concentrate)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Granite-related	3 720	0	0	3 720	0
Total	3 720	0	0	3 720	0

Total uranium stocks

(tonnes natural U-equivalent)

Holder	Natural uranium stocks in concentrate	Enriched uranium stocks	Depleted uranium stocks	Reprocessed uranium stocks	Total
Government	168	0	0	0	168
Producer	0	0	0	0	0
Utility	0	0	0	0	0
Total	168	0	0	0	168

Russia

Uranium exploration and mine development

Historical review

Since the beginning of uranium exploration in Russia in 1944, more than 100 uranium deposits have been discovered in 14 districts. The most significant deposits are located in four uranium-bearing districts:

- the Streltsovsk district, which includes 19 volcanic, caldera-related deposits where underground mining of some deposits is ongoing;
- the Trans-Ural and Vitim districts, where basal-channel sandstone-type deposits are being developed for uranium production by in situ leaching (ISL);
- the Elkon district, which contains large metasomatite-type deposits prospective for future mining.

Recent and ongoing uranium exploration activities

There are two types of uranium exploration activities in Russia. One involves early-stage prospecting aimed at new deposit discovery and preliminary evaluation, and the second involves additional, more detailed exploration of earlier discovered deposits to improve resource estimates and delineate new resources.

Uranium prospecting

Uranium prospecting is financed by the federal budget of Russia through the Federal Agency for Mineral Resources (Rosnedra). In 2021-2022, the work was carried out mainly in the Siberian Federal District (Irkutsk Region) and in the Far Eastern Federal District (Republic of Buryatia, Trans-Baikal Region, Amur Region and Jewish Autonomous Region). The work was focused on identifying large deposits and occurrences evaluation suitable for development by ISL and conventional mining methods.

In 2021, exploration expenditures amounted to 197 million rubles: 66 million rubles were spent to conduct mining tests and prepare technical reports on resources for assessing near-surface uranium occurrences at the Karenga area within the Vitim-Karenga district in the Trans-Baikal Region; 24.5 million rubles were spent to complete exploration at the Kuldur area of the Khingan Plateau (Amur Region, Jewish Autonomous District); 100 million rubles were associated with a comprehensive airborne geophysical survey and greenfield exploration within the Tuyukan area of the Tonod district (Irkutsk region).

In 2022, a geological and geophysical survey was carried out and 17 holes were drilled at several sites of the Tuyukan area. The expenses amounted to 97 million rubles. Several promising zones, up to 40 m thick and containing 0.01-0.03% of U, were identified in granites.

Exploration of existing deposits

Exploration of identified deposits is carried out by subsidiary uranium mining enterprises of JSC Atomredmetzoloto (ARMZ), which is a part of the Russian State Atomic Energy Corporation Rosatom.

In 2021, the Priargunsky production centre continued limited exploration focused on identifying uranium resources on the flanks of the deposits by drilling boreholes from underground mine workings.

In 2022, exploration investments amounted to 40.4 million rubles and activities were concentrated at the Dobrovolnoye and Dalmatovskoe deposits (Dalur mine). Main drilling operations were focused on the Ust-Uksyanskaya section exploration of the Dalmatovskoe deposit. The company also continued exploration at the Dobrovolnoye deposit. The exploration programme is scheduled to continue to 2025.

Uranium exploration abroad

From 2018 to 2020, through Uranium One Group, owned by the State Atomic Energy Corporation Rosatom, Russia carried out exploration for uranium at joint ventures in Kazakhstan, exploration at the Wings deposit in Namibia, and works in Tanzania to prepare for the development of the Mkuju River uranium project in Tanzania,

In Kazakhstan, six uranium mines jointly owned by Uranium One are in commercial operation. In 2021, exploration in the expanded geological allotment of the Zarechnoye deposit was completed and additional resources were identified for the extension of the life of the mine. During 2021-2023 a new exploration programme was carried out at the Kharasan mine to convert resources into more reliable categories.

In Tanzania, Mantra Resources completed major exploration of the Mkuju River deposit in 2016. During 2017-2019, further development was suspended due to unfavourable uranium market conditions. In 2020, a decision was made to build a pilot processing plant during 2021-2023 and to proceed with pilot open-pit mining during 2023-2025. In 2022, the company received all approvals for construction works. At the beginning of 2023, the construction of the main production facilities was completed, and the equipment of the processing complex was installed.

In Namibia, Uranium One Group, through its subsidiary Headspring Investments Pty., completed an intensive drilling exploration programme in 2021. As a result, JORC compliant resources of the sandstone-type uranium deposit, Wings, increased to 18 536 tU of RAR (measured and indicated) and 22 977 tU of inferred resources. Additional exploration potential was estimated to be 30 000 tU. A pre-feasibility study completed in 2021 has confirmed positive economics for the ISL mining method. The Wings deposit is the first deposit in Namibia which is potentially amenable for development by ISL. In 2022-2023, the company planned to start with an on-site ISL pilot test. A pilot test site has been prepared for commissioning. The test will start after regulatory approval is received.

Recent mine development activities

JSC Dalur (Kurgan Region) continued with preparation for pilot uranium mining at the Dobrovolnoye deposit in 2021-2022. Completion of pilot plant facilities construction is planned for 2023.

In 2021-2022, JSC Khiagda (Republic of Buryatia) continued development at the Kolichikan deposit with 6 530 tU RAR and the Dybryn deposit with RAR of 6 634 tU. Dybryn is planned for commercial mining in 2023.

During 2021-2022, the Priargunsky production centre continued construction of the surface complex and infrastructure elements of new mine No. 6 with a design capacity of 2 300 tU/yr. It will support the development of the Argunskoye and Zherlovoye deposits.

The development of deposits in the Elkon uranium region was suspended due to unfavourable market conditions. In 2020, pilot mining started for gold resources extraction from the upper oxidised part of the Severnoye gold-uranium deposit of the Elkonsky district. Constructed infrastructure may be used in future for the development of uranium deposits.

Uranium resources

Identified resources (reasonably assured and inferred resources)

As of 1 January 2023, total recoverable uranium resources in Russia (RAR + inferred resources) amounted to 652 535 tU, while in situ known resources comprised 835 184 tU. Compared with the data as of 1 January 2021, this is a decrease of 4 329 tU in recoverable resources due to depletion of the resources by mining in 2021 and 2022. More than 70% of total resources are from existing and prospective uranium mines.

Total recoverable RAR amounted to 247 728 tU (in situ 321 690 tU), of which 82% are recoverable at a cost of <USD 130/kgU and 7% at <USD 80/kgU. With respect to RAR, 70% belong to volcanic-related and metasomatic geologic types and are planned to be developed by conventional underground mining methods. The majority in this group relates to metasomatic-type uranium deposits in the Elkon region. All resources in the cost category of <USD 80/kgU relate to the sandstone-type deposits that are planned to be developed by ISL.

Inferred recoverable uranium resources in Russia amounted to 404 807 tU (in situ 513 494 tU), of which less than 4% can be recovered at less than USD 80/kg. More than 75% of inferred resources are planned to be developed by underground mining from metasomatic and volcanic type deposits.

Undiscovered conventional resources (prognosticated and speculative resources)

In the Russian classification system, prognosticated resources relate to the P1 category and speculative resources relate to the P2 category. As of 1 January 2023, prognosticated (P1) resources in Russia amounted to 163 990 tU, of which 115 280 tU are in the cost category of <USD 130/kgU. Speculative (P2) resources amounted to 551 700 tU, of which 151 110 tU are categorised as <USD 130/kgU. The majority of the undiscovered uranium resources are located in the Trans-Baikal Region (106 510 tU), in the Irkutsk Region (167 800 tU), and in the Republic of Buryatia - Vitim uranium region (225 500 tU).

Compared with the data as of 1 January 2021, the undiscovered resources increased by 22 440 tU, 13 540 tU of which are in the cost category of <USD 130/kgU (4 630 tU prognosticated and 8 910 tU speculative). Changes are explained by resources re-evaluation at known areas and estimates at new areas from recent geological survey data.

Undiscovered resources categorised at <USD 130/kgU are dominated by sandstone-type deposits, and in the cost category of <USD 260/kgU, volcanic-related and unconformity-type deposits prevail. The main sandstone-type resources are concentrated in the Republic of Buryatia (the Vitim and South Vitim uranium regions), where prognosticated (P1) resources amount to 85 300 tU and speculative (P2) resources amount to 103 010 tU. Additional prognosticated (P1) resources (20 000 tU) associated with fishbone detritus (phosphate deposit type) are located in the Ergeninsky uranium region in the Republic of Kalmykia. Resources related to unconformity and volcanic type mineralisation prevail in the Trans-Baikal Region and the Irkutsk region, categorised at <USD 260/kgU.

Uranium production

Historical review

As of 1 January 2023, cumulative uranium production in Russia amounted to 181 625 tU. Total production at the Priargunsky production centre amounted to 155 914 tU, making it the world's largest enterprise for aggregate production of uranium.

Uranium production centre technical details

(as of 1 January 2023)

	Centre #1	Centre #2	Centre #3	Centre #4
Name of production centre	Priargunsky Mining Combine (Priargunsky)	Dalur	Khiagda	Elkon Mining and Metallurgical Complex (Elkon)
Production centre classification	Existing	Existing	Existing	Prospective
Date of first production	1968	2004	2010	After 2035
Source of ore:				
Deposit name(s)	Antei, Streltsovskoe and others	Dalmatovskoe, Khokhlovskoe, Dobrovolnoye	Khiagda, Vershinnoe and others	Yuzhnoe, Severnoe
Deposit type(s)	Volcanic	Sandstone basal channel	Sandstone basal channel	Metasomatic
Recoverable resources (tU)	73 600	8 700	23 400	303 600
Grade (% U)	0.16	0.04	0.05	0.15
Mining operation:				
Type (OP/UG/ISL)	UG, HL	ISL	ISL	UG
Size (tonnes ore/day)	3 300	NA	NA	5 500
Average mining recovery (%)	95	75	75	85
Processing plant:				
Acid/alkaline	Acid	Acid	Acid	Acid
Type (IX/SX)	IX	IX	IX	IX
Size (tonnes ore/day)	4 700	No data	No data	No data
Average process recovery (%)	95	98	98	95
Nominal production capacity (tU/year)	1 200	600	1 300	5 000
Plans for expansion	Mine #6	Dobrovolnoye dep.	Yes	No

Status of productive capabilities

Uranium mining in Russia is carried out by three enterprises that are part of the uranium mining company Uranium Holding ARMZ (JSC Atomredmetzoloto). The annual uranium production in Russia in 2022 amounted to 2 508 tU, of which 1 002 tU were obtained by traditional underground mining and 1 506 tU by ISL.

The PJSC Priargunsky Industrial Mining and Chemical Union (PIMCU) remains the main uranium mining centre in Russia. The resource base for the enterprise includes the volcanic type uranium deposits of the Streltsovsk uranium ore region with recoverable resources of 73 600 tU as of 1 January 2023.

Uranium mining was carried out at two underground mines (mine No. 1 and mine No. 8) and mined ore was processed either at a hydrometallurgical plant or heap leaching site. Of the 1 002 tU mined in 2022 by the underground method, 906 tU were produced at the hydrometallurgical plant and 96 tU were processed by heap leaching. During 2020-2022, construction of the mine No. 6 surface complex and infrastructure elements continued (design capacity of 2 300 tU/yr) for the development of the Argunskoye and Zherlovoye deposits.

JSC Dalur in the Kurgan Oblast carries out the development of the Dalmatovskoye, Khokhlovskoye and Dobrovolnoye deposits by ISL to maintain a production capacity of 600 tU/yr. As of 1 January 2023, recoverable resources of the three deposits amounted to 8 700 tU. Uranium production in 2022 amounted to 585 tU. In 2022, Dalur produced about 600 kg of scandium oxide in concentrates as by-product to uranium. Pilot mining at the Dobrovolnoye deposit will commence in 2023 and commercial operation is planned for 2029.

JSC Khiagda carries out ISL uranium mining of deposits at the Khiagda ore field in the Republic of Buryatia with recoverable resources of 23 400 tU. In 2022, 920 tU were produced. Commercial mining started at the Kolichican deposit in 2022 and will start at the Dybryn deposit in 2023.

Future production centres

Since 2017, the development of deposits in the Elkon uranium ore region has been suspended due to unfavourable market conditions. Development of deposits in the Trans-Baikal uranium ore region is not considered currently.

Employment in the uranium industry

In 2022, the number of employees working in the uranium industry amounted to 6 099, of which 5 023 were PIMCU employees, 488 were Dalur employees and 588 were Khiagda employees. Considering that a portion of PIMCU personnel is involved in general-purpose auxiliary and service facilities, the number of employees directly related to PIMCU uranium production amounted to 3 592.

Uranium requirements

As of 1 January 2023, there were 11 nuclear power plants in Russia, comprised of 36 units, with a total installed capacity of 29.6 GWe. In 2022, Russian nuclear power plants generated 223.4 TWhr of electricity, which amounted to 19.9% of the electricity produced in the country.

The current annual consumption of Russian nuclear power plants amounts to a uranium equivalent of about 4 400 tU. Uranium fuel requirements are supplied by uranium produced in Kazakhstan and Russia, from uranium stockpiles and secondary sources.

The development of nuclear energy and the construction of new power plants in Russia foresees installed capacity growing to 32.4 GWe by 2035 and growth in uranium requirements to 4 700 tU/yr. Starting from 2036 to 2045, an analytical scenario is used that assumes an increase in capacity to 47.7 GWe and achievement of nuclear energy share up to 25% of total electricity production in Russia by 2045. Taking into account planned replacement of retiring RBMK reactors with more efficient VVER, fast breeder and fast neutron reactors, the demand for uranium by 2045 will increase slightly. This scenario assumes nuclear energy development based on new nuclear power generation technologies and takes into account the UN Sustainable Development Goals on the global climate agenda and global energy security.

Uranium exploration and development expenditures and drilling effort – Government domestic

(RUB millions)

	2020	2021	2022	2023 (expected)
Rosatom* exploration expenditures	468	17	40	82
Rosnedra** exploration expenditures	326	197	97	233
Rosatom development expenditures	168	1 632	4 626	8 581
Rosnedra development expenditures	0	0	0	0
Total Government expenditures	962	1 846	4 763	8 896
Rosatom exploration drilling (m)	100 000	5 000	20 600	17 100
Rosatom exploration holes drilled	194	166	59	61
Rosnedra exploration drilling (m)	12 008	0	2 644	6 175
Rosnedra exploration holes drilled	75	0	17	40
Rosatom development drilling (m)	NA	NA	NA	NA
Rosatom development holes drilled	NA	NA	NA	NA
Rosnedra development drilling (m)	0	0	0	0
Rosnedra development holes drilled	0	0	0	0
Subtotal exploration drilling (m)	112 008	5 000	23 244	23 275
Subtotal exploration holes	269	166	76	101
Subtotal development drilling (m)	NA	NA	NA	NA
Subtotal development holes	NA	NA	NA	NA
Total Government drilling (m)	112 008	5 000	23 244	23 275
Total number of Government holes drilled	269	166	76	101

* Russian State Corporation Rosatom. In previous editions, these expenditures were attributed to industry.

** Rosnedra is the Federal Agency for Mineral Resources.

Uranium exploration and development expenditures (non-domestic)

(USD millions)

	2020	2021	2022	2023 (expected)
Industry exploration expenditures	0	0	0	0
Government* exploration expenditures	9.74	20.5	2.58	0.09
Industry development expenditures	0	0	0	0
Government* development expenditures	1.36	4.8	16.43	22.5
Total expenditures	11.1	25.3	19.0	22.6

* Russian State Corporation Rosatom. In previous reports, these expenditures were attributed to industry.

Reasonably assured conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	0	169 628	169 628	75-85
In situ leaching acid	0	18 224	18 224	18 224	75
Co-product and by-product	0	0	0	45 424	65
Unspecified	0	0	14 452	14 452	75
Total	0	18 224	202 304	247 728	77

Reasonably assured conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	0	152 209	152 209	75-85
In situ leaching acid	0	18 224	18 224	18 224	75
In-place leaching*	0	0	516	516	70
Heap leaching** from UG	0	0	16 903	16 903	70
Unspecified	0	0	14 452	59 876	65-75
Total	0	18 224	202 304	247 728	77

* Also known as stope leaching or block leaching. ** A subset of open-pit and underground mining, since it is used in conjunction with them.

Reasonably assured conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	18 224	18 224	18 224
Granite-related	0	0	1 550	1 550
Intrusive	0	0	0	45 424
Volcanic-related	0	0	69 230	69 230
Metasomatite	0	0	103 982	103 982
Phosphate*	0	0	9 318	9 318
Total	0	18 224	202 304	247 728

* Considered conventional resources because uranium is the main commodity of interest.

Inferred conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	0	251 014	301 448	75-85
Open-pit mining (OP)	0	0	0	1 973	70
In situ leaching acid	0	14 168	14 168	22 518	75
Co-product and by-product	0	0	0	35 217	65
Unspecified	0	0	9 087	43 651	75
Total	0	14 168	274 269	404 807	79

Inferred conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	0	242 522	290 281	75-85
In situ leaching acid	0	14 168	14 168	22 518	75
In-place leaching*	0	0	2 068	4 565	70
Heap leaching** from UG	0	0	6 425	6 602	70
Heap leaching** from OP	0	0	0	1 973	70
Unspecified	0	0	9 086	78 868	65-75
Total	0	14 168	274 269	404 807	79

* Also known as stope leaching or block leaching. ** A subset of open-pit and underground mining, since it is used in conjunction with them.

Inferred conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	14 168	14 168	50 996
Granite-related	0	0	2 686	5 689
Intrusive	0	0	0	34 701
Volcanic-related	0	0	29 036	42 683
Metasomatite	0	0	221 252	258 031
Phosphate*	0	0	7 127	12 707
Total	0	14 168	274 269	404 807

* Considered conventional resources because uranium is the main commodity of interest.

Prognosticated conventional resources

(in situ tonnes U)

Cost Ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	115 280	163 990

Speculative conventional resources

(in situ tonnes U)

Cost Ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
157 110	551 700	0

Historical uranium production by mining method

(tonnes U concentrate)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Open-pit mining	38 655	0	0	38 655	0
Underground mining	119 672	1 150	1 002	121 824	1 000
In situ leaching	18 155	1 485	1 506	21 146	1 600
Total	176 482	2 635	2 508	181 625	2 600

Historical uranium production by processing method

(tonnes U concentrate)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Conventional	153 515	1 037	906	155 458	900
In-place leaching*	241	0	0	241	0
Heap leaching**	4 571	113	96	4 780	100
In situ leaching	18 155	1 485	1 506	21 146	1 600
Total	176 482	2 635	2 508	181 625	2 600

* Also known as stope leaching or block leaching.

** A subset of open-pit and underground mining, since it is used in conjunction with them.

Historical uranium production by deposit type

(tonnes U in concentrate)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Sandstone	18 155	1 485	1 506	21 146	1 600
Volcanic and caldera-related	158 327	1 150	1 002	160 479	1 000
Total	176 482	2 635	2 508	181 625	2 600

Ownership of uranium production in 2022

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
2 508	100%	0	0	0	0	0	0	2 508	100%

Uranium industry employment at existing production centres

(person-years)

	2020	2021	2022	2023 (expected)
Total employment related to existing production centres	6 103	6 002	6 099	7 351
Employment directly related to uranium production	4 700	4 425	4 668	4 995

Mid-term production projection (tonnes U/year)

2025	2030	2035	2040	2045	2050
2 600	4 900	4 000	1 500	NA	NA

Mid-term production capability

(tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
1 700	1 700	2 600	2 600	1 700	1 700	4 900	4 900

2035				2040			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
1 600	1 600	4 000	4 000	1 500	1 500	1 500	1 500

Net nuclear electricity generation

(TWh net)

	2021	2022
Nuclear electricity generated (TWh net)	222.4	223.4

Installed nuclear generating capacity to 2040

(GWe net)

2021	2022	2025		2030	
		Low	High	Low	High
29.6	29.6	27.8	27.8	26.8	26.8

2035		2040		2045		2050	
Low	High	Low	High	Low	High	Low	High
32.4	32.4	37.8	37.8	47.7	47.7	NA	NA

Annual reactor-related uranium requirements to 2040 (excluding MOX)

(tonnes U)*

2021	2022	2025		2030	
		Low	High	Low	High
4 400	4 400	4 400	4 400	4 700	4 700

2035		2040		2045		2050	
Low	High	Low	High	Low	High	Low	High
4 700	4 700	4 900	4 900	4 900	4 900	NA	NA

* Assumed enrichment tails assay of 0.22%.

Saudi Arabia

Uranium exploration and mine development

Historical review

Historical uranium exploration programmes were completed in Saudi Arabia from the 1960s to the 1990s by contracted foreign organisations including the United States Geological Survey (USGS) and Lockwood, leading to the identification of airborne radiometric anomalies. The USGS also studied the uranium potential of the Ghurayyah deposit that was known for its rare earth elements (REE), Nb, Ta and Zr contents. Tertiary Minerals Plc identified 385 Mt of niobium-tantalum bearing ore grading 0.0245% Ta_2O_5 at Ghurayyah. Minatome completed a multi-year uranium exploration programme (1979-1984) including the follow-up of airborne radiometric anomalies and the evaluation and drill testing of U and Th prospects.

The mining and metals processing sector in Saudi Arabia is expected to grow as the country pursues its Vision 2030 goal of having the mining sector be a third pillar of the economy. The country is going through a large industrial and economic diversification that will grow resource-heavy manufacturing sectors such as industrial machinery, electrical equipment and automotive, leading to an increase in demand for metal and mineral products.

Saudi Arabia is hosting the annual Future Minerals Forum in 2024 on the future of exploration, mining and processing. Saudi Arabia has introduced reforms to the mining sector legislation that encourage private sector participation in the industry.

Recent and ongoing uranium exploration and mine development activities

Saudi Arabia has initiated a strategic exploration programme for mineral resources including uranium. Several government entities were aligned and co-operated with well-known international institutions. From March 2017 to March 2019, the first phase of uranium (U) and thorium (Th) exploration was conducted, including the evaluation of nine designated areas (including 36 subareas) covering a total area of 27 000 km^2 across Saudi Arabia. Exploration targets included intrusive, volcanic, phosphate, calcrete and sandstone-hosted deposit types.

The project’s aim was to carry out general exploration and geological assessment, including the estimation of inferred resources for uranium at promising sites, according to the JORC standard. Geological, geochemical and geophysical surveys, as well as trenches, were completed over the 36 subareas, and 9 subareas were tested by drilling (70 763 m in 1 467 holes). The cost of the exploration programme was USD 37 million.

The Ghurayyah, Jabal Sayid and Thaniyat Turayf subareas were selected for detailed exploration and the estimation of inferred resources. The next phase of exploration will include the continued exploration of uranium prospects and the development of reasonably assured resources at select deposits.

In 2022, another exploration programme was implemented to follow up on the results of the 2017-2019 work. The first phase was carried out with modern exploration techniques and brought the database up to modern levels. The second phase continued testing many subareas both within the Arabian Shield and in the cover rocks (eastern part of the Arabian Shield).

The current and future perspectives for uranium exploration in the sedimentary cover of Saudi Arabia are based on experience gained from past activities in uranium exploration, in which uranium occurrences and provinces were determined by geological analogy to worldwide uranium deposits and occurrences.

In 2020, sandstone uranium deposits accounted for over 60% of annual global production, largely through in-situ leach (ISL) mining (Australia, China, Kazakhstan, Niger and Western United States). Therefore, Saudi Arabia's current exploration targets will include:

- Sandstone uranium deposits in sedimentary basins in the Tabuk area of northern Saudi Arabia in a terrain similar to that hosting Wyoming sandstone-type uranium deposits in the United States.
- Large sandstone uranium deposits associated with hydrocarbon reservoirs in Saudi Arabia similar to Kazakhstan-type sandstone deposits.
- Six sites selected for regional exploration for the sandstone-type uranium deposits associated with shallow marine to deltaic sedimentary facies, high background uranium content, and the presence of lignite in the sedimentary depositional environments. These sites include areas where shallow marine and deltaic facies are prevailing.

Saudi Arabia uranium exploration expenditures and drilling activities

(USD)

	2017-2020*	2021-2022**	2023 (expected)***
Government exploration expenditures (USD)	37 000 000	19 778 580	18 355 492
Total expenditures (USD)	37 000 000	19 778 580	18 355 492
Government exploration drilling (metres)	70 763	77 374	30 409
Government exploration holes drilled	1 467	290	176
Government trenches (number)	967	11	7
Total drilling (metres)	70 763	77 374	30 409
Total number of holes drilled	1 467	290	176

* Exploration activities were carried out in the field from March 2017 to March 2019.

** Exploration activities and office-based evaluation of information continued from 2021 onwards.

*** Preliminary numbers are reported from the beginning of the year 2023 up to 30 June 2023.

Uranium resources

Identified unconventional resources (reasonably assured resources and inferred resources)

The following uranium resources are considered unconventional resources according to the Red Book resource classification scheme (see Appendix 3) because they are associated with (occur in) unconventional deposit types, which typically have very low grades of uranium, and therefore do not have an established history of production where uranium is a primary product, co-product or an important by-product. In some instances, however, where uranium grades are unusually high for the unconventional deposit type, the specific uranium deposit and its uranium resources may be considered conventional if the deposit is actively being mined for uranium.

Ghurayyah Deposit (intrusive type: plutonic, peralkaline granite complex subtype – U, Nb, Zr, REE, Ta + Th)

The Ghurayyah deposit is located in the northwestern part of the Arabian Shield in Saudi Arabia. This polymetallic deposit is hosted in a sub-circular granite complex with an outcrop area of 0.27 km^2. Based on geological and geophysical surveys and the drill core results, the granite's size was increased to 0.89 km^2 in area. It is distributed along a north-west trending regional fault and extends approximately 1 100 m along strike with a maximum width of 1 100 m. The maximum uranium mineralisation depth is up to 500 m, and an audio-magnetotelluric survey showed that the depth of the granite could reach more than 1 000 m. The uranium-bearing minerals (including uranothorite) in the deposit are accessory minerals, which occur as fine-grained disseminations as well as along micro-fractures in the granitic rocks. In addition, Th-U-Nb-Ta and REE-bearing minerals are recorded, including thorite, columbite-tantalite, fergusonite, pyrochlore, zircon, cassiterite, xenotime, bastnaesite and monazite. They are the major economically interesting minerals, which are mainly hosted within the matrix of the granite. Therefore, the Ghurayyah deposit is a granite intrusion with polymetallic mineralisation, including uranium, thorium, niobium, tantalum, zirconium, hafnium, tin and REEs, of which U is considered to be a co-product of the Ta and Nb.

- Ghurayyah Deposit mineral resource estimation

The Ghurayyah deposit is a large polymetallic deposit containing inferred in situ resources of 424 million tonnes grading 116 ppm U, (0.012% U) at a cut-off grade of 100 ppm U (0.01% U), and 324 ppm ThO_2, 185 ppm Ta_2O_5, 2 486 ppm Nb_2O_5, 960 ppm Y_2O_3 and 7 511 ppm ZrO_2, with contained metal including 49 028 tU and 137 359 tonnes of ThO_2. The ThO_2, Ta_2O_5, Nb_2O_5, Y_2O_3 and ZrO_2 resource estimates were completed based on the uranium mineralisation modelling. The resource remains open at depth and on the periphery of the deposit.

Summary of the in situ inferred unconventional mineral resources in the Ghurayyah deposit, November 2019

(at a cut-off grade of 100 ppm U)

Classification	Tonnage	Grade (ppm)					
	(Mt)	U	ThO_2	Ta_2O_5	Nb_2O_5	Y_2O_3	ZrO_2
Inferred	424	116	324	185	2 486	960	7 511

Contained Metal (t)						
tU	U_3O_8 (t)	ThO_2 (t)	Ta_2O_5 (t)	Nb_2O_5 (t)	Y_2O_3 (t)	ZrO_2 (t)
49 028	57 816	137 359	78 194	1 053 260	406 699	3 182 232

Jabal Sayid prospect (intrusive type: plutonic, peralkaline granite complex subtype – U, Nb, Zr, REE, Ta + Th)

The Jabal Sayid U-Th prospect is in the central Arabian Shield about 320 km northeast of Jeddah and 150 km southeast of Medina, covering an area of 588 km^2. The prospect is characterised by a large, exposed, pegmatite-aplite mineralisation zone extending nearly 2 km in a northeast-east to southwest-west direction, with varying widths of more than 50 m in the centre to 5-10 m in both the easternmost and westernmost sections. The outcropping mineralisation zone is consistent with the high eU (>300 ppm) and high eTh (>1 000 ppm) radiometric anomalies revealed by ground gamma-ray spectrometric surveys, indicating a promising U-Th mineralisation potential. The mineralisation potential is supported by radon anomalies in the Quaternary cover area to the north of the main mineralisation zone. Besides U and Th (including uranothorite), the pegmatite-aplite is also enriched in rare earth elements (REE) and transition metals such as Nb, Ta and Zr.

The major U-, Th-, REE-, and rare metal (Nb, Ta, Zr)-bearing minerals include thorite, uranothorite, pyrochlore, xenotime, monazite, bastnaesite, parisite-(Ce), samarskite, synchysite-(Y), fergusonite-(Y) and zircon.

The geology and grade continuity of the outcropped mineralisation zone was well established by systematic trenching (200 m spacing), surface channel sampling (100 m spacing), and drilling (200 m × (160-200 m) spacing). The drilling results indicated that the mineralisation remains open to both depth and along strike to the west, with a maximum extension along the dip direction of approximately 700 m and 400 m in the central and western parts of the mineralised zone, respectively.

- Jabal Sayid prospect mineral resource estimation

The uranium and thorium mineral resources in the Jabal Sayid U-Th prospect were estimated using the kriging method. Indicated in situ resources are 19 million tonnes of ore grading 424 ppm U for a total of 8 056 tU and 1 813 ppm Th for a total of 39 920 $tThO_2$, reported at a cut-off grade of 300 ppm U (0.03% U). Inferred in situ resources are 10 million tonnes grading 437 ppm U (0.044% U) for a total of 4 370 tU and 1 853 ppm Th for a total of 21 124 t ThO_2. During the exploration programme, 96 drill holes totalling 30 751 m were completed at the Jabal Sayid U-Th prospect. The chemical assay results from a total of 218 907 samples, including 5 466 quality control samples, were used for the resource estimation. Two domains were delineated and estimated.

Summary of in situ indicated and inferred uranium and thorium unconventional resources for the Jabal Sayid U-Th prospect

(at a cut-off grade of 300 ppm U)

Category	Tonnage	Average grade	Contained Metal (t)		
	(Mt)	U (ppm) Th (ppm)	U (t)	Th (t)	U_3O_8 (t) ThO_2 (t)
Indicated	19	424 1 813	8 056	34 447	9 506 39 200
Inferred	10	437 1 853	4 370	18 530	5 157 21 124

Notes:

1. Mineral resources have been estimated in accordance with the JORC Code 2012.
2. Mineral resources have been estimated using the ordinary kriging method.
3. No deductions for mining or metallurgical losses have been factored at this stage.

Thaniyat Turayf prospect (phosphate type)

The phosphorite deposits within the sediments of the Sirhan-Turayf shelf in northern Saudi Arabia form part of the large North African Middle East Tethyan phosphate province, which stretches from Morocco to Iraq. The Thaniyat phosphorite member at the base of the Jalamid Formation of the late Cretaceous (Campanian) to Palaeocene age, was deposited in a shallow marine shelf to intertidal zone. The uraniferous phosphorite layer extends continuously within a target area of about 70 km^2 and has an average thickness of 1.8 m, with an average density of 2.0 g/cm^3. The inferred in situ resources are estimated at 14 551 tU.

Inferred unconventional mineral resources in the Thaniyat prospect

(at cut-off grade of 50 ppm U)

Category	Tonnage (Mt)	Average grade		Uranium resources		Phosphate resources
		U_3O_8 (ppm)	P_2O_5 (%)	tU	tU_3O_8	tP_2O_5
Inferred	178	96	19.8	14 551	17 170	35 201 000

Undiscovered unconventional resources (prognosticated and speculative resources)

Prognosticated and speculative undiscovered unconventional resources have not been identified.

Uranium production

Historical review

No uranium has been produced in Saudi Arabia.

Status of production facilities, production capability, recent and ongoing activities, and other issues

No uranium has been yet produced in Saudi Arabia. However, numerous preliminary studies and economic assessments have been initiated to evaluate uranium production from the Ghurrayyah and Jabal Sayid deposits and the uranium-bearing phosphorite deposits in the northern part of Saudi Arabia.

Secondary sources of uranium

Production and/or use of mixed oxide fuels

Saudi Arabia has not produced or used mixed oxide fuels.

Production and/or use of re-enriched tails

Saudi Arabia does not have a uranium enrichment facility. Re-enriched tails have not been produced or used.

Production and/or use of reprocessed uranium

There is no production or use of reprocessed uranium.

Regulatory regime

The Nuclear and Radiological Regulatory Commission (NRRC) and the Ministry of Environment, Water and Agriculture (MEWA) are mandated to regulate the radiological and non-radiological activities, respectively, for uranium mining in Saudi Arabia. The MEWA and NRRC are legal public organisations with financial and administrative autonomy. The environmental activities related to uranium mining (both radiological and non-radiological) are guided by national policies, strategies and laws (including the National Policy for the Atomic Energy Program, the National Policy for Radioactive Waste Management, the National Policy on Occupational Safety and Health, the National Environment Strategy, and national nuclear and environmental laws) to ensure environmental compliance across all sectors in Saudi Arabia and achieve the goal of preserving and protecting humans and the environment.

The NRRC aims to regulate activities, practices and facilities involving the peaceful use of nuclear energy and ionising radiation; to control and ensure the safety and security of such use and compliance with nuclear safeguards; to protect humans and the environment against any actual or potential exposure to radiation, including exposure to natural radiation; and to implement Saudi Arabia's obligations under relevant treaties and conventions. The Cabinet of Ministers issued a resolution that states that Saudi Arabia shall follow IAEA safety standards as the minimum safety requirements.

The NRRC has issued technical regulations that cover nuclear and radiological regulatory aspects, including radiation safety, notification on and authorisation of facilities and activities with radiation sources, leadership and management for safety, construction and commissioning of nuclear facilities, nuclear material accountancy and control, safe transport of radioactive materials, management of radioactive waste, security of radioactive materials, decommissioning of nuclear facilities and others.

Uranium requirements, and supply and procurement strategy

Uranium requirements

Saudi Arabia has announced Vision 2030, which includes a large number of economic and social development goals, and launched several economic initiatives and programmes aiming at shifting away from a single income source – hydrocarbons – towards economic diversification with multiple sources. The mining sector is one of these sources of income in which Saudi Arabia aims to increase investment. The results of exploration activities showed the abundance of several promising minerals in Saudi Arabia, including uranium. Therefore, Saudi Arabia intends to exploit uranium resources commercially and in accordance with its international commitments. In addition, Saudi Arabia is preparing to introduce its first nuclear power plant in the country. The nuclear power plant is expected to come into operation in the mid-2030s, which will introduce a local demand for uranium in the next decade to fuel the nuclear power plant.

Supply and procurement strategy

The supply and procurement strategy for uranium has not yet been finalised.

Reasonably assured unconventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Intrusive	0	0	0	8 056
Total	0	0	0	8 056

Inferred unconventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Intrusive	0	0	0	53 398
Total	0	0	0	53 398

Inferred unconventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Phosphate	0	0	0	14 551
Total	0	0	0	14 551

Senegal

Historical review

There are two important phases of uranium exploration in Senegal: 1) 1957 to 1965, when a general inventory of the uranium potential of Africa was undertaken, at which time the large deposits in Niger and Gabon were discovered, and 2) 1974 to present, which is characterised by specific surveys focused on the Birimian Superior Precambrian sediments and secondary and tertiary basins with phosphate deposits. The collapse of uranium prices in the 1980s raised questions about the value of these focused surveys and the viability of uranium mineralisation in areas far inland and with no infrastructure – areas that could have been eliminated because of the limited chances of finding uranium concentrations large and rich enough to be economic.

1957-1965

The first work undertaken in Senegal by the French Atomic Energy Commission (CEA) from 1957 to 1961 was part of a systematic aerial survey of West Africa covering Senegal, Mali, Upper Volta (today Burkina Faso) and Niger. It was during these survey flights in 1960 that an aerial radiometric anomaly, Saraya, was identified at Kédougou (Southeast Senegal). Fourteen trenches were dug, and geochemical samples taken, which resulted in the identification of two types of anomalies: one in a fracture striking North 130° with yellow mineralisation and the other in a light-coloured syenite with calcite. Around the same time, ground verification of other airborne anomalies was undertaken, mainly by geochemical sampling and small research wells. Some geochemical anomalies were detected (the Dalafinn site, for example), which were usually associated with laterites. In 1961, the CEA made the decision to suspend the study of anomalies at Kédougou and nothing was undertaken in this area until work resumed in 1974.

In 1966, as part of a joint study between Mauritania and Senegal, the CEA undertook a systematic radiometric study of the continental sedimentary basin of the Ferlo (northern Senegal) and along the bank of the Senegal River. This work, however, yielded no interesting results.

1974-present

On 29 May 1974, the Minister of Development of Senegal sent a letter to the General Administrator of the CEA, which later became the Compagnie Générale des Matières Nucléaires (COGEMA), requesting a resumption of uranium research. After a positive response, a research permit within East Senegal of 38 600 km² was awarded on 27 November 1974. From 1975 to 1976, studies focused on a series of Cambrian and Precambrian Superior lithologies on the remaining area of the permit. From 1979 to 1984, magnetometry and electromagnetism surveys on the Saraya granite identified uranium mineralisation in conjunction with episyenites, representing a geological in situ resource estimated at about 1 500 tU at an average grade of 0.2%.

COGEMA extensively explored uranium in eastern Senegal in the period 1975-1985 (about 400 vertical and oblique drill holes). The drastic drop in the price of uranium, in the context of rather mixed results, led to discontinuation of the exploration programme. In 1975, the Total Mining Company of Senegal led exploration studies on uranium anomalies associated with phosphates in secondary and tertiary basins of Cape Verde. The results were not encouraging.

In 2007, due to uranium price increases, exploration was revived, and as a result the East Saraya licence was purchased by Areva (ex COGEMA) from the junior South African company UraMin. The Saraya western perimeter was awarded to Kansala Resources on 22 March 2007. The exploration licence was renewed again in 2013 for a period of three years. The results of the work showed that the structural setting of the Saraya granitic complex can be considered favourable for alaskite type uranium mineralisation.

Historical exploration has not identified any uranium resources of economic interest but has nevertheless contributed greatly to understanding the geology of Senegal, particularly in eastern Senegal, on the upper Precambrian basin, including equivalents that exist throughout West Africa (i.e. the uranium belt of Zaire) prospected in the past by CEA-COGEMA teams. The research carried out in Senegal, as well as in Guinea and Mali, helped establish a detailed map and improved understanding of the geological history of the country.

Recent and ongoing uranium exploration and mining development

Currently, the Saraya project is owned by Haranga Resources Ltd. Upon acquisition of the project, Haranga launched confirmatory drilling programmes to test the validity of historical results, which prompted the company in 2022 to announce an exploration target for the project area of 4 to 35 Mlbs U_3O_8 at an average grade of 0.055% U_3O_8.

In March 2023, Haranga reported results of the drill programme, consisting of 22 holes completed for 3 021 m. The drill programme reportedly validated the geological model used to estimate the recently published exploration target, validated the historical drill data, and identified extensions to known uranium mineralisation.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

In September 2023, Haranga Resources reported a maiden inferred mineral resource estimate of 16.11 Mlbs U_3O_8 (6 200 tU) at 0.0587% U_3O_8 (0.050 %U) at Saraya. The maiden Saraya mineral resource estimate is based on a database containing data from 541 historical drillholes, together with data from Haranga's 2022 drill campaign.

Undiscovered conventional resources (prognosticated and speculative resources)

No undiscovered resources are currently reported. Senegal previously reported prognosticated conventional resources of 1 500 tU (Red Book 2018), subsequently classified as inferred resources (Red Book 2020, 2022) after an IAEA Uranium Group Secretariat review, and now reports an increase in the maiden Saraya mineral resource estimate reported in 2023, discussed above.

Unconventional resources and other materials

Senegal does not report unconventional resources.

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Granite-related	0	0	0	6 200
Total	0	0	0	6 200

Slovak Republic

Uranium exploration and mine development

Historical review

Beginning in 1947, uranium exploration (surface radiometric prospecting) was performed in different areas of the Slovak Republic (part of the former Czechoslovakia). Surface and airborne radiometric techniques, along with prospecting, borehole logging, geoelectric and geomagnetic prospecting and hydrogeochemistry, were used to determine six regions of uranium mineralisation. Based on the results of this early work, it was concluded that the Slovak Republic had few uranium resources of economic interest.

Between 1985 and 1990, state exploration activities in the eastern part of the Slovak Ore Mountains led to the estimation of resources of economic interest at the Košice deposit, but the deposit was not mined. Uranium mining was terminated in 1989-1990 and an attenuation programme for exploration and mining was instituted between 1990 and 2003, bringing state-funded exploration activities to an end. No uranium exploration occurred between 1990 and 2005.

Ludovika Energy Ltd (a subsidiary of European Uranium Resources) continued exploration in two prospecting areas in the east of the Slovak Republic. The most promising exploration licence concerns uranium mineralisation in Kuriskova, near Košice, which is located within the Jahodná pri Košiciach recreational area. In January 2012, European Uranium Resources announced the results of a preliminary feasibility study (PFS), prepared by Tetra Tech Inc., for an underground mine and a processing facility that would utilise conventional alkaline (non-acid) processing. The PFS included an initial rate of return of 30.8%, a 1.9-year payback, a net present value of USD 277 million at an 8% discount rate (pre-tax, base case assuming prices of USD 68/lb U_3O_8 and USD 15/lb Mo). Indicated resources total 28.5 Mlb U_3O_8 (10 960 tU) and inferred resources amount to 12.7 Mlb U_3O_8 (4 885 tU), using a cut-off of 0.05% U. Operating costs covering the life of the mine were estimated at USD 22.98/lb U_3O_8 (USD 59.75/kgU), assuming a net molybdenum credit of about USD 1.27/lb U_3O_8 (USD 3.30/kgU).

In April 2014, European Uranium Resources Ltd agreed to sell its Kuriskova and Novoveská Huta uranium projects to Forte Energy NL. In October 2014, European Uranium Resources Ltd announced that the company had executed a definitive agreement that allowed Forte Energy NL to earn a 50% interest in the company's uranium projects. The interest would be held through ownership of 50% of the company's wholly owned Slovak subsidiaries at that time, Ludovika Energy and Ludovika Mining, which held the mineral licences comprising the Kuriskova and Novoveská Huta uranium projects.

In November 2014, European Uranium Resources Ltd reported that the management committee of the joint venture between Forte Energy NL and European Uranium Resources Ltd had met in the Slovak Republic to discuss and develop plans for the Kuriskova project to be funded solely by Forte. These discussions were unsuccessful and exploration licences expired in 2015. Further discussions led to the Ministry of Environment rejecting Ludovika Energy's application to identify a new exploration area for rare earth elements in the Jahodná-Kurišková area in late 2016.

In 2011, Crown Energy Ltd (a subsidiary of GB Energy) drilled five exploration holes (totalling 204 m). During 2012, GB Energy completed exploration programmes over the Kluknava and Vitaz-II exploration areas. In June 2012, following an extensive review of archival material, Crown Energy

Ltd uncovered data from a 1960s drilling programme in the vicinity of the Kluknava and Vitaz-II licence areas. Given the volume of data generated from this historic activity, GB Energy deferred new exploration work until the data could be fully analysed. Detailed results of the 1960s programme were expected to be published in 2014. However, no new information on prospection activities appeared publicly and exploration licences expired in 2014.

The activity and exploration results of Beckov Minerals Ltd in the Horka nad Vahom-Kalnica area were not published.

Recent and ongoing uranium exploration and mine development activities

Since 2015, there have been several protests and lawsuits over the allocation of exploration areas, as well as political discussions about banning uranium mining and exploration in the country, and no new uranium exploration licences have been issued in the Slovak Republic.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

No new identified conventional resources have been assessed since 2012, when a pre-feasibility study was finalised and a reserves calculation report for Košice I (Kuriskova area) was approved by the Commission for Reserves Classification (Ministry of Environment of the Slovak Republic). As of 2023, total identified resources (reasonably assured and inferred categories) in the two registered uranium deposits amounted to 19 319 tU.

Deposit	Organisation	Ore resources (t)	U resources (tU)
Košice I	Ludovika Energy Ltd	5 427 000	15 830
Novoveská Huta	Ludovika Energy Ltd	3 876 000	3 489

Undiscovered conventional resources (prognosticated and speculative resources)

Prognosticated resources are estimated to occur in areas surrounding identified deposits and a new estimate of prognosticated resources for the Košice deposit was developed. No other changes have been made since Red Book 2022.

Deposit	Estimated grade (%)	Ore resources (t)	U resources (tU)
Košice I	0.2% U	1 845 432	3 691
Novoveská Huta	0.06% U	12 040 000	7 224

Uranium production

Historical review

During the first period of uranium exploration (1954-1957), a small amount (1.4 tU) was mined in the Novoveská Huta – Hnilcik region. From 1961 to 1990, a total of 210 tU was mined, mainly from Novoveská Huta as a by-product of copper mining, but also from the Muran, Kravany, Svabovce and Vikartovce deposits.

There is currently no uranium production in the Slovak Republic and none is expected in the future.

Secondary sources of uranium

There is no production and no use of secondary sources of uranium in the Slovak Republic.

Environmental activities

Environmental activities have covered monitoring in the historical mining area of the Novoveská Huta deposit. Monitoring has included chemical analyses of mine water outflow as well as geochemical and geological engineering evaluations of the condition of tailings and waste rock piles.

Partial monitoring of such factors has been part of a national environmental monitoring network focused on natural or anthropogenic geological hazards (as indicated by the acronym ČMS GF). Selected mining sites have been monitored, including the above-mentioned area.

Waste rock management must be performed according to Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the management of waste from extractive industries and amending Directive 2004/35/EC. In the Slovak Republic, the related legislation is NR SR (National Council of the Slovak Republic) Act No. 514/2008 Col. on the management of waste from extractive industries and the Decree of the MŽP SR (Ministry of the Environment of the Slovak Republic) No. 255/2010 Col., which executes the act on the management of waste from extractive industries.

Uranium requirements

As of 1 January 2023, the Slovak Republic had two nuclear power plants (Bohunice and Mochovce) with a total of four pressurised water reactors of the VVER-440 type. Two reactors were in operation at each site. As of 1 January 2023, the total installed capacity amounted to 1 868 Mwe, net with uranium requirements of 600 tU per year.

In 2009, the construction of two additional reactors at the Mochovce site (units 3 and 4) began. On 31 January 2023, Mochovce 3 was connected to the grid. Mochovce 4 is expected to be commissioned in 2024.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Energy Policy of the Slovak Republic (Resolution of the Government of the Slovak Republic No. 29/2006)

One of the priorities set to meet energy policy objectives is to utilise domestic primary energy sources for electricity and heat production in an economically effective way.

Energy Security Strategy of the Slovak Republic (Resolution of the Government of the Slovak Republic No. 732/2008)

The objective of the Energy Security Strategy is to achieve a competitive, secure, reliable, and efficient supply of all forms of energy at reasonable costs that protects consumers and the environment and promotes sustainable development, security of supply and technical safety.

The high share of nuclear energy in the energy mix of the Slovak Republic relies on dependable sources of a sufficient number of fuel elements, which in Europe are offered only by France and Russia. It is possible that in the future these fuel element producers could require from customers a counter-value in the form of uranium as a certain form of payment. If this occurs it will be necessary to create the appropriate legislative conditions for the extraction of uranium by amending the relevant laws and strategic documents, including the Raw Materials Policy, since domestic deposits of uranium ore are located near Košice and Spisska Nova Ves – Novoveská Huta.

Legislative and economic support for the efficient and rational use of domestic uranium resources is needed to considerably reduce the dependency on imported energy sources, whose market prices have risen sharply in past years. Increased uranium prices and higher nuclear fuel costs can privilege those states that will be able to supply their own uranium and require its further processing to produce nuclear fuel.

The possibility of extracting uranium in the Slovak Republic is also to be assessed from the perspective of maximum environmental protection. Mining projects must be harmonised with the development of documentation by concerned municipalities and regional governments in conformity with the applicable legislation.

To meet the Energy Security Strategy targets, it is necessary to assess the feasibility of uranium extraction in the Slovak Republic. It is important to support the use of domestic energy sources rationally and effectively with the aim of decreasing dependency on imports.

Assessing the viability of uranium mining in the Slovak Republic was one of the priorities of the country's 2008 Energy Security Strategy. However, in May 2014 the government resolved to ban uranium mining in the country unless it is approved by a referendum of local inhabitants. The Slovak Environment Ministry proposed the amendment to the law, which came into effect in June 2015.

European Uranium signs a Memorandum of Understanding with the Slovak Ministry of Economy

In December 2012, European Uranium Resources Ltd (EUU) reported that it had signed a Memorandum of Understanding with the Ministry of Economy of the Slovak Republic. The memorandum defines the parameters by which EUU and the ministry will co-operate in advancing the Košice uranium deposit – on which EUU holds the exploration licence – through ongoing feasibility and environmental studies. A PFS completed by Tetra Tech, Inc. indicates that the Košice uranium deposit can be developed as an economically feasible underground mine using the best available technologies with minimal environmental impact.

After the affected municipalities and civic associations voiced disagreement, all the mentioned activities were stopped.

Uranium stocks

The Slovak Republic does not maintain an inventory of natural or reprocessed uranium.

Slovenské Elektrárne has a small stock of enriched uranium in the form of complete fuel assemblies. The exact amount is not available.

Uranium exploration and development expenditures and drilling effort – domestic

(EUR million)

	2020	2021	2022	2023 (preliminary)
Industry* exploration expenditures	NA	NA	NA	NA
Government exploration expenditures	0	0	0	0
Industry* development expenditures	NA	NA	NA	NA
Government development expenditures	0	0	0	0

* Expenditures made by private companies. Government expenditures refer to those corresponding to majority government funding.

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	10 950*	10 950*	10 950*	80
Total	0	10 950	10 950	10 950	

* Indicated resources (pre-feasibility study).

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	10 950*	10 950*	10 950*	80
Total	0	10 950	10 950	10 950	

* Indicated resources (pre-feasibility study).

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Volcanic-related	0	10 950*	10 950*	10 950*
Total	0	10 950	10 950	10 950

* Indicated resources (pre-feasibility study).

Inferred conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	4 881*	8 369*	8 369*	80
Total	0	4 881	8 369	8 369	

* Inferred resources (pre-feasibility study).

Inferred conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	4 881*	8 369*	8 369*	80
Total	0	4 881	8 369	8 369	

* Inferred resources (pre-feasibility study).

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Volcanic-related	0	4 881*	8 369*	8 369*
Total	0	4 881	8 369	8 369

* Inferred resources (pre-feasibility study).

Conventional prognosticated resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	3 691	10 915

Note: Category shift concerning new reserves calculation and estimated ore quality.

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Open-pit mining*	50**	0	0	50	0
Underground mining*	161**	0	0	161	0
Total	211	0	0	211	0

* Pre-2020 totals may include uranium recovered by heap and in-place leaching.

** Estimate.

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Conventional	211	0	0	211	0
Total	211	0	0	211	0

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Volcanic-related	211	0	0	211	0
Total	211	0	0	211	0

Net nuclear electricity generation (TWh net)

	2021	2022
Nuclear electricity generated (TWh net)	14.495	15.211

Installed nuclear generating capacity to 2050
(MWe net)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
1 814	1 868	2 748	2 748	2 748	2 748	2 282	2 748	1 349	3 748	NA	NA	NA	NA

Annual reactor-related uranium requirements to 2050 (excluding MOX)
(tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
483	600	527	527	527	527	351	1 084	170	743	NA	NA	NA	NA

Total uranium stocks
(tonnes natural U-equivalent)

Holder	Natural uranium stocks in concentrates	Enriched uranium stocks	Enrichment tails	LWR reprocessed uranium stocks	Total
Government	0	NA	NA	0	NA
Producer	0	0	0	0	0
Utility	0	NA	0	0	NA
Total	0	NA	NA	0	NA

Slovenia

Uranium exploration and mine development

Historical review

Exploration of the Žirovski Vrh area began in 1961. In 1968, the P-10 tunnel was developed to access the orebody. Mining began at Žirovski Vrh in 1982 and uranium concentrate production (as yellow cake) began in 1985. The mine ceased operations in 1991.

Recent and ongoing uranium exploration and mine development activities

Expenditures for exploration ended in 1990. There are no recent or ongoing uranium exploration activities in Slovenia.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

A resource assessment of the Žirovski Vrh deposit was carried out in 1994. Reasonably assured resources are estimated to amount to 2 200 tU (in situ) with an average grade of 0.14% U in the <USD 80/kgU cost category. In situ inferred resources total 5 000 tU in the <USD 80/kgU cost category, and 10 000 tU in the <USD 130/kgU cost category at an average grade of 0.13% U. This deposit occurs in the grey sandstone of the Permian Groeden Formation, where the orebodies occur as linear arrays of elongated lenses within folded sandstone.

Undiscovered conventional resources (prognosticated and speculative resources)

Undiscovered resource estimates remain the same as previously reported.

Uranium production

Historical review

The Žirovski Vrh uranium mine, located 20 km south-west of Škofja Loka, was the only uranium production centre in Slovenia. Ore production began in 1982 and the associated ore processing plant (annual production capability of 102 tU) began operations in 1984, initially treating stockpiled ore. The ore, which occurs in numerous small bodies in the mineralised coarse-grained sandstone, was mined selectively using a conventional underground room and pillar, cut-and-fill operation with a haulage tunnel and ventilation shaft. In 1990, operations were terminated. Cumulative production from the Žirovski Vrh mine and mill complex totalled 386.7 tU (calculated). Mill tailings were disposed of in the Jazbec mine tailings disposal site and hydrometallurgical tailings were disposed of at the Boršt hydrometallurgical tailings disposal site.

Status of production capability

In 1992, a decision was made to close and decommission the Žirovski Vrh mine and mill complex and there has been no production at the facility since. All production was carried out in the former Yugoslavia. In 1994, the Slovenian government adopted the plan for decommissioning the facility. The production facility was dismantled and no longer exists.

Environmental activities and socio-cultural issues

The government-owned former Žirovski Vrh Uranium Mine Company manages all activities connected with the rehabilitation of the former uranium production site, consisting of underground mining facilities, surface milling facilities, the waste rock pile and tailings disposal site. It obtains all remediation permits required, performs the remediation works and monitors the environmental impact of the site during the remediation phase. After finishing the remediation work, the remaining disposal sites and the mine water effluents are put under long-term environmental surveillance, which is carried out by the national Agency for Radioactive Waste Management. The mine effluents are monitored for uranium, radium and other chemical contaminants, and the disposal sites are monitored for radon exhalation and uranium and radium in water effluents.

The annual dose contribution from all mine sites has significantly decreased as a result of remediation activities. Since 2011, it has dropped below 0.1 mSv/a, and in 2022 it was 0.140 mSv/a (for adults), which is below the prescribed annual exposure limit of 0.3 mSv.

All remediation work is finished on the mine tailings disposal site, and in 2015, the long-term environmental surveillance of the site started.

Monitoring

The mine's air and water effluents have been monitored on a regular basis since the start of the ore production in 1982. The programme was modified when production stopped in 1990 and is ongoing. Emissions to surface waters and air are monitored, and doses to the local population have been calculated since 1980. Treatment of the mine's effluents is not planned, considering the low concentrations of radioactive contaminants.

The monitoring of the environmental radioactivity of the former uranium mine consists of measuring radon releases, liquid radioactive discharges, and concentrations of radionuclides in the environment. An integrated programme of measurements has been implemented, including the radionuclide-specific activities of the uranium-radium decay chain in environmental samples, the concentrations of radon and its decay products in the air, as well as external radiation. As part of the long-term surveillance and maintenance programme, the surfaces of the Jazbec mine tailings disposal site and the Boršt hydrometallurgical tailings disposal site are controlled regularly. In the event of heavy rain or an earthquake, additional site controls are implemented. The rate of sliding of the base of the Boršt hydrometallurgical tailings disposal site is measured in real time, using a GPS system, at control points on the hydrometallurgical tailings. Since 2018, geodetic surveillance has been carried out every year.

Tailings impoundment

There is one 4.2 ha specially designed long-term site for hydrometallurgical tailings Boršt. It is situated on the slope of a hill between 535 and 565 m above sea level. At this disposal site, 610 000 tonnes (t) of hydrometallurgical waste, 111 000 t of mine waste and 9 450 t of material, collected during decontamination of the mill tailings in the Boršt site vicinity, have been disposed of, with a total activity of 48.8 TBq. The amount of excavated ore was about 630 000 t and the amount of processed ore was about 610 000 t.

The tailings have been stored in a dry condition as a result of the filtration of the leached liquor. The surface was topped with a 2 m thick, engineered multilayer soil cover with a clay base to prevent leaching of contaminants, and covered with grass. Although remediation of the site was completed in 2010, it required drainage intervention measures to reduce the groundwater level and slow down landslide movement that was activated beneath the disposal site. The results of additional slope stabilisation work, performed in 2016 and 2017, will help determine if the disposal site meets the conditions for site closure and the beginning of long-term environmental surveillance.

In order to reduce the impact of precipitation on the increase in groundwater levels and thus the velocity of landslide, additional measures have been taken in recent years. In the period from 2011 to 2017, seven drainage wells were drilled, and in 2019, seven additional piezometers were installed. In 2021, a new automatic extensiometer was added to the existing mechanical extensiometer.

In 2015, 2016 and 2021, three studies were carried out. In the first study, the distribution of tailings in the case of an extraordinary event (e.g. intensive rain or an earthquake) was assessed. On the basis of the study, the Ministry of the Environment and Spatial Planning ordered an additional study on the radiation exposure of residents and the workers who would carry out the remediation of the deposited material on the riverbeds of the Todraščica, Brebovščica and Poljanska Sora rivers. The results of both studies were included in the revised safety report. In the third study the scenarios and probabilities of possible movements of the landslide into the Potoška Grapa valley and the possibility of temporary damming of Todraščica river were assessed.

The safety report for the Boršt hydrometallurgical tailings disposal site is under revision. This is the basic document for the closure of the disposal facility and the transition to long-term surveillance and maintenance, which will be carried out by the Agency for Radioactive Waste Management (ARAO) as part of a mandatory service of general economic interest.

Waste rock management

All waste rock piles were relocated to the central mine waste pile, Jazbec. All other sites have been restored to a green field condition. The 6.7 ha Jazbec facility contains 1 910 425 t of mine waste, low-grade uranium ore, red mud, filter cake from the mine water treatment station, and contaminated material from the decommissioning of mining and milling facilities, with a total activity of 21.7 TBq. It is covered with an engineered two-metre thick multilayer of soil and planted grass. A concrete drainage tunnel was constructed at the bottom of the waste rock pile to drain seepage and groundwater into a local stream. Environmental remediation works at the Jazbec disposal site were completed and the administrative procedure for site closure finalised in 2015. The responsibility for long-term surveillance and maintenance of the site was transferred to the ARAO in 2015.

Uranium requirements

The sole nuclear power plant in Slovenia is Krško Nuclear Power Plant. It started commercial operation in January 1983 and was modernised in 2000 with replacement steam generators that increased net capacity to 676 MWe. In 2006, net capacity was increased to 696 MWe with low-pressure turbine replacement and in 2022 to approximately 701 MWe after the installation of a new high-pressure turbine. The power plant is 50% owned by Croatia and Slovenia.

There has been no significant change in the Slovenian nuclear energy programme in the last few years. Uranium requirements for Krško Nuclear Power Plant are relatively stable and account for about 149 tU per year. The current fuel cycles are 18 months in duration and are planned to continue on this cycle basis. In 2012, the Slovenian Nuclear Safety Administration approved the ageing management programme, a prerequisite for the operation of Krško Nuclear Power Plant beyond 2030 until the year 2043. In January 2023 the Slovenian Ministry of Environment and Spatial Planning issued the final approval for Krško Nuclear Power Plant until 2043 following the completion of an environmental assessment. In 2020, the Krško Nuclear Power Plant started the third periodic safety review (PSR3) which is required for operating licence extension of 10 years. The PSR3 will be completed in 2023 with the approval of a summary report and an action plan that needs to be completed within five years.

Supply and procurement strategy

The total uranium requirement of Krško Nuclear Power Plant per operating cycle remains unchanged and as reported in previous editions of the Red Book. There are no operating or strategic uranium reserves in Slovenia and supply is imported based on requirement contracts.

The current uranium supply contract covers requirements until 2028. The current procurement strategy utilises enriched UF_6 supplied to the fuel manufacturer from the uranium supplier when it is required for fuel assembly construction. No physical deliveries of U_3O_8 or UF_6 are made to the Krško Nuclear Power Plant site. The manufactured fuel assemblies arrive just before they are used for power production. There are no plans in the foreseeable future to build a uranium stockpile by Krško Nuclear Power Plant. The strategy for commercial spent nuclear fuel management currently does not include the use of reprocessed uranium and Krško Nuclear Power Plant is not licensed for MOX use.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Slovenia is not a uranium-producing country. Uranium stocks are imported for the commercial operation of Krško Nuclear Power Plant as final products (manufactured nuclear fuel assemblies).

Uranium stocks

There is no uranium stock policy in Slovenia. Krško Nuclear Power Plant has no uranium stocks and there is no intention to create such a policy. All required uranium stocks are purchased on a "just-in-time" basis.

Uranium prices

This information is considered confidential.

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Underground mining	0	2 200	2 200	2 200
Total	0	2 200	2 200	2 200

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Unspecified	0	2 200	2 200	2 200
Total	0	2 200	2 200	2 200

Reasonably assured conventional resources by deposit type
(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	2 200	2 200	2 200
Total	0	2 200	2 200	2 200

Inferred conventional resources by production method
(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Underground mining	0	5 000	10 000	10 000
Total	0	5 000	10 000	10 000

Inferred conventional resources by processing method
(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Unspecified	0	5 000	10 000	10 000
Total	0	5 000	10 000	10 000

Inferred conventional resources by deposit type
(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	5 000	10 000	10 000
Total	0	5 000	10 000	10 000

Prognosticated resources
(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	1 060	1 060

Historical uranium production by production method
(tonnes U in concentrate)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 preliminary
Underground mining*	386.7	0	0	386.7	0
Total	386.7	0	0	386.7	0

* Pre-2020 totals may include uranium recovered by heap and in-place leaching.

Net nuclear electricity generation

	2021	2022
Nuclear electricity generated (TWh net)	5.42	5.31

Installed nuclear generating capacity to 2050

(MWe net)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
685	690	666	701	666	701	666	701	666	701	NA	NA	NA	NA

Note: Low and high values were taken as dependable power and maximum designed net power, respectively.

Annual reactor-related uranium requirements to 2050 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
149	149	119	179	119	179	119	179	119	179	NA	NA	NA	NA

Note: Krško Nuclear Power Plant operates 18-month cycles with a fresh fuel load of 224 tonnes of natural uranium equivalent. In some years, no uranium supply will be required (e.g. 2024 and 2027). The values in the table are the average yearly values (i.e. 224 tU x 12/18 = 149 tU). Low and high variability is ±20% from the expected value; this is calculated from maximum change that could occur from a change in fuel assembly design or variation in cycle length (i.e. 12-24 months). The variability shown in some previous reports (2005, 2007, 2009 and 2011) was lower than shown in more recent editions, as it was based on observed 18-month cycle-to-cycle differences and may not be a fair representation in such a long timescale prediction. Since 2013, the larger variability has been reported.

South Africa*

Uranium exploration and mine development

Historical review

South Africa has been an important player in the international market since it first started producing uranium in 1952. It has steadily and consistently produced uranium since then, albeit at a lower level in recent years. Seven of the fifteen deposit types defined in the Red Book are found in South Africa, namely paleo-quartz-pebble conglomerate, sandstone, lignite, and coal, intrusive, surficial, phosphate and granite-related deposits. A major part of the resource base is hosted by the quartz-pebble conglomerates and derived tailings, with significant amounts of resources in the sandstone and coal-hosted deposits. The other deposit types make a relatively small contribution to the national uranium resource inventory.

There are six distinct uranium provinces in South Africa. The oldest are the Palaeozoic-aged Mozaan basin in the northeast and the slightly younger Witwatersrand Basin in central South Africa. The Precambrian-aged Palabora and Pilanesberg carbonatite complexes lie in the north, with the Precambrian to Cambrian granite complexes in the northwest. The sandstone deposits of the Karoo in the south-central parts, as well as the coal-hosted deposits of the Springbok Flats, are of Permo-Triassic age. The youngest are the Tertiary to recent surficial deposits in the Northwest Cape and the phosphorite deposits off the southwest coast.

The surge in uranium prices between 2005 and 2007 stimulated significant corporate interest in South Africa. Much of the ground over the Witwatersrand Basin was held by existing mining companies and extensive re-evaluations of uranium resource holdings were undertaken. Of great interest were the resources held in the vast tailings storage facilities (TSFs) created by over 100 years of gold mining. Gold Fields, Rand Uranium, Harmony, and AngloGold Ashanti launched detailed feasibility studies into the resources contained in tailings.

Available areas with known uranium occurrences, such as in the Karoo Basin and Springbok Flats, were quickly acquired by companies UraMin, Holgoun Energy, and others. UraMin was subsequently acquired by Areva (now Orano), the assets of which included the Trekkopjie deposit in Namibia and the Ryst Kuil Channel in the Karoo Basin. Smaller companies obtained prospecting licences over lesser-known deposits in the Karoo Basin, as well as deposits in the granitic and surficial terrains in the northwest of the country.

Peninsula Energy operated in South Africa through its subsidiary Tasman RSA Holdings (Pty) Ltd and had a total of 41 prospecting rights covering 7 774 km^2 in the Karoo Uranium Province. Peninsula Energy identified new areas of uranium mineralisation in the stacked sandstone units that host extended uranium mineralisation beyond the historic drilling limits, thereby increasing the resource potential. In December 2012, Peninsula Energy acquired all of Areva's properties located in the Karoo Uranium Province, including the Ryst Kuil deposit. Since the commencement of exploration in 2006, Tasman has completed approximately 31 000 m of reverse circulation and diamond drilling, and geophysically logged an additional 15 000 m of open historic holes. In February 2013, Tasman commenced drilling along the Ryst Kuil channel in the Eastern Sector of its Karoo projects, which has returned encouraging initial results.

* Report prepared by the NEA/IAEA, based on previous Red Books and public data.

In 2013, Peninsula released positive results from an initial scoping study, and commenced a pre-feasibility study in the second half of 2013, which included extensive metallurgical test work. In June 2014, the company submitted mining rights applications over all their prospecting areas in the Karoo region. The application process was expected to take up to two years and hence the planned start of mine development was delayed from 2016 to 2018.

In 2012, HolGoun Uranium and Power Limited completed a pre-feasibility study of its project in the Springbok Flats Basin, where uranium is hosted by coal, and then followed up with a more detailed economic feasibility study. The economic feasibility study comprised resource and reserve estimations, bulk sampling and pilot plant test work, geotechnical and groundwater study, mine and underground infrastructure design, overall environmental issues, financial and economic evaluations, and a mining rights application. The initial development of this project envisaged an annual production capacity of about 700 tU_3O_8 (595 tU) at a feed grade of 0.096% U of ore during the first seven years of production. Thereafter, the annual production was planned to be about 500 tU_3O_8 (425 tU) at a feed grade of 0.063% U of ore.

Gold One International Ltd acquired the Rand Uranium properties, as well as the Ezulwini mine, in 2012. One of the key objectives associated with these acquisitions was to re-establish the Cooke underground and Randfontein surface operations as gold mines and subsequently to develop uranium co-product potential. The Cooke underground operations comprise Cooke 1, 2, 3 and Ezulwini. Ezulwini was integrated into the Cooke underground complex as Cooke 4. Ongoing exploration and resource development work highlighted numerous potential resource extensions. A feasibility study was completed in 2012 on a high uranium-yielding area at Cooke 3, which consists of both unmined ground and several higher-grade pillars. The area is associated with existing underground development. The feasibility study considered uranium extraction through the Cooke 4 uranium plant (Ezulwini). The Randfontein surface operations host gold and uranium surface resources that present attractive opportunities for future extraction. These tailings include the Cooke tailings dam, the Millsite complex, Lindum, Dump 20 slime, and the Old 4 dam.

In 2012, Harmony Gold Ltd developed two uranium projects to the feasibility stage: Harmony Uranium TPM (Tshepong, Phakisa and Masimong) and the Free State Tailings Uranium Project. The initial plans were that the TPM project would be extracting uranium from the Tshepong, Phakisa, and Masimong underground mines while the Free State Tailings Uranium Project would be extracting uranium from the old tailings storage facilities owned by Harmony. The feasibility study of the TPM project was supported by a demonstration plant campaign and associated metallurgical test work. However, these projects have been deferred because of financial constraints.

Namakwa Uranium conducted uranium exploration on the Henkries Project. Most of the delineated resources, mainly in Henkries Central, occur within 20 metres from the surface. Given the shallow and soft nature of the deposit, as well as good infrastructure serving the project area, the project was regarded as potentially viable for future uranium extraction. Xtract Resources conducted due diligence to acquire the Henkries Project in the Namaqualand, Northern Cape Province in 2014. However, Xtract has decided not to go ahead with the acquisition of the Namakwa Uranium deposit as it has found that the project does not meet its investment criteria.

In 2014, Sibanye Gold Ltd acquired the Cooke assets and Randfontein operations from Gold One Ltd, and the Witwatersrand Consolidated Gold Resources Limited (Wits Gold) assets. A detailed feasibility study of the West Rand Tailings Retreatment Project (WRTRP) was completed by mid-2015. The definitive feasibility study focused on leveraging existing surface infrastructure, as well as the available uranium treatment capacity at the Ezulwini gold and uranium processing plant, to sustain surface gold and uranium production before the development of the central processing plant.

The Driefontein, Kloof and Cooke surface operations and associated processing facilities are located on the West Rand of the Witwatersrand Basin, while Beatrix is in the southern Free State goldfields. Sibanye-Stillwater also has an interest in surface tailings retreatment facilities located from the East Rand to the West.

Recent and ongoing uranium exploration and mine development activities

In 2017, Peninsula completed a draft environmental impact assessment and environmental management programme reports for the Ryst Kuil and Quaggasfontein areas (Karoo projects). The proposed mining operation was to be known as the Tasman RSA Mines and would be operated as a single entity, but with multiple production centres (Kareeport, Ryst Kuil and Quaggasfontein) feeding a central processing plant to be located near the main ore body within the Ryst Kuil project area. In April 2018, Peninsula announced its decision to withdraw from the Karoo projects in which it had a 74% interest. It suspended all development activities including preparation of exploration and mining rights applications.

In August 2018, Mintails Mining South Africa (Pty) Ltd and several related companies announced their liquidation. Mintails used to mine and process gold and uranium from waste piles and open pits in Krugersdorp near Johannesburg.

AngloGold Ashanti's operations in South Africa are all located in the Witwatersrand Basin, in two mining districts: the Vaal River and West Wits areas. The Vaal River Surface operations are located to the north of the Vaal River, close to the town of Orkney in the North West province. The Mine Waste Solution (MWS) operations are located approximately 15 km from the town of Klerksdorp near Stilfontein within 20 km of the Vaal River Surface operations. The MWS feed sources are scattered over an area that extends approximately 13.5 km north-south and 14 km east-west. The West Wits surface operations are located near the town of Carletonville, straddling the border between the North West and Gauteng provinces. These operations extract gold and uranium from the low-grade stockpile material emanating as a by-product of the reef mining activities within the mines in the Vaal River area. In October 2017, AngloGold Ashanti announced that it was selling assets, including the Moab Khotsong mine and related infrastructure, its interest in Nuclear Fuels Corp of South Africa, and its interest in the Margaret Water Company to Harmony Gold Mining. Anglo Gold Ashanti kept the Mponeng mine and MWS surface operations. As of 1 January 2019, AngloGold Ashanti uranium resources of Vaal River and MWS operations amounted to 39 466 tU of reasonably assured resources (6 131 tU of measured resources and 33 335 tU of indicated resources).

As of 1 January 2019, Sibanye-Stillwater resources amounted to 10 338 tU of reasonably assured resources (3 288 tU of measured resources and 7 050 tU of indicated resources), 35 tU of inferred resources at the Beatrix underground mine, and 19 894 tU of reasonably assured resources (16 072 tU of measured resources and 3 822 tU of indicated resources) at WRTRP. In 2018, uranium resources declined due to the sale of a portion of WRTRP to DRDGOLD. The surface rock dumps at Driefontein were depleted in 2018.

In 2022, a pre-feasibility study was initiated to determine the optimal uranium extraction strategy for Cooke tailings.

On 31 August 2023, Sunshine released a SAMREC compliant inferred resources of 34 320 tU and 2.63 M ounces of gold for Beisa North and South. The feasibility of the Beisa uranium project is being closely watched, as it could be a strategic development opportunity under favourable uranium market conditions.

Uranium resources

The last official country report by South Africa was in 2016. New resource estimates have been made since 2016, but mainly for tailings and a few deposits. In 2021 and 2022, resource re-estimations were completed for the following deposits: Beatrix (quartz-pebble conglomerate; QPC), Cooke surface dumps (tailings), Freestate-Harmony (tailings), Kopanang (tailings), Mine Waste Solution [formerly Hartebeestfontein/Buffelsfontein] (tailings), Mispah (tailings), Moab Knotsong (quartz-pebble conglomerate; QPC) and Vaal River (tailings). The following table shows the changes of recoverable resources (tU) between 1 January 2021 (Red Book 2022) and the date of re-estimation for these deposits. As for the previous estimates, the new resource estimates give a breakdown according to confidence level (RAR and IR), but not per cost category. Resource estimates, as of 1 January 2023, have been obtained by discounting the resource changes to the <USD 260/kgU cost category.

Uranium resource re-estimations to the <USD260/kgU cost category for selected deposits

(as of 1 January 2023, recoverable tonnes U)

Deposit	Type	RAR 2021 (tU)	RAR 2023 (tU)	Change (tU)	IR 2021 (tU)	IR 2023 (tU)	Change (tU)
Beatrix	QPC	7 450	7 732	282	27	29	2
Cooke	Tailings	14 318	11 453	(2 865)	0	0	0
Freestate	Tailings	8 862	11 048	2 186	0	0	0
Kopanang	Tailings	881	910	29	0	0	0
Mine Waste Solutions	Tailings	11 632	11 764	132	0	0	0
Mispah	Tailings	5 539	5 770	231	0	0	0
Moab Knotsong	QPC	7 001	7 190	189	2 223	1 174	(1 049)
Vaal River	Tailings	19 940	12 479	(7 461)	0	0	0
Total		75 623	68 346	(7 277)	2 250	1 203	(1 047)

Identified conventional resources (reasonably assured and inferred resources)

The total recoverable identified conventional resources for South Africa, as of 1 January 2023, amounted to 436 425 tU (RAR: 248 436 tU, IR: 187 989 tU).

The Witwatersrand Basin contains about 80% of total identified uranium resources in South Africa, in both the underground, hosted by quartz-pebble conglomerates, and their resulting tailings storage facilities. Approximately 47% of the total national identified resources are in the Witwatersrand underground operations, 28% in their associated tailings facilities, 20% in the Springbok Flats Basin, and about 5% in the sandstone-hosted deposits of the Karoo Basin. The uranium pay limit in most parts of the Witwatersrand Basin is calculated on a by-product basis, according to which the uranium is not classified as a resource unless it occurs in an area of gold mineralisation that satisfies the estimated gold cut-off grades. In addition, uranium production in these projects only includes the costs of transporting ore from the underground or tailings operations to the processing plants and the treatment of uranium, while gold carries all other costs.

Undiscovered conventional resources (prognosticated and speculative resources)

Undiscovered conventional resources amount to 850 000 tU, which includes the <USD 260/kgU and unassigned cost categories.

The Witwatersrand Basin has a total of about 470 tailings storage facilities with uranium resources, most of which are not included as reasonably assured and inferred conventional resource totals. The Karoo Uranium Province is estimated to contain between about 90 000 tU and 150 000 tU. This estimate has not changed since the last reporting period.

Unconventional resources and other materials

As reported in the 2011 edition of the Red Book, a field of manganiferous phosphate nodules was identified off the west and southwest coast of South Africa on the continental shelf. The nodules contain low grades of uranium and are currently considered uneconomic with respect to both phosphate and uranium extraction. Renewed interest in phosphate-hosted uranium deposits, however, may generate future investigation. The unconventional resources have been previously estimated to amount to 180 000 tU and are unchanged for this reporting period.

Uranium production

Historical review

South Africa has been a consistent producer of uranium since 1952, but its international importance has declined in recent years. In the late 1970s and early 1980s, it ranked as the second or third-largest producer in the world, but since the end of the 1990s output has declined significantly, and by 2022, South Africa ranked 10th in global uranium production. Peak production was achieved at over 6 000 tU/yr in the early 1980s when it accounted for 14% of total world output.

Most of South Africa's historical uranium production was derived from quartz-pebble conglomerate deposits with a small proportion being from the Palabora copper-bearing carbonatite. Current production is sourced from the quartz-pebble conglomerate deposits and associated tailings.

Most of the past production was as a by-product of gold or, to a minor extent, copper. Only two primary uranium producers have existed in South Africa. The first was the Beisa mine in the Free State in the early 1980s, and the second was the Dominion Reefs Uranium Mine near Klerksdorp, which operated in the early 2000s.

In 2019 and 2020, estimated uranium production amounted to 346 tU and 250 tU respectively at the Harmony Gold Vaal River operation (Moab Knotsong mine).

At the end of March 2020, the government imposed a 21-day lockdown in response to the coronavirus pandemic. As part of the lockdown, all mining operations (apart from coal mines supplying Eskom) were initially suspended. The lockdown regulations were amended in mid-April 2020 to allow mining to resume at up to 50% of normal capacity.

In 2021 and 2022, estimated uranium production amounted to 192 tU and 200 tU, respectively. Uranium is currently produced from Vaal River operations by processing the reef material from the Moab Khotsong mine (gold underground mine).

Status of production facilities, production capability, recent and ongoing activities and other issues

AngloGold Ashanti acquired the MWS tailings retreatment operation in the Vaal River region in July 2012. MWS comprises tailings storage facilities that originated from the processing of ore from the Buffelsfontein, Hartebeestfontein and the Stilfontein gold mines. After selling its Vaal River assets to Harmony Gold Mining in early 2018, operations at the MWS uranium plant ceased in 2018.

Uranium production from the Sibanye-owned Cooke operations began in May 2014. The Cooke shafts were used to mine multiple reefs. Uranium processing was done at the Cooke 4 (Ezulwini) Uranium plant. Uranium production at the Ezulwini-Cooke plant and mine operations ended in 2016, and the associated surface rock dumps at Driefontein were depleted in 2018.

The Moab Khotsong mine is located in the northern part of South Africa, in North West province, about 180 kilometres southwest of Johannesburg. Moab Khotsong represents one of the largest gold and uranium reserves in South Africa having indicated recoverable resources of 7 190 tU at 0.061 %U and inferred recoverable resources of 1 174 tU at 0.060% (estimate as of 30 June 2022). Moab Khotsong claims to be home to the world's deepest mine shaft at 3 000 metres. Harmony Gold acquired Moab Khotsong from AngloGold Ashanti Limited on 1 March 2018 for USD 300 million. The assets were the Moab Khotsong mine and related infrastructure, its entire interest in Nuclear Fuels Corp of South Africa and its entire interest in the Margaret Water Company.

Ownership structure of the uranium industry

Most of the uranium projects in South Africa are controlled by gold mining companies. In 2022, Sibanye assumed control of the Beatrix (Beisa) underground mine, the Cooke surface operations (tailings), and the Driefontein, Kloof and Randfontein mines. Harmony Gold Mining Company controls the Moab Khotsong mine, the Mponeng projects, Mine Waste Solutions project, Vaal River and Klerksdorpgoldfield surface tailings. Shiva Uranium Pty controls Dominium and Rietkuil deposits. In April 2018, Peninsula announced its decision to withdraw from the Karoo projects, in which it had a 74% interest. It suspended all development activities including preparation of exploration and mining right applications.

Future production centres

Under favourable uranium market conditions, future production centres could include the Beisa (underground mine) and Cooke (tailings) projects.

Environmental activities and socio-cultural issues

Exploration and mining companies are committed to the responsible use and management of the natural resources under their prospecting and mining rights. Site visits and inspections are conducted regularly to verify that the commitments detailed in their environment management programmes are being adhered to. Exploration and drilling include a responsibility to rehabilitate each site once drilling has been completed. In terms of applications for mining rights, and as part of the Social and Labour Plan, companies are required to inform the interested and affected parties in the proposed mining area of its intended activities.

The Broad-Based Socio-Economic Empowerment Charter for the South African Mining and Minerals Industry (The Mining Charter), which gives effect to the Mineral and Petroleum Resources Development Act No. 28 of 2002, is aimed at transforming the mining industry to redress historical imbalances by substantially and meaningfully expanding opportunities for historically disadvantaged South Africans (HDSA). The charter has given mining companies provision to offset the value of the level of beneficiation achieved against a portion of its HDSA ownership requirements of up to 11% as compared to the current required level of 26% (to be achieved by the end of 2014). Furthermore, mining companies are required to procure a minimum of 40% of their capital goods, 70% of services and 50% of consumables from Black Economic Empowerment entities.

AngloGold Ashanti has designed a framework, following extensive stakeholder engagement, to integrate community development into core business activities, while providing support for national development policies and objectives, particularly those addressing youth unemployment. AngloGold Ashanti's contribution to education in both local and labour-sending communities is a priority. In addition, the Merafong Agricultural Project, which employs 20 people, is funded by AngloGold Ashanti. Other social responsibilities included economic initiatives in the labour-sending areas such as the remote villages of the Eastern Cape Province.

Regulatory regime

The Department of Mineral Resources, the Department of Water Affairs, the Department of Environmental Affairs and the Department of Energy, including the National Nuclear Regulator, perform regulatory functions relating to the exploration and mining of uranium in South Africa.

According to the Mineral Resources and Development Act No. 28 of 2002, an applicant for prospecting or mining rights must make the prescribed financial provision for the rehabilitation or management of negative environmental impacts before the approval of such rights. If the holder of the prospecting or mining right fails to rehabilitate or is unable to undertake such rehabilitation, then part or all of the financial provision will be used for rehabilitation. The holder of a prospecting or mining right must annually assess their environmental liabilities and accordingly increase their financial provision to the satisfaction of the Minister of Mineral Resources. If the minister is not satisfied with the assessment and the financial provision, the minister may appoint an independent assessor to conduct the assessment and determine the financial provision. The requirement to maintain and retain the financial provision remains in force until a closure certificate has been issued after the closure of mining or prospecting operations. The minister may still retain a portion of the financial provision as may be required to rehabilitate the closed mining or prospecting operation in respect of latent or residual environmental impacts. No closure certificate will be issued until the rehabilitation has been done and the chief inspector, as well as all the governmental regulatory departments related to uranium exploration and mining, have confirmed that the provisions pertaining to health, safety, environment, and management of potential pollution to water have been addressed.

Uranium requirements

Koeberg is South Africa's only nuclear power plant. It has two light-water thermal reactors: Koeberg I, commissioned in 1984, and Koeberg II, commissioned in 1985, with a combined installed capacity of 1 840 MW. Together, they require about 294 tU/yr.

In August 2018, the government announced that it had abandoned plans to build up to 9.6 GWe of new nuclear capacity by 2030. The Integrated Resources Plan (IRP) 2018, an update of that issued in 2010, did not include any new nuclear capacity by 2030. IRP 2010 had outlined a required 52 GWe of new capacity by 2030, with nuclear to provide at least 9.6 GWe of that capcity. An update to the IRP issued in November 2016 called for 1.4 GWe of new nuclear capacity by 2037, and a total of 20 GWe long-term. IRP 2016 was released in the context of the Integrated Energy Plan (IEP), which projected a more than threefold increase in electricity demand by 2050.

In May 2020, the Department of Mineral Resources and Energy of South Africa stated that it was to begin working on a roadmap for the construction of 2.5 GWe of new nuclear capacity. It is to consider all options, including small modular reactors.

In August 2021 the National Energy Regulator of South Africa (NERSA) approved the plan.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

The National Nuclear Regulator Act No. 47 of 1999, the Nuclear Energy Act No. 46 of 1999, the National Radioactive Waste Disposal Institute Act No. 53 of 2008, and the Mineral and Petroleum Resources Development Act No. 28 of 2002, are the basis of national policies relating to prospecting for and mining of uranium in South Africa, as well as the export of uranium and disposal of spent nuclear fuel. More information on these policies can be found at the following links:

- www.gov.za/documents/national-nuclear-regulator-act;
- www.gov.za/documents/nuclear-energy-act;
- www.energy.gov.za/files/policies/act_nuclear_53_2008_NatRadioActWaste.pdf;
- www.gov.za/documents/mineral-and-petroleum-resources-development-act.

Uranium stocks

The information and figures on uranium stocks are classified as confidential, and hence could not be accessed from Eskom (a South African electricity public utility, established in 1923, as the Electricity Supply Commission by the South African Government in terms of the Electricity Act).

Uranium prices

No uranium prices were available.

Reasonably assured conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)*	0	0	7 261	9 672	80
Co-product and by-product	0	166 337	228 784	238 764	75
Total	0	166 337	236 045	248 436	75

* The resources for sandstone-hosted deposits in the Karoo Basin are included in the open-pit method; however, in reality the potential production will be conducted by both open-pit and underground mining. The ratio of resources to each method is unknown at present.

Reasonably assured conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG*	0	166 337	228 784	238 764	75
Conventional from OP	0	0	7 261	9 672	80
Total	0	166 337	236 045	248 436	75

* Conventional from UG also includes tailings resources from the Witwatersrand Basin.

Reasonably assured conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	7 261	8 526
Paleo-quartz-pebble conglomerate*	0	166 337	228 784	238 764
Surficial	0	0	0	1 146
Total	0	166 337	236 045	248 436

* Paleo-quartz-pebble conglomerate resources include tailings resources as well.

Inferred conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)*	0	0	0	70 775	68.0
Open-pit mining (OP)**	0	0	10 467	14 080	80.0
Co-product and by-product	0	61 656	74 361	103 134	75.0
Total	0	61 656	84 828	187 989	72.5

* Underground mining resources only include resources from the Springbok Flats Basin. The resources from underground operations in the Witwatersrand Basin are included in the "co-product and by-product" category.

** Resources in the Karoo Basin are included in the open-pit mining method, even though both open-pit and underground mining method are expected to be used. The recovery factor used for the open-pit method (80%) is speculative only.

Inferred conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	61 656	74 361	173 909	72.0
Conventional from OP	0	0	10 467	14 080	80.0
Total	0	61 656	84 828	187 989	72.5

Inferred conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	10 467	13 491
Paleo-quartz-pebble conglomerate*	0	61 656	74 361	103 134
Surficial	0	0	0	589
Lignite and Coal	0	0	0	70 775
Total	0	61 656	84 828	187 989

* Includes tailings resources in the Witwatersrand Basin.

Prognosticated conventional resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	74 000	159 000

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
243 000	411 000	280 000

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Co-product/by-product	161 643	192	200	162 035	200
Total	161 643	192	200	162 035	200

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Conventional	161 643	192	200	162 035	200
Total	161 643	192	200	162 035	200

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Paleo-quartz-pebble conglomerate	161 643	192	200	162 035	200
Total	161 643	192	200	162 035	200

Ownership of uranium production in 2022

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
0	0	200	100	0	0	0	0	200	100

Mid-term production projection

(tonnes U/year)

2023	2024	2025	2030	2035	2040
200	200	200	NA	NA	NA

Short-term production capability

(tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
1 000	1 000	1 000	1 000	1 000	3 000	1 000	3 000

2035				2040			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
1 000	3 000	1 000	3 000	NA	NA	NA	NA

Net nuclear electricity generation

	2020	2021
Nuclear electricity generated (TWh net)	9.9	12.1

Installed nuclear generating capacity to 2040

(MWe net)

2025		2030		2035		2040	
Low	High	Low	High	Low	High	Low	High
1 840	1 840	1 840	1 840	1 840	NA	1 840	NA

Annual reactor-related uranium requirements to 2040 (excluding MOX)

(tonnes U)

2025		2030		2035		2040	
Low	High	Low	High	Low	High	Low	High
294	294	294	294	294	NA	294	NA

Spain

Uranium exploration and mine development

Historical review

Uranium exploration in Spain started in 1951 and was carried out by the Junta de Energía Nuclear (JEN). The initial targets were the Hercynian granites of western Spain. In 1957 and 1958, the first occurrences in Precambrian-Cambrian schists were discovered, including the Fe deposit in the province of Salamanca. In 1965, exploration of sedimentary rocks began and the Mazarete deposit in Guadalajara province was discovered. In 1972, the Empresa Nacional del Uranio S.A., today Enusa Industrias Avanzadas S.A., S.M.E. (hereinafter ENUSA), a state-owned company, was established to take charge of all the nuclear fuel cycle front-end activities. Its shareholders are the Sociedad Estatal de Participaciones Industriales (SEPI), holding 60% of the capital, and the Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT, previously JEN), with the remaining 40%. Exploration activities by ENUSA ended in 1992. Joint venture exploration between ENUSA and other companies continued until the end of 1994. During this period, most of the Spanish territory was surveyed using a variety of methods, adapted to different stages of exploration, and ample airborne and ground radiometric coverage of the most interesting areas was achieved.

Recent and ongoing uranium exploration and mine development activities

Berkeley Minera España S.L.U. (hereinafter Berkeley) was granted one mining licence in the province of Salamanca (covering 2 519 ha) and a total of 17 investigation licences (covering a total of 91 141 ha), spanning the provinces of Salamanca, Cáceres and Badajoz. This company has been actively exploring for uranium for several years, with a focus on several historically known uranium projects located within their tenements.

Berkeley's Salamanca Project comprised the Retortillo, Zona 7 and Alameda deposits (in Salamanca province) and also the Gambuta deposit in Cáceres province, which according to Berkeley accounted for 12.3 Mlb U_3O_8 (4 730 tU) in the measured and 47.5 Mlb U_3O_8 (18 270 tU) in the indicated resource categories, with an additional 29.5 Mlb U_3O_8 (11 350 tU) in the inferred resource category. All deposits are the granite-related type (perigranitic subtype), hosted by a sequence of metasediments that are adjacent to a granite intrusion.

According to the company, Retortillo, Alameda and Zona 7 might have achieved a production capacity of 4.4 Mlb U_3O_8/yr (1 690 tU/yr) over a mine life of 14 years. However, the construction authorisation request for the Retortillo milling radioactive facility for the manufacturing of yellowcake was denied in November 2021 by the Ministry for the Ecological Transition and the Demographic Challenge (MITECO), as were the site authorisations for the related projects in Zona 7 and Alameda.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Total reported in situ identified resources are 89.3 Mlb U_3O_8 (34 350 tU), which include 59.8 Mlb U_3O_8 (23 000 tU) in the reasonably assured category (12.3 Mlb U_3O_8 or 4 730 tU as measured resources and 47.5 Mlb U_3O_8 or 18 270 tU as indicated resources) and 29.5 Mlb U_3O_8 (11 350 tU) as inferred. All resources are reported as in situ and mineable by conventional open pit. According to the feasibility study 95% of resources may be recovered by open-pit mining and a factor of 87% is applied for processing recovery. The overall recovery factor is about 83%.

Uranium production

Historical review

Production started in 1959 at the Andújar plant (Jaén province) and continued until 1981. The Don Benito plant (Badajoz province) remained in operation from 1983 to 1990. Production at the Fe mine (Salamanca province) started in 1975 with heap leaching (Elefante plant). A new dynamic leaching plant (Quercus) started operation in 1993 and was shut down in December 2000. The licence for the definitive shutdown of production, submitted to regulatory authorities in December 2002, was approved in July 2003.

Status of production capability

Mining activities were terminated in December 2000 with the closure of Saelices el Chico uranium mines and production of uranium concentrates ended in November 2002 when the associated Quercus processing plant was shut down.

A dismantling plan for the Quercus processing plant and mines was presented to the regulatory authorities in 2005. However, it was put on standby a first time due to the need to dismantle the former Elefante processing plant and restore mines at that site before dismantling Quercus, and then a second time in 2009 due to an agreement between ENUSA and Berkeley to complete a feasibility study on the state reserves in Salamanca province. Despite these delays, once the Elefante processing plant was dismantled, the associated mines restored, and the agreement between ENUSA and Berkeley finalised, a new plan for dismantling Quercus was presented to the regulatory authorities in September 2015. This plan has been subject to several additional information requirements since 2016 and is still being evaluated by the national regulatory body.

Ownership structure of the uranium industry

Quercus, the only production facility in Spain still pending dismantling, belongs to the company ENUSA.

Employment in the uranium industry

There is no uranium production in Spain. Since there are no existing production centres, employment is associated with decommissioning and mine development activities only.

Employment at the former Fe mine totalled 23 at the end of 2022. All of these workers are dedicated to the mining remediation, monitoring and decommissioning programmes.

Secondary sources of uranium

Spain reports mixed oxide fuel, re-enriched tails and reprocessed uranium production and use as zero.

Environmental activities and socio-cultural issues

The conditions of the former uranium production facilities in Spain are as follows:

- Fábrica de Uranio de Andújar (Jaén province): Mill and tailings piles have been closed and remediated, with an ongoing ten-year surveillance and control programme (groundwater quality, erosion control, infiltration and radon control). This programme has been extended.

- Mine and plant "LOBO-G" (Badajoz province): The open-pit and mill tailings dump have been closed and remediated, with a surveillance and control programme (groundwater quality, erosion control, infiltration and radon control) in place until 2004. A long-term stewardship and monitoring programme was begun after the declaration of closure.
- Old mines (Andalucía and Extremadura regions): Underground and open-pit mines were restored, with work completed in 2000.
- Two old mines in Salamanca (Valdemascaño and Casillas de Flores) were restored in 2007, following which a surveillance programme was initiated, ending in 2011. Results were evaluated by regulatory authorities, and it was determined that an extension of the surveillance period was required.
- Elefante plant (Salamanca province): The decommissioning plan, including industrial facilities and heap leaching piles, was approved by regulatory authorities in January 2001. The plant was dismantled, and ore stockpiles were levelled and covered in 2004. A monitoring and control programme has been in place since 2005.
- In 2004, the mining restoration plan of the open-pit exploitation in Saelices el Chico (Salamanca province) was approved by regulatory authorities. Implementation of this plan was finished in 2008 and the proposed surveillance and control programme was approved by regulatory authorities in March 2014. A monitoring and control programme has been in place since then.
- Quercus plant (Salamanca province): Mining activities ended in December 2000 and uranium processing in November 2002. A decommissioning plan was submitted to regulatory authorities in 2005. However, because of the need for the decommissioning of the former Elefante processing plant and for the restoration of some of the mines at that site before turning to the decommissioning of Quercus, as well as the 2009 agreement between ENUSA and Berkeley, this decommissioning plan was put on standby. In September 2015, a new plan for decommissioning was presented to the regulatory authorities, which after several additional information requirements (corrections submitted in 2017 and 2020), is still pending approval. During this time, a surveillance and maintenance programme has remained active for the plant and associated facilities.

Uranium mining regulatory regime

In Spain, the general mining regime is regulated by the Mines Act (Act 22/1973), modified by Act 54/1980, and by Royal Decree 2857/1978. As for the existing projects or ongoing permit requests submitted before May 2021, the investigation and use of radioactive ores is governed by this act in those areas that are not specifically considered in the Nuclear Energy Act (Act 25/1964), Chapter IV of which deals with the prospecting, investigation, and use of radioactive ores, as well as the commercialisation of such ores and their concentrates.

According to Article 2 of the Mines Act, all-natural deposits and other geological resources in Spain are assets belonging to the public domain, investigation and use of which may be undertaken directly by the state or assigned in accordance with the rules. Pursuant to Article 1 of Act 54/1980, which amends the Mines Act, radioactive ores are part of Section D, i.e. resources of national energy interest.

Pursuant to Article 19 of the Nuclear Energy Act, the prospecting, investigation and use of radioactive ores and the obtaining of concentrates are declared to be open throughout the entire national territory, except in those areas set aside by the state. Individuals or companies who wish to prospect for radioactive ores are required to request an investigation permit from the state and subsequently, if the existence of one or more resources open to rational exploitation is revealed, to request an exploitation licence. This licence confers the right to exploit the resources and is granted for a 30-year period, extendable by similar periods of time to a maximum of 90 years. The permits and licences are granted by the autonomous communities, in keeping with the transfer to them of state competences in mining and energy issues, except when the mining activity in question affects several autonomous communities or state reserves, in which case the competent authority is the MITECO, by virtue of the Mines Act.

The Nuclear Safety Council is the organisation responsible for nuclear safety and radiological protection. In accordance with Article 2 of the act creating the Nuclear Safety Council (Act 15/1980), one of the main competences of the Council is to issue reports to the MITECO on nuclear safety and radiological protection, prior to the resolutions adopted by the latter regarding the granting of authorisations for the operation, restoration or closure of uranium mines and production facilities. These reports are mandatory in all cases and binding when negative in their findings or denying authorisation, or with regard to the conditions established when they are positive.

Regarding restoration plans and financial guarantees for the mining activities, according to the Royal Decree 975/2009 on the management of waste resulting from extractive industries and the protection and restoration of the environment affected by mining activities, a restoration plan must be submitted for approval to the mining authority (the autonomous regional government or MITECO, in the case of those mining activities affecting several autonomous communities or state reserves), the approval of which will be given together with the granting of the exploitation licence. The mining authority will neither grant the licence nor approve the plan unless environmental restoration of the site is guaranteed. To that end, two financial guaranties must be set up by the company before starting any mining activity. One must be set up for the rehabilitation of the environment affected by the exploitation of the ores and the second for the management of the generated waste. Both must comply with the objectives and conditions established in the authorised restoration plan even in the case that the company does not exist at the time of the restoration.

Dismantling of the associated milling facilities is pursuant to the Regulation on Nuclear and Radioactive Installations (RINR, approved by Royal Decree 1836/1999 and modified several times afterwards). As radioactive facilities of the nuclear fuel cycle, existing facilities are subject to all previous site, construction and exploitation licences. An exploitation licence requires the applicant to submit decommissioning and closure forecasts, including, among other things, the final management of the radioactive wastes as well as the economic and financial calculations to guarantee closure of the site.

However, it must be emphasised that the Climate Change Law 7/2021 of May 2021 on climate change and the energy transition includes a section regarding uranium mining and milling facilities in Spain, where: a) no new requests for permits to exploit radioactive mineral deposits, when such resources are extracted for their radioactive, fissile or fertile properties, will be admitted after the entry into force of the Law; and b) no new applications will be admitted either, after such entry into force, for the authorisation of radioactive facilities of the nuclear fuel cycle, i.e. milling facilities for the manufacturing of yellow cake.

Uranium requirements

As of 31 December 2022, the net capacity of the seven Spanish nuclear reactors under commercial operation (Almaraz units 1 and 2, Ascó units 1 and 2, Cofrentes, Vandellós 2 and Trillo nuclear power plants) was about 7.1 GWe. No new reactors are expected to be built in the near future.

In 2020, the Spanish government approved licence renewals for Almaraz unit 1 until 2027, Almaraz unit 2 until 2028 and Vandellós unit 2 until 2030.

In 2021, the lone Cofrentes unit's licence was renewed until 2030 and both Ascó units I and II for another nine and ten years, respectively. In 2014, the Trillo Nuclear Power Plant received its renewal for operation until 2024 and an extension to 2034 has been requested to the corresponding authorities. These renewals of the nuclear power plant licences and their terms were requested and authorised in line with the Comprehensive National Energy and Climate Plan 2021-2030. This plan forecasts the evolution of nuclear energy's contribution to the energy mix according to the subsequent Protocol signed in March 2019 by the electric companies and ENRESA agreeing to a scheduled closure of the nuclear power plants during the period 2027-2035.

Accordingly, for the coming years, uranium requirements for the Spanish nuclear fleet will range from 900 to 1 550 tU/yr, decreasing once the closure dates approach.

Supply and procurement strategy

All uranium procurement activities are carried out by ENUSA on behalf of the Spanish utilities that own the seven nuclear reactors under commercial operation in Spain.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Spain's uranium import policy provides for diversification of supply.

Uranium stocks

Spanish regulation provides that a strategic uranium inventory contained in enriched uranium should be held jointly by the utilities that own nuclear power plants. The current stock contains the equivalent of at least 608 tU. Additional inventories could be maintained depending on uranium market conditions.

Uranium exploration and development expenditures and drilling effort – domestic

(EUR)

	2020	2021	2022	2023 (preliminary)
Industry* exploration expenditures	253 749	374 323	239 494	324 294
Total expenditures	253 749	374 323	239 494	324 294
Industry* exploration drilling (m)	0	0	0	0
Industry* exploration holes drilled	0	0	0	0
Total drilling (m)	0	0	0	0
Total number of holes drilled	0	0	0	0

* Non-government.

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	9 800	23 000	23 000	23 000	83
Total	9 800	23 000	23 000	23 000	83

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	9 800	23 000	23 000	23 000	83
Total	9 800	23 000	23 000	23 000	83

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Granite-related	9 800	23 000	23 000	23 000
Total	9 800	23 000	23 000	23 000

Inferred resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	11 350	11 350	11 350	83
Total	0	11 350	11 350	11 350	83

Inferred resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	0	11 350	11 350	11 350	83
Total	0	11 350	11 350	11 350	83

Inferred resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Granite-related	0	11 350	11 350	11 350
Total	0	11 350	11 350	11 350

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Open-pit mining*	5 028	0	0	5 028	0
Total	5 028	0	0	5 028	0

* Pre-2020 totals may include uranium recovered by heap and in-place leaching.

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Conventional	4 961	0	0	4 961	0
Other methods*	67	0	0	67	0
Total	5 028	0	0	5 028	0

* Includes mine water treatment and environmental restoration.

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (preliminary)
Granite-related	5 028	0	0	5 028	0
Total	5 028	0	0	5 028	0

Uranium industry employment at existing production centres*

(person-years)

	2020	2021	2022	2023 (preliminary)
Total employment related to existing production centres	79	79	42	42
Employment directly related to uranium production	0	0	0	0

* Since there are no existing production centres in Spain, employment is related to decommissioning and mine development activities only. In 2022 for example, 23 employees were involved in Fe decommissioning and the remainder in Salamanca mine development work.

Net nuclear electricity generation

	2021	2022
Nuclear electricity generated (TWh net)	54.0	55.9

Installed nuclear generating capacity to 2050

(MWe net)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
7 069	7 069	7 069	7 069	3 020	5 059	NA	NA	NA	NA	NA	NA	NA	NA

Annual reactor-related uranium requirements to 2050 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
1 287	1 109	1 150	1 200	650	1 250	NA	NA	NA	NA	NA	NA	NA	NA

Total uranium stocks

(tonnes natural U-equivalent)

Holder	Natural uranium stocks in concentrates	Enriched uranium stocks	Enrichment tails	LWR reprocessed uranium stocks	Total
Government	NA	NA	NA	NA	NA
Producer	0	0	0	0	0
Utility	NA	608	0	NA	NA
Total	NA	608	0	NA	NA

Tajikistan*

There are currently no uranium resources and no production in Tajikistan but in the past the establishment and development of the uranium industry in the former Soviet Union was closely related to the country.

Uranium resources

The Taboshar and Adrasman uranium deposits in northwestern Tajikistan were previously mined and both are depleted. They had a similar geological setting and were related to the granite-related deposit type.

First reports on the presence of uranium in Tajikistan go back to the 1920s, when uranium occurrences were discovered, including the Taboshar deposit in the Kuramin range. The Taboshar deposit was located about 40 km north of Leninabad (now Khudzhand). It was discovered in 1927 and exploited in the 1930s for radium, the first to be produced in the Soviet Union. Radium extraction at a special plant in the Taboshar settlement (currently Istiklol) started in 1934. Underground mining for uranium started in 1943. Taboshar was the first uranium deposit mined in the former USSR after World War II. Secondary ore minerals constituted the bulk of mined ore. The deposit identified resources yielded about 500 tU and the ore grade averaged about 0.06% U.

The Adrasman deposit was situated 70 km northeast of Khodzent. It was discovered in 1934 and mined until 1945 for copper and bismuth extraction. Uranium mineralisation was discovered at Adrasman in 1940 and was mined by underground methods from 1946 to the early 1960s. Uranium resources amounted to 103 tU at the grade 0.053% U.

Several uranium occurrences are known in the Gissar and Karetegin ranges of the Pamir Mountains. They are associated with Paleozoic complexes and include pitchblende mineralisation in Permian volcanics; pitchblende-brannerite-fluor-apatite mineralisation in granite; pitchblende-fluor apatite mineralisation in Middle Paleozoic carbonatic rocks; and bitumen-pitchblende as well as fluor apatite-bitumen pitchblende mineralisation in metasediments.

Uranium production historical review

The first uranium-producing centre in the former USSR was built in Tajikistan in 1945. It was located in Chkalovsk, 10 km from Khudzhand (former Leninabad). Originally established as Plant # 6, it was renamed in 1968 as the Leninabad Mining and Chemical Plant, in 1990 as the Vostokredmet Industrial Complex, and since 2014 as the State Enterprise Tajredmet.

Ore processing started in 1945 and ceased at the beginning of the 1990s. Initially, production was based on the ore mined at both of the Tajikistan deposits as well as the Mailisu (Kyrgyzstan), Uigur-Sai, and Tuya-Muyun (Uzbekistan) deposits. Primary ore beneficiation and processing were conducted at the Taboshar and Adrasman mining sites. First uranium at about 50 tU was produced in 1946 and by 1950 annual production increased to 400 tU. Later, annual capacity reached 2 000 tU with mill feed derived from ores and uranium concentrates shipped from

* Report prepared by the NEA/IAEA based on previous Red Books and public information.

Eastern European countries: Bulgaria, Czechoslovakia, the German Democratic Republic, and Poland. The plant also processed ores from deposits of the Karamazar region and ISL slurries from the Kyzylkum region of Uzbekistan.

The mill was transformed in 1993 to treat Pb-Zn-Ag ores from other mines in Tajikistan and currently provides services for vanadium concentrate processing and purification.

Reclamation of uranium mining industries

From 1945 to 1990, more than 170 million tonnes of waste rock and tailings were accumulated at uranium mining and processing enterprises in Tajikistan, of which about 55 million tons are in 10 tailings dumps. A significant part of the uranium ore processed in the country was imported from Kazakhstan, Kyrgyzstan and Uzbekistan, as well as from Eastern European countries.

Based on the results of the assessment of the negative impact on the environment and public health, a "national concept of the Republic of Tajikistan for the rehabilitation of tailings dumps of uranium ore processing wastes for 2014-2024" was developed. In 2012, the government of the Republic of Tajikistan and neighbouring Central Asian countries developed the interstate target programme "rehabilitation of the territories of the EurAsEC member States affected by uranium mining" to solve the problems associated with uranium tailings dumps.

The Digmai tailings and Taboshar mining sites (currently Istiklol) were prioritised for rehabilitation. About 16 million tonnes of waste from uranium ore processing were accumulated at the Taboshar site from 1945 to 1965. Following the approved programme, the Russian state corporation Rosatom carried out comprehensive engineering surveys at the Taboshar site from 2013 to 2016, and in September 2023 completed the rehabilitation of low-grade ores dumps, four tailings dumps, and the dismantling of enrichment plant equipment. Local organisations and construction companies were contracted for this work.

From 2025 to 2028, it is planned to rehabilitate the Digmai tailings in Bobochon (Gafurov district), and the remaining rock dumps and mine sites of the Taboshar site in Istiklol. This work will be conducted within the framework of the "strategic master plan". The Agency for Chemical, Biological, Radiation and Nuclear Safety of the National Academy of Sciences of Tajikistan provides supervision over the implementation of safety requirements during rehabilitation.

Tanzania*

Uranium exploration and mine development

Historical review

Uranium was first discovered in Chiwiligo pegmatite in the Uluguru Mountains in 1953. The first general evaluation of uranium potential of Tanzania was a countrywide airborne geophysical survey for the government between 1976 and 1979. Results revealed a large number of radiometric anomalies in a variety of geological settings.

A uranium exploration programme was subsequently carried out by Uranerzbergbau GmbH between 1978 and 1983 but ended because of declining uranium prices. Targets of this survey were anomalies in the Karoo, in younger surficial sediments, in phosphatic sediments of the Pleistocene age and carbonatite of the Gallapo. Numerous occurrences of surface uranium mineralisation have been identified and there is potential for several uranium deposit types in the country.

Interest in uranium exploration was revived after the rise of uranium prices in 2007 and the Tanzanian government issued over 70 licences. Major exploration activities were focused on identification of sandstone-type uranium deposits in the Karoo Basin in the southern part and surficial-type deposits in the central part of the country.

Since 2007, four uranium deposits were discovered in Tanzania. Identified JORC and NI 43-101 compliant uranium resources (measured, indicated and inferred) are presented in the following table.

In situ uranium resources of Tanzania (company reports)

Deposit name	Resources (tU)		Grade (% U)	Estimated in	Type	Subtype	Current owner
	Measured + indicated	Inferred					
Likuyu North	875	866	0.023	2022	Sandstone	Tabular	Gladiator Resources
Manyoni (Bahi)	1 669	9 477	0.012	2010	Surficial	Lacustrine-playa	AuKing Mining
Mtonya		775	0.022	2013	Sandstone	Tabular/ roll-front	Gladiator Resources
Nyota (Mkuju River)	47 927	10 562	0.026	2013	Sandstone	Tabular	Mantra/ Uranium One
Total	50 471	21 680					

Over 80% of the total resources are contained in the large Nyota sandstone-type deposit, also known as Mkuju River Project. The systematic exploration at Nyota started in 2007 and in 2009 a maiden inferred resource estimate of 13 800 tU (35.9 Mlbs U_3O_8) and a pre-feasibility study were released. In 2011, Mantra Resources was acquired by the Russian Atomredmetzoloto and Uranium

* Report prepared by the NEA/IAEA based on previous Red Books and company reports.

One Inc. was appointed as the project operator. An update of in situ resources of the Nyota deposit estimate in September 2011 boosted total in situ resources to 45 924 tU (119.4 Mlbs U_3O_8) and formed the basis of a feasibility study. During 2012 and 2013, Mantra Resources continued exploration focused on new resource estimates and engineering optimisation.

Drilling activities and analysis of historical data resulted in a further in situ resource increase in June 2013 to 152.1 Mlbs U_3O_8 (58 489 tU), including 124.6 Mlbs U_3O_8 (47 927 tU) in the measured and indicated categories at an average grade of 303 ppm U_3O_8 (0.0257% U). The Mkuju River feasibility study was completed in 2013 and the Tanzanian government issued a special mining licence (SML) to Mantra for project development. During 2013-2014, the main exploration activities of Mantra Resources focused on verifying Nyota deposit resources and on-site push-pull testing to identify amenability of the principal mineralisation to ISL mining. During 2015-2017, exploration was focused on additional investigations to test the amenability of ISL extraction of resources. The laboratory tests resulted in high uranium recoveries with acceptable values of uranium content in sulphuric acid solutions, acid consumption and liquid-to-solid ratio. The results of the hydrogeological test confirmed acceptable aquifer permeability. The on-site ISL test was conducted over ten months in 2016 using a two-well pattern and the final report was issued in 2017. The results confirmed the amenability of ISL mining for the portion of the resources located below the water table. During 2017, rehabilitation of aquifers and the surface was completed after ISL tests.

Exploration drilling by Uranex at the Likuyu North deposit during 2009-2012 identified a maiden resource at 6.1 Mlb U_3O_8 (2 346 tU) with an average grade of 237 ppm U_3O_8 (0.02% U) reported at a 100 ppm U_3O_8 (0.0085% U) cut-off grade.

In 2010, Uranex reported resources of 11 146 tU in a shallow Manyoni deposit, also known as the Bahi project. The region incorporates an extensive closed draining system developed over weathered uranium rich granites. This drainage captures dissolved uranium leached from underlying rocks and transports it to suitable precipitation trap sites (playa lakes). The Manyoni Project encompasses up to five playa lakes.

Uranium Resources Plc. in 2013 announced the maiden resource of 3.6 Mt ore containing 2.014 Mlb U_3O_8 (775 tU) at a grade of 255 ppm U_3O_8 (0.0022% U) at the Mtonya deposit. The uranium mineralisation occurs at depths of 350 m in continuous 30 to 50 metre-wide roll fronts. The resource is potentially amenable to the in situ leach recovery mining method.

Recent and ongoing uranium exploration and mine development activities

In December 2016, Mantra Resources applied to the Ministry of Energy and Minerals (MEM) for a suspension of the Special Mining License and the works programme for the project, due to the state of the uranium market. Pending such response, the MEM accepted an 18-month suspension of the works programme. During 2017-2019, further development of Mkuju River was suspended due to unfavourable uranium market conditions. In 2020, Mantra Resources decided to build a pilot processing plant, to be constructed during 2021-2023, to proceed with small-scale pilot open-pit mining during 2023-2025. Annual pilot plant capacity of 15 000 t of ore assumes production of 5tU/y. In 2022, Mantra Resources received all necessary approvals for construction works: they agreed on a work programme with the Ministry of Mineral Resources, received permission from the Tanzania Atomic Energy Commission (TAEC), the Environment Commission (National Environment Management Council – NEMC), and agreed on the design of the tailings storage facilities (TSF) at the Ministry of Water Resources. At the beginning of 2023, construction of the main production facilities was completed, and the equipment of the processing complex installed. The start of operations is subject to final approval by regulators.

In mid-2021, Australian company Gladiator Resources Ltd. entered into an agreement to acquire Zeus Resources Ltd. and granted Tanzanian tenements known as the Likuyu North, Mtonya, Minjingu, Mkuju, Liwale, Foxy and Eland uranium projects. Gladiator started with a thorough review of the project's historical data sets to feed future exploration programmes and to generate future drill targets. In 2021, Gladiator began exploration at the Minjingu Uranium Project in northern Tanzania and completed planned radiometric traverses and drilled holes to evaluate historical intercepts. In 2022, Gladiator reviewed historical data of the Likuyu North deposit and issued a JORC compliant Mineral Resource Estimate that totals 7.7 Mt with an average grade of 267 ppm U_3O_8 (0.0023% U) containing 4.6 Mlb U_3O_8, (1 770 tU), 50% of which are in indicated and 50% in inferred categories.

In January 2023, AuKing Mining Ltd. acquired uranium projects in Tanzania (Mkuju, Manyoni, Itigi, Magaga) and started an exploration programme that includes near-surface drilling and associated soil sampling exploration at the Manyoni Uranium Project in central Tanzania, to verify historical resources.

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2023, total in situ resources amounted to 72 151 tU, including 50 471 tU in RAR (measured and indicated) and 21 680 tU in inferred categories. Over 80% of the total relates to the Nyota sandstone deposit at the Mkuju River Project. It contains 47 927 tU of in situ measured and indicated resources and 10 562 tU of inferred resources all in the <USD 80/kgU cost category. The Manyoni playa lake calcrete deposits make up 11 146 tU of identified resources, of which 9 477 tU are inferred. The remaining inferred resources include two sandstone-type deposits: Likuju North with 1 741 tU and the Mtonya deposit, which comprises 775 tU and is potentially amenable to ISL extraction. An 80% recovery factor was applied to convert all in situ resources into recoverable resources.

Undiscovered conventional resources (prognosticated and speculative resources)

Undiscovered resources are not reported. There is, however, a high potential for sandstone-type uranium deposits in Karoo sediments in several areas of Tanzania.

Uranium production

There has been no uranium produced in Tanzania.

Future production centres

The Mkuju River feasibility study was completed in 2013 and the Tanzanian government issued an SML to Mantra for project development. Front-end engineering and design (FEED) and Pre-FEED initiatives continued until June 2014.

According to the current definitive feasibility study the resources will be mined in multiple pits feeding a single mill with conventional acid leach and resin-in-pulp recovery. Sulphuric acid ISL mining may be employed, particularly for about 15% of resources lying outside designed pits and below the water table. One-third of the total resource is situated below the water table, so the ISL potential could be greater.

Activities at the project during 2015 and 2016 focused on an ISL pilot test programme. ISL could prove to be an alternative extraction method for the Mkuju River Project and similar ore bodies in the region.

In late December 2016, Mantra Resources applied to the Ministry of Energy and Minerals of Tanzania (MEM) for suspension of its SML due to the unfavourable uranium market. In September 2017, the Ministry approved an amendment to the SML, which permits construction work to start in 2020. During 2018 and 2019, Mantra Resources and MEM negotiated conditions for a further suspension of the SML. Development of the project was postponed until uranium demand increases.

Mantra Resources built a pilot processing plant during 2021-2023 and plans to proceed with small-scale pilot open-pit mining during 2023-2025. In 2023, construction of the main production facilities was completed and the equipment of the processing complex installed. Start of operations is subject to final approval by regulators.

Uranium production centre technical details

(as of 1 January 2023)

	Centre #1
Name of production centre	Mkuju River
Production centre classification	Planned
Date of first production (year)	NA
Source of ore:	
Deposit name(s)	Nyota
Deposit type(s)	Sandstone
Recoverable resources (tU)	41 040
Grade (% U)	0.0425
Mining operation:	
Type (OP/UG/ISL)	OP
Size (tonnes ore/day)	18 000
Average mining recovery (%)	90
Processing plant:	
Acid/alkaline	Acid
Type (IX/SX)	Resin-in-pulp
Size (tonnes ore/day) For ISL (mega or kilolitre/day or litre/hour, specify)	18 000
Average process recovery (%)	85
Nominal production capacity (tU/year)	3 000
Plans for expansion (yes/no)	no
Other remarks	ISL option not assumed

Environmental activities and socio-cultural issues

The Tanzanian government has worked to allay public concerns over the prospect of uranium mining. The environmental, health, economic and social impacts are to be carefully considered and the government indicated that it is aware of the high safety standards required for uranium mining in order to protect people and the environment.

Elephant poachers have taken advantage of the road constructed for access to the Mkuju River uranium project, located in the area excised from the Selous Game Reserve. In May 2014, the operator entered into a memorandum of understanding with the Ministry of Natural Resources and Tourism to conduct combined anti-poaching initiatives. The UNESCO World Heritage Committee is monitoring the situation since all its demands must be met in order to fulfil the Mkuju River Project requirements.

National policies relating to uranium

In 2010, the Tanzanian government substantially amended the Mining Act of 1998. The revised act increased royalty payments for mineral extraction on the gross value of minerals produced (from 3% to 5% for uranium) and gave the government the ability to acquire shareholdings in future mining projects through a development agreement negotiated between the government and the mineral rights holder. The Parliamentary Committee for Energy and Minerals in Tanzania has directed that no mining of uranium can take place until a policy and legislation on extraction are in place.

In 2017, the Tanzanian government amended the Mining Act No.14 of 2010 and in 2019 introduced new miscellaneous amendments No. 7. The amended legislations and regulations are:

1. The Written Laws (Miscellaneous Amendments) Act, 2017 amending the Mining Act 2010 (Amendment Act);
2. The Natural Wealth and Resources (Permanent Sovereignty) Act, 2017 (Sovereignty Act) and the Natural Wealth and Resources Contracts (Review and Renegotiation of Unconscionable Terms) Act, 2017 (Unconscionable Terms Act);
3. The Wildlife Conservation (Protecting, mining of uranium, exploring and production of Oil and Gas in Game reserve) Regulations, 2017;
4. The Mining (Radioactive Minerals) Regulations, 2018;
5. The Mining (Minerals and Mineral Concentrates Trading) (amendments) regulations, 2019.

The IAEA conducted a Uranium Production Site Appraisal Team review in 2013, providing recommendations to the country, a newcomer to uranium mining, in the application of international good practices and preparations for planned uranium mining activities. The scope of the appraisal process included exploration, resource assessment, planning, environmental and social impact assessment, mining, processing, waste management, site management, remediation and final closure.

Reasonably assured conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	38 342	40 377	40 377	80
Total	0	38 342	40 377	40 377	80

Reasonably assured conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	0	38 342	40 377	40 377	80
Total	0	38 342	40 377	40 377	80

Reasonably assured conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	38 342	39 042	39 042
Surficial	0	0	1 335	1 335
Total	0	38 342	40 377	40 377

Inferred conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	8 450	16 724	16 724	80
In situ leaching acid	0	0	620	620	80
Total	0	8 450	17 344	17 344	80

Inferred conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	0	8 450	16 724	16 724	80
In situ leaching acid	0	0	620	620	80
Total	0	8 450	17 344	17 344	80

Inferred conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	8 450	9 762	9 762
Surficial	0	0	7 582	7 582
Total	0	8 450	17 344	17 344

Short-term production capability

(tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	0	0	0	0	0	0	0

2035				2040			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	3 000	0	3 000	0	3 000	0	3 000

2045				2050			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	NA	0	NA	0	NA	0	NA

Thailand

Uranium exploration and mine development

Historical review

Intensive uranium exploration was carried out in the early 1970s by the Royal Thai Department of Mineral Resources (DMR). Uranium occurrences were found in various types of geological settings, particularly in sandstone and granite-related rocks. Sandstone-type mineralisation occurs in Phu Wiang District of Khon Kaen Province, northeastern Thailand. This area was first independently investigated by DMR, then in co-operation with foreign organisations. Granite-related uranium occurrences are associated with fluorite veins, discovered in Doi Tao District and Omkoi District, Chiang Mai Province, northern Thailand.

The most important uranium exploration activity carried out in Thailand was the nationwide airborne geophysical survey, completed between 1985 and 1987, covering an area of approximately 570 000 square kilometres. The survey was conducted by Kenting Earth Sciences International Limited of Canada under a contract with DMR. In 1994, based on available data, a series of airborne radioactive maps were generated as well as a uranium potential map.

Other uranium exploration-related activities were associated with reconnaissance/regional surveys of rare earth element (REE) deposits, which started in 2011 by DMR. Based on the preliminary results of reconnaissance/regional surveys, low contents of uranium and thorium had been found within granitic weathering crusts in some areas.

Recent and ongoing uranium exploration and mine development activities

During the last 3-4 years, Thailand has had no activity related to uranium exploration and mine development. However, from 2017 to 2018, DMR conducted reconnaissance/regional survey activities for REE deposits in various parts of Thailand to define areas of high potential, focusing on granitic weathering crusts. According to the preliminary results, uranium and thorium have been identified, associated with some weathered granitic profiles in the vicinities of Mae Hong Son, Chiang Mai and Tak Provinces.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Based on the results of intensive exploration during the 1970s, the total inferred resources of uranium are 17 tU (in situ) including sandstone-type deposits (4 tU at 0.01% U_3O_8 cut-off) and granite-related deposits (13 tU at 0.02% U_3O_8 cut-off).

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	0	4
Granite-related	0	0	0	13
Total	0	0	0	17

Undiscovered conventional resources (prognosticated and speculative resources)

Undiscovered conventional resources have not been estimated.

Unconventional resources and other materials

A study on uranium extraction from Thailand's seawater has been ongoing since the end of 2011. To date, no uranium has been separated and purified. The objective of the study is to improve the extraction technique, rather than to recover uranium.

It should be noted that unconventional resources of uranium had been found associated with some rare-earth-element (REE) deposits. Although a significant amount of uranium may be removed as a by-product, those REE deposits are not yet regarded as economic deposits.

Uranium production

Historical review

There has been no historical uranium production in Thailand.

Status of production facilities, production capability, recent and ongoing activities and other issues

There are no past or current production facilities in Thailand.

Ownership structure of the uranium industry

Not applicable.

Employment in the uranium industry

None.

Future production centres

There are no uranium production centres planned in Thailand.

Secondary sources of uranium

Production and/or use of mixed oxide fuels

There is no production or use of mixed oxide fuels in Thailand.

Production and/or use of re-enriched tails

There is no production or use of re-enriched fuels in Thailand.

Production and/or use of reprocessed uranium

There is no production or use of reprocessed uranium in Thailand.

Regulatory regime

There is no regulatory regime for uranium mining in Thailand because there is no uranium industry. The Office of Atoms for Peace (OAP) is the regulator on the use of atomic energy in Thailand. If there is a uranium mining industry in Thailand in the future, OAP will most likely be the main agency responsible for regulation.

Uranium requirements

According to Power Development Plan 2022 of Thailand (PDP 2022), which covers the years 2022-2037, nuclear power is not included in the plan.

Supply and procurement strategy

Not applicable.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Although there is no government policy on uranium, there are laws and regulations on the use of atomic energy and radioactive materials. Uranium import and export is included in these laws. The applicable laws are the Atomic Energy for Peace Act B.E. 2504 (1961) and the Ministerial Act on Licensing and Management Procedures for Special Nuclear Materials B.E. 2550 (2007).

Uranium stocks

There is no uranium stock for use in nuclear power reactors in Thailand.

Türkiye

Uranium exploration and mine development

Historical background

Uranium exploration in Türkiye began in 1956-1957 and was directed towards the discovery of vein-type deposits in crystalline terrain, such as acidic igneous and metamorphic rocks. As a result of these activities, some uneconomic occurrences of pitchblende mineralisation were found. Since 1960, studies have been conducted in sedimentary rocks that surround the crystalline rocks, and some small mineralised occurrences containing autunite and torbernite mineralisation have been found in various parts of the country. In the mid-1970s, the first uranium deposit was found in the Köprübaşı area of Manisa, consisting of black-coloured ore located below the water table. After 2010, the Avanos-Gülşehir and Malatya-Kuluncak uranium fields were discovered by the General Directorate of Mineral Research and Exploration (MTA). Uranium mineral resources were increased after intensive exploration and drilling operations by the MTA and the private sector.

The state-owned organisation, General Directorate of Eti Mining Operations (Eti Maden), is responsible for the exploration and development activities of five uranium deposits with identified resources. The MTA has performed geological exploration at these sites in the past. Between 1960 and 1980, uranium exploration included aerial prospecting, general and detailed prospecting, geologic mapping, and drilling. The uranium deposits were transferred from the MTA to Eti Maden as potential mines, which can be operated by the state under Law No. 2840, "Operation of Boron Salts, Trona and Asphaltite Mines and Nuclear Energy Raw Materials", issued on 10 June 1983.

Recent and ongoing uranium exploration and mine development activities

Eti Maden and the MTA signed a contract on 22 August 2017 for drilling exploration in Eti Maden's licensed areas to confirm resource development and to verify the previous exploration. Under this contract a total of 14 914 metres of drilling in 200 wells was carried out in the Manisa-Köprübaşı: 2 562 metres of drilling in 18 wells in 2018, and 12 352 metres of drilling in 182 wells in 2019.

Due to the continuation of the exploration activities on the same licences and the expiration of the contract, another agreement "Eti Maden License Fields Uranium Exploration Project" was signed between Eti Maden and MTA on 19 March 2020. Within the scope, a total of 5 837 metres was drilled in 35 wells in 2020, including 7 wells in the Manisa-Köprübaşı area, 14 wells in Aydın-Söke, and 14 wells in Aydın-Nazilli. In addition, a total of 3 995 metres was drilled in 23 wells in 2021, including 6 wells in Manisa-Köprübaşı, 7 wells in Uşak-Eşme, and 10 wells in Aydın-Söke area.

In 2020, 2021 and 2022, granite, acidic igneous and sedimentary rocks around the Thrace Basin (Edirne, Kırklareli and Tekirdağ provinces), Çanakkale, Nevşehir, Yozgat, Giresun, Manisa, Malatya and Aydın provinces were explored for radioactive raw materials. Drilling was conducted at sites licensed by the MTA inside the Thrace Basin, Nevşehir, Yozgat, Çanakkale, Giresun, Malatya and Aydın provinces. In 2021 and 2022, a total of 156 402 m was drilled in 445 boreholes.

Additional drilling was carried out to increase the uranium resources in Nevşehir Region. Exploration for rare earth elements in the Malatya region led to the identification of uranium in nepheline syenite in the Malatya-Kuluncak area.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2023, identified in situ conventional uranium resources in Türkiye amounted to 45 421 tU (53 562 tonnes U_3O_8) including 4 340 tU of reasonably assured resources and 41 081 tU of inferred resources. Compared to the previous report, an additional 28 685 tU of inferred resources were identified, including 18 236 tU at the Avanos-Gülşehir deposit located in Tertiary sediments and limestones, and 10 449 tU at the Malatya-Kuluncak area in nepheline syenites. The discoveries were made at Manisa, Uşak, Yozgat, Aydın, Nevşehir and Malatya. Follow-up economic and technical studies have not been conducted for the discoveries.

Inferred resources are distributed in the following deposits:

- Manisa-Köprübaşı: 3 011 tU in ten orebodies and at grades of 0.04-0.05% U_3O_8 (0.034-0.042% U) in fluvial Neogene sediments;
- Uşak-Eşme: 416 tU at 0.044% U_3O_8 (0.037% U) in Neogene lacustrine sediments;
- Aydın-Koçarlı: 176 tU at 0.05% U_3O_8 (0.042% U) in Neogene sediments;
- Aydın-Söke-Nazilli: 1 466 tU at 0.08% U_3O_8 (0.068% U) in gneiss fracture zones;
- Avanos-Gülşehir: 24 795 tU at 0.03% U_3O_8 (0.028% U) in Eocene sediments;
- Malatya-Kuluncak: 10 449 tU at 0.02% U_3O_8 (0.017% U) in nepheline syenite.

The Yozgat/Sorgun (formerly known as Temrezli) deposit is potentially amenable to in situ leach (ISL) mining. This Eocene basal sandstone channel type uranium deposit is one of Türkiye's largest and highest-grade uranium deposits, with a mineral resource estimate of 13 282 Mlb U_3O_8 (5 108 tU) at an average grade of 0.116% U_3O_8 (0.098% U) and at an average depth of 120 m. A detailed mineral resource estimate follows:

Resource category	Tonnes	Grade (ppm U_3O_8)	Contained resources (pounds U_3O_8)	Contained resources (tonnes U)
Measured*	2 008 000	1 378	6 100 000	2 346
Indicated*	2 178 000	1 080	5 185 000	1 994
Inferred*	1 020 000	888	1 997 000	768
Total resource*	5 206 000	1 157	13 282 000	5 108

* Numbers rounded for reporting purposes.

Uranium production

Historical review

In the past, pilot laboratory studies for uranium extraction were carried out during uranium exploration. The pilot plant established by MTA in Köprübaşı (Manisa) operated between 1974 and 1982. Approximately 1 200 kg of yellow cake was produced from the uranium ores mined in the Köprübaşı and Fakılı (Uşak) regions and handed over to the Turkish Atomic Energy Authority (TAEK) in 1996. Between 1996 and 2000, research on uranium extraction was performed as a part of the Seventh National Development Plan of the Republic of Türkiye.

Status of production facilities, production capability, recent and ongoing activities and other issues

None reported.

Environmental activities and socio-cultural issues

Uranium exploration is assessed within the scope of Article 55 of the Annex-II list in the by-law on environmental impact assessments (EIAs) by the Ministry of Environment, Urbanisation and Climate Change. Mine production activities for 25 ha and above, together with the mine enrichment activities, are evaluated within the scope of the Annex-I list of the EIA by-law.

Regulatory regime

As the regulatory authority of Türkiye, the Nuclear Regulatory Authority (NDK), undertakes regulatory activities concerning facilities, including nuclear power plants, devices, substances, and activities related to nuclear energy and ionising radiation. The NDK was originally established by a decree having the force of Law No. 702 dated 2 July 2018 as an independent authority associated with the Ministry of Energy and Natural Resources (MENR). However, this decree has been revoked and the current legal framework governing the activities of the NDK is provided by the Nuclear Regulation Law No. 7381 (NRL 7381).

In addition to Law No. 7381, Presidential Decree on the Organization and Duties of the Nuclear Regulatory Authority No. 95 (PD No. 95), which entered into force on 8 March 2022, lays out the functions and organisational structure of the NDK.

Nuclear installations in Türkiye are licensed by the NDK regarding nuclear safety, security and radiological protection issues. Before the NDK, the Turkish Atomic Energy Authority (TAEK) was the licensing authority according to Law No. 2690, which regulated the duties and responsibilities of TAEK as a regulatory body.

The duties and responsibilities of the NDK were determined in the Presidential Decree on Organization and Duties of the Nuclear Regulatory Authority No 95 (PD 95) and TAEK was reorganised as a research and development and technical support service organisation. In 2020, the Turkish Energy, Nuclear and Mineral Research Authority (TENMAK) was founded as an affiliate to the Ministry of Energy and Natural Resources with Presidential Decrees No. 4 and 57 by incorporating three governmental institutions related to nuclear, boron and rare earth elements research (named as TAEK, BOREN and NATEN, respectively). The Nuclear Energy Research Institute (NUKEN) was established within TENMAK to carry out studies on nuclear science and technologies. Nuclear fuel cycle research and fuel development studies are conducted on a laboratory scale within the Istanbul campus of NUKEN.

As a part of the transition process, the NDK will issue new regulations according to the new licensing system. The authorisation process of nuclear installations is carried out in accordance with the provisions of Regulation on Authorization of Nuclear Installations published in 2023. According to this Regulation, the licensing procedure for nuclear mining facilities is initiated by an application from the owner. The licensing process comprises a construction permit and an operating licence for nuclear mining facilities. The documents required for review and assessment by the NDK are defined in the Regulation on Authorization of Nuclear Installations.

Uranium requirements

There are no nuclear power plants in operation or decommissioning activities underway. However, four reactor units are under construction in Türkiye. Türkiye has considered building a nuclear power plant since the 1970s. Rising energy demand, import dependence, and industrial activity are the driving forces behind Türkiye's move towards developing a civil nuclear power generation programme. Türkiye's recent efforts in this area can be characterised as a first-of-a-kind approach in the nuclear sector and have been referred to as an intergovernmental agreement (IGA) model, with long-term contracts of power purchase agreements. In this approach, a project company undertakes to design, build, operate and maintain a power plant, whereas the Turkish government is responsible for providing the site, various financial and non-financial guarantees, construction support, and licensing. The project company is also responsible for managing wastes and decommissioning the facility.

The construction and operation of a nuclear power plant, through a co-operation agreement between the government of Russia and the government of Türkiye, is being carried out at Akkuyu, Mersin Province, Türkiye. The Akkuyu Nuclear Power Plant project plans for the construction of four VVER-1200 reactors with a total capacity of 4 800 MWe. Türkiye plans to build three more nuclear power plants. Negotiations continue with China, Korea and Russia.

Supply and procurement strategy

According to Article 12 of the agreement between the government of Russia and the government of Türkiye on co-operation in the construction and operation of the Akkuyu Nuclear Power Plant, nuclear fuel will be sourced from suppliers based on long-term agreements entered between the project company and the suppliers. The Akkuyu Nuclear Joint-Stock Company is planning to secure a supply of nuclear fuel from TVEL, a subsidiary of Rosatom. The first fresh nuclear fuel assemblies were delivered to the Akkuyu Nuclear Power Plant site on 27 April 2023.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

The law on the "Operation of Boron Salts, Trona and Asphaltite Mines and Nuclear Energy Raw Materials" No. 2840, dated 10 June 1983, states that exploration and mine operations are to be carried out by the state.

Uranium stocks

TENMAK-NUKEN holds natural uranium stocks in different forms for research activities.

Uranium exploration and development expenditures and drilling effort – domestic

(TRY [Turkish lira] – excluding VAT)

	2021	2022
Government exploration expenditures	36 597 467	55 204 620
Total expenditures	36 597 467	55 204 620
Government exploration drilling (m)	98 662	57 740
Government exploration holes drilled	290	140
Total drilling (m)	98 662	57 740
Total number of holes drilled	290	140

Reasonably assured resources by production and processing method

(in situ tonnes U)

Production method	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
ISL	0	4 340	4 340
Total	0	4 340	4 340

Reasonably assured resources by deposit type

(in situ tonnes U)

Deposit type	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	4 340	4 340
Total	0	4 340	4 340

Inferred resources by production and processing method

(in situ tonnes U)

Production method	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional OP	0	28 398	28 398
ISL	0	768	768
Unspecified	0	0	11 915
Total	0	29 166	41 081

Inferred resources by deposit type

(in situ tonnes U)

Production method	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	4 371	4 371
Metamorphite	0	0	1 466
Carbonate	0	24 795	24 795
Intrusive	0	0	10 449
Total	0	29 166	41 081

Installed nuclear generating capacity to 2045

(MWe net)

2022	2025		2030		2035		2040		2045	
	Low	High	Low	High	Low	High	Low	High	Low	High
0	1 200	1 200	4 800	4 800	7 200	7 200	12 600	12 600	15 600	15 600

Annual reactor-related uranium requirements to 2045 (excluding MOX)

(tonnes U)

2022	2025		2030		2035		2040		2045	
	Low	High	Low	High	Low	High	Low	High	Low	High
0	190	190	380	380	1 150	1 150	2 000	2 000	2 500	2 500

Total uranium stocks

(tonnes natural U-equivalent)

Holder	Natural uranium stocks in concentrates	Enriched uranium stocks	Enrichment tails	LWR reprocessed uranium stocks	Total
Government	4.1	0	0	0	4.1
Total	4.1	0	0	0	4.1

Ukraine

Uranium exploration and mine development

Historical review

Prospecting for uranium in Ukraine began in 1944 with the analysis of geological exploration data and mining activity results in the Northern Kryvyy Rig ore basin. The Pervomayske and Zhovtorechenske uranium deposits were discovered in the 1950s. These deposits were mined out in 1967 and 1989, respectively. During the same period, sandstone-type deposits were discovered.

In the mid-1960s, the main geological exploration was concentrated in the Kirovograd ore area for the discovery of metasomatite-type uranium deposits. The Michurinske, Vatutinske, Severinske, Tsentralne and Novokostyantynivske deposits were discovered in this area.

Metasomatite-type deposits make up the bulk of the uranium resources of Ukraine. The average ore grade in these deposits is 0.1-0.2% U. The second type is represented by sandstone-type deposits, with an average ore grade between 0.02 and 0.06% U. They are suitable for mining by the in situ leaching (ISL) method.

Ongoing uranium exploration and mine development activities

During 2021-2022, State Enterprise "Kirovgeology" undertook analytical work on existing geological data to identify areas prospective for uranium exploration within the Ukraine. Ukrainian companies do not carry out any exploration for uranium in other countries.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2023, identified recoverable uranium resources (reasonably assured and inferred resources) were 184 754 tU at a cost of <USD 260/kgU, 106 733 tU at a cost of ≤USD 130/kgU and 71 498 tU at a cost of <USD 80/kgU. Mining and processing losses are considered in this estimation. Original in situ identified resources amounted to 210 341 tU at a cost of <USD 260/kgU, 121 434 tU at a cost of ≤USD 130/kgU and 81 644 tU at a cost of <USD 80/kgU.

The main uranium resources of economic interest are found in two types of deposits:

- Metasomatite-type deposits located within the Kirovograd block of the Ukrainian Shield. The uranium ore grade is 0.1-0.2% U. All deposits are suitable for underground mining.
- Sandstone-type deposits located within the Dnieper-Bug metallogenic area (17 300 km^2). The uranium ore grade is 0.02-0.06% U. In addition to uranium, molybdenum, selenium and rare earth elements of the lanthanide group occur in these ores. These deposits are amenable for mining by ISL.

Undiscovered resources (prognosticated and speculative resources)

Undiscovered in situ uranium resources amount to 277 500 tU, including:

- Prognosticated resources of 22 500 tU situated on the flanks of identified deposits.
- Speculative resources of 255 000 tU, based on the data from the uranium prognostic map (scale of 1:500 000), which was created by SE “Kirovgeology”. Speculative resources are subdivided according to geological types as follows:
  - 133 500 tU metasomatite-type;
  - 20 000 tU in sandstone deposits on the Ukrainian Shield;
  - 16 500 tU in sandstone (in bitumen) on the slopes of the Ukrainian Shield;
  - 40 000 tU in “unconformity-related” type deposits;
  - 30 000 tU in granite-related type deposits;
  - 15 000 tU in “intrusive” potassium metasomatite deposits.

Uranium production

Historical review

Uranium mining began in 1946 at the Pervomayske and Zhovtorechenske deposits using conventional underground methods. In 1949, the first uranium production began at the Pridniprovskyy Chemical Plant (PCP), in the town of Dniprodzerzhinsk (now Kamyanske).

In 1951, the government founded the State Enterprise “Eastern Ore Dressing Complex” (VostGOK) in Zhovti Vody in the Dnipropetrovsk region for the mining and processing of ore from the Pervomayske and Zhovtorechenske deposits. In 1959, a second uranium processing plant was built in Zhovti Vody. The Pervomayske deposit was mined out in 1967 and the Zhovtorechenske deposit was mined out in 1989.

ISL uranium mining began in the Ukraine in 1961. From 1966 to 1983, uranium from the Devladovske and Bratske deposits was recovered by the sulphuric acid ISL method at a depth of about 100 m. At present, aquifers of both deposits are undergoing monitoring.

Status of production facilities, production capability, recent and ongoing activities, and other issues

VostGOK operates four underground mining units: the Michurinske deposit (3 km south of Kropyvnytskyy; formerly Kirovograd), Tcentralne deposit (on the south-east end of Kropyvnytskyy), Vatutinske deposit (near the town of Smolino) and Novokostyantynivske deposit (40 km west of Kropyvnytskyy). The government approved the decision to shut down mining at the Smolinska mine for the period 2023-2027, due to mining resource depletion.

Hydrometallurgical processing plant

At present, only one processing plant is in operation. The VostGOK hydrometallurgical processing plant is situated in the town of Zhovti Vody. The annual capacity of the plant is 1.5 Mt of ore. Each working shift employs 30 to 35 people. Uranium ore is transported to the plant by specially equipped trains from the Ingulska (100 km west), Novokostyantynivske (130 km west) and Smolinska (150 km) mines.

Uranium production method

Metasomatite-type deposits in Ukraine have a uranium ore grade of about 0.1% U on average, with disseminated mineralisation (uraninite, brannerite, coffinite, pitchblende) throughout the steeply dipping ore bodies. Mining is carried out by the underground method. Processing of mined ore begins with crushing, followed by extraction by sulphuric acid leaching in autoclaves at the hydrometallurgical processing plant. Low-grade uranium ore, expensive underground mining technology, processing technology and transportation (mines are located some 100 km and 130 km from the processing plant) are factors contributing to high production costs, considering current market prices. To decrease production costs, some innovative technologies, such as underground radiometric sorting, in-place leaching, heap leaching, and reprocessing of material from dumps of operating mines are being introduced.

A multistage radiometric separator, designed by VostGOK for different particle sizes of crushed ore, allows sorting of both mined ore and material from the mine dumps. After the radiometric sorting, the uranium content in the ore may reach 0.03-0.3% U. The uranium content in tailings after radiometric sorting is 0.006% U or less.

At the Vatutinske deposit (Smolinske mine) crushed uranium ore undergoes heap leaching (HL) with a recovery factor of about 82-83%. The uranium production cost of HL was 15% lower than at the hydrometallurgical processing plant due to lower logistical expenses. Four heaps with a total volume of 160 Kt of ore have been built. Each heap contains 40 Kt of ore. After radiometric sorting, the ore grade is 0.05-0.08% U.

Although most metasomatite-type ore deposits are suitable for HL, additional ore treatment for effective HL is necessary since the degree of crushing and permeability are the most important parameters that determine uranium recovery. The maximum size of uranium mineral particles is usually from 1 to 5 mm. With an optimum size of ore material of 10 mm, 80-90% uranium recovery can be achieved after 2-3 months of leaching.

Uranium production centres technical details

(as of 1 January 2023)

	Centre #1	Centre #2	Centre #3	Centre #4	Centre #5
Name of production centre	Ingulska mine	Smolinska mine	Novokostyantynivska mine	Safonivska mine	Severinska mine
Production centre classification	Existing	Existing	Existing	Planned	Planned
Date of first production (year)	1968	1973	2011	N/A	N/A
Source of ore:					
Deposit name(s)	Michyrinske, Tsentralne	Vatutinske	Novokostyantynivske	Safonivske	Severinske Podgaytsevske
Deposit type(s)	Metasomatic	Metasomatic	Metasomatic	Sandstone	Metasomatic
Recoverable resources (tU)	51 810	1 577	79 830	2 248	45 060
Grade (% U)	0.1	0.11	0.14	0.02	0.1
Mining operation:					
Type (OP/UG/ISL)	UG	UG	UG	ISL	UG
Size (tonnes ore/day)	2 000	2 000	6 000	N/A	4 200
Average mining recovery (%)	95	96	96	75	96
Processing plant:					
Acid/alkaline	Acid	Acid	Acid	Acid	Acid
Type (IX/SX)	IX	IX	IX	IX	IX
Size (tonnes ore/day) For ISL (mega or kilolitre/day or litre/hour)	N/A	N/A	N/A	20 000 kilolitre/day	N/A
Average process recovery (%)	93	94	94	95	92
Nominal production capacity (tU/year)	450	500	1 500	150	1 200
Plans for expansion (yes/no)	Yes	No	No	No	No

Ownership of uranium industry

At present all enterprises in the Ukrainian uranium industry (geology, mining, processing) are owned by the state. The State Enterprise "VostGOK" ("Eastern Ore Dressing Complex") belongs to the Ministry of Energy of Ukraine. The State Enterprise "Kirovgeology" is responsible for geological surveys, resource evaluations and exploration of deposits in Ukraine. It is part of the State Service of Geology and Resources of Ukraine, in the Ministry of Ecology and Natural Resources.

Secondary sources of uranium

- Mixed oxide fuel (MOX) has never been produced in Ukraine or used in its nuclear power plants.
- Re-enriched tails have never been produced or used in Ukraine.
- Reprocessed spent nuclear fuel is not produced or used in Ukraine.

Environmental activities and socio-cultural issues

The main environmental impacts of uranium production at mines come from ore stockpiles, tailings, radiometric ore-sorting sites, waste dumps, ventilation systems infrastructure and transport (railways, technological roads).

The main environmental impacts from the hydrometallurgical process plant and heap leaching sites are harmful chemical and ore dust emissions, airborne transportation of aerosols and groundwater contamination from tailings impoundments. Permanent monitoring is conducted to control the environmental impacts.

In the hydrometallurgical plant (Zhovti Vody), process water is recycled for the technological process. There are two tailings impoundments. One is situated 9 km from the hydrometallurgical plant, consisting of two sections (614.9 ha containing 45.346 Mt of waste) with total activity of $455.68 \cdot 10^{12}$ Bq, and the second is 0.5 km from the plant (55 ha containing 16 Mt of waste) with total activity of $93.3 \cdot 10^{12}$ Bq. The second one is no longer used and reclamation is ongoing.

There are also issues connected with the decommissioning of uranium mining and uranium processing enterprises.

At the closed Prydniprovskyy Chemical Plant, there are nine tailings impoundments (covering a total area of 268 ha containing 42 Mt of waste) with a total activity of $2\,775 \cdot 10^{12}$ Bq and some buildings and other facilities are contaminated by radioactive elements. The Cabinet of Ministers of Ukraine has had a state programme for the reclamation of sites since 2005.

The total cost of improving radiological protection across all enterprises in the nuclear industry and all contaminated areas resulting from the mining and processing of uranium is expected to amount to USD 360 million, including decontamination of polluted soils, environmental monitoring, installation of monitoring systems where necessary, and improved technology for the management of water flows, radioactive rocks in dumps, polluted equipment and land areas.

Uranium requirements

As of 1 January 2023, 15 reactors were operating at 4 nuclear power plants: 6 VVER-1000 units at Zaporizhzhia, 3 VVER-1000 units at South Ukraine, 2 VVER-1000 units and 2 VVER-400 units at Rovenskyy, and 2 VVER-1000 units at Khmelnitskyy.

Uranium production in Ukraine meets 30% of domestic nuclear energy requirements. Until 2022 nuclear fuel has always been provided by importing from Russia (TVEL) and Westinghouse

Electric (United States). At present all contracts with Russia are broken down and fuel will be imported from Westinghouse Electric. Annual fuel loadings of the 4 operating nuclear power plants (comprised of 13 VVER-1000 units and 2 VVER-440 units) are 15 sets of fuel elements at a total cost of about USD 500 million and around 2 500 tU. The "Energy Strategy of Ukraine to 2035", which was approved by the government in 2017, set a target that uranium requirements for the Ukrainian nuclear reactors be met by domestic production.

Implementation of the national programme for nuclear energy development by 2035 will involve increasing installed capacity of nuclear energy up to 26.2GWe. The target is to almost double annual nuclear energy production to about 160 TWh or additional 75 TWh. This will require a life extension for operating nuclear power plants, the construction of 12 additional units (with total capacity of 15 000 MWe), and during this time frame, the decommissioning of 12 nuclear power plants that will reach the end of their operational lifetime.

The programme was under government review in 2021 and postponed as a result of the armed conflict in Ukraine that started in 2022.

Uranium policy, uranium stock and uranium price

In 2017, the Ukrainian government approved the "Energy Strategy of Ukraine to 2035". Ukraine views nuclear generation as an economic and carbon-free energy source and plans to increase the nuclear energy portion in the total energy balance up to 2035. This serves as background for uranium policy.

The Ukrainian government's uranium policy includes the following goals:

- improve the uranium resource base through the exploration of new uranium deposits;
- increase uranium production by mining existing uranium deposits;
- extend the range of components that Ukraine manufactures for nuclear fuel assemblies;
- create a stock of uranium concentrate (U_3O_8);
- diversify nuclear fuel supply.

The Ukrainian operator of nuclear power plants SE NNEGC "Energoatom's" plans to import nuclear fuel from Westinghouse Electric and uranium, for the fuel manufacturing, from Cameco Corporation, with whom Ukraine has reached agreement on commercial terms for a major supply contract in February 2023.

At present the construction of a nuclear fuel plant is not crucial.

A decision to build a central storage facility for used fuel from domestic VVER reactors in the Chernobyl exclusion zone (Law of Ukraine N4384, dated 2 September 2012) was made by the government in 2012. "Holtec International" (United States), was chosen as the design company, with initial commissioning planned for 2016, but the first storage facility was opened in August 2021 and now accepts used fuel from the Khmelnitsky, Rovensky and Uzhno-Ukrainian nuclear power plants.

In August 2021, Ukrainian "Energoatom" signed a Memorandum with Westinghouse Electric (United States), for the construction of five nuclear power units.

A nuclear power unit (AP 1000) will be constructed at the Khmelnitsky Nuclear Power Plants as a pilot project, with a plan to build three more reactors in the future. The total cost of the project is estimated at USD 30 billion.

Uranium exploration and development expenditures and drilling efforts – domestic

(UAH million as of 1 January 2023)

	2019	2020	2021	2022
Industry* exploration expenditures	0	0	0	0
Government exploration expenditures	5.8	1.9	8.0	0
Industry* development expenditures	39.3	24.4	70.0	0
Government development expenditures	13.4	21.1	16.4	4.7
Total expenditures	58.5	47.4	94.4	4.7
Industry* exploration drilling (m)	0	0	0	0
Industry* exploration holes drilled	0	0	0	0
Government exploration drilling (m)	601	0	1 485	0
Government exploration holes drilled	2	0	18	0
Industry* development drilling (m)	0	0	0	0
Industry* development holes drilled	0	0	0	0
Government development drilling (m)	10 524	12 740	9 710	2 065
Government development holes drilled	624	688	561	98
Subtotal exploration drilling (m)	601	0	1 485	0
Subtotal exploration holes drilled	2	0	18	0
Subtotal development drilling (m)	10 524	12 740	9 710	2 065
Subtotal development holes drilled	624	688	561	98
Total drilling (m)	11 125	12 740	11 195	2 065
Total number of holes drilled	626	688	579	98

* Non-government.

Reasonably assured conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining	0	41 094	69 197	116 232	88.4
In situ leaching acid	0	3 718	3 718	3 718	75.0
Total	0	44 812	72 915	119 950	

Reasonably assured conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	41 094	69 197	116 232	88.4
In situ leaching acid	0	3 718	3 718	3 718	75.0
Total	0	44 812	72 915	119 950	

Reasonably assured conventional resources by deposit type
(recoverable tonnes U)

Deposits type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	3 718	3 718	3 718
Metasomatite	0	41 094	69 197	116 232
Total	0	44 812	72 915	119 950

Inferred conventional resources by production method
(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining	0	26 284	33 416	60 652	88.7
In situ leaching acid	0	402	402	4 152	75.0
Total	0	26 686	33 818	64 804	

Inferred conventional resources by processing method
(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	26 284	33 416	60 652	88.7
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Inferred conventional resources by deposit type
(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Sandstone	0	402	402	4 152	75.0
Metasomatite	0	26 284	33 416	60 652	88.4
Total		26 686	33 818	64 804	

Prognosticated conventional resources
(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	8 400	22 500

Speculative conventional resources
(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	120 000	255 000

Historical uranium production by production method

(tonnes U in concentrate)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Open-pit mining*	10 000	0	0	10 000	0
Underground mining*	110 515	496	120	111 131	300
In situ leaching	3 925	0	0	3 925	0
Co-product/by-product	10 000	0	0	10 000	0
Total	134 440	496	120	135 056	300

* Pre-2018 totals may include uranium recovered by heap and in-place leaching.

Historical uranium production by processing method

(tonnes U in concentrate)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Conventional	130 076	496	120	130 692	300
In situ leaching	3 925	0	0	3 925	0
In-place leaching*	26	0	0	26	0
Heap leaching**	413	0	0	413	0
Total	134 440	496	120	135 056	300

* Also known as stope leaching or block leaching.

** A subset of open-pit and underground mining, since it is used in conjunction with them.

Historical uranium production by deposit type

(tonnes U in concentrate)

Deposits type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Sandstone	3 925	0	0	3 925	0
Granite-related	35 000	0	0	35 000	0
Metasomatite	95 515	496	120	96 131	300
Total	134 440	496	120	135 056	300

Ownership of uranium production in 2022

Domestic				Abroad				Total	
Government		Private		Government		Private			
(t U)	(%)	(t U)	(%)	(t U)	(%)	(t U)	(%)	(t U)	(%)
120	100	0	0	0	0	0	0	120	100

Uranium industry employment at existing production centres

(persons/years)

	2021	2022	2023 (expected)
Total employment at existing production centres	3 721	3 642	3 644
Direct employment at uranium production	1 295	1 267	1 267

Mid-term production projections (tonnes U/year)

2023	2024	2025	2030	2035	2040
300	500	800	1 500	1 500	2 000

Mid-term production capability (tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
N/A	N/A	800	1 000	N/A	N/A	1 500	1 700

2035				2040			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
N/A	N/A	1 500	1 700	N/A	N/A	N/A	N/A

Net nuclear electricity generation

	2021	2022
Net nuclear electricity generation (TWh net)	86.0	N/A

Installed nuclear generating capacity to 2040

(GWe net)

2021	2022	2025		2030		2035		2040	
		Low	High	Low	High	Low	High	Low	High
13.8	13.8	13.8	13.8	16.5	20.2	18.8	26.2	26.0	30.5

Annual reactor-related uranium requirements to 2040 (excluding MOX)

(tonnes U)

2021	2022	2025		2030		2035		2040	
		Low	High	Low	High	Low	High	Low	High
2 480	N/A	2 480	2 480	3 020	3 660	3 600	4 800	4 800	5 300

United States

Uranium exploration and mine development

Historical review

From 1947 through 1970, the US government fostered a domestic private-sector uranium exploration and production industry to procure uranium for military uses and to promote research and development in peaceful atomic energy applications. By late 1957, both the number of new deposits that private industry brought into production and production capability had increased sufficiently to meet projected requirements. Federal exploration programmes ended at that time.

Private exploration by the US uranium industry increased throughout the 1970s in response to rising prices and the projected high demand for uranium to fuel an increasing number of nuclear reactors under construction or planned for construction to power civilian electric generation stations. Total annual surface drilling peaked in 1978.

Exploration has been primarily for sandstone-type uranium deposits in districts such as the Colorado Plateau, the Wyoming Basin and the Texas Coastal Plain uranium provinces.

Recent and ongoing uranium exploration and mine development activities

In 2021 and 2022, the uranium industry in the United States continued to contract most of its uranium requirements from non-domestic sources. Market activity reached its lowest point in 2021 but increased in 2022. Total uranium industry expenditures increased from USD 72.5 million in 2021 to USD 84.7 million in 2022. Exploration and development drilling activity data were released again in 2022 by the US Energy Information Administration (EIA) after four years of being withheld due to extremely low levels of drilling activity. In 2022, nuclear power plant operators paid the highest uranium prices since 2018 for long-term contracts and 2013 for spot contracts. Private companies that explore for and produce uranium in the United States have started to increase activity due to sustained higher uranium prices and uranium purchases by the federal government. These purchases were publicly announced in late 2022 as part of a newly funded federal programme to purchase US-produced uranium to be held in a national reserve.

United States uranium expenditures, 2010–2022 (USD million)

Year	Drilling	Production	Land and other				Total expenditures
			Total land and other	Land	Exploration	Reclamation	
2010	44.6	133.3	99.5	20.2	34.5	44.7	277.3
2011	53.6	168.8	96.8	19.6	43.5	33.7	319.2
2012	66.6	186.9	99.4	16.8	33.3	49.3	352.9
2013	49.9	168.2	90.6	14.6	21.6	54.4	308.7
2014	28.2	137.6	74.0	11.6	10.7	51.7	239.7
2015	28.7	118.5	76.2	12.1	4.7	59.4	223.5
2016	22.3	98.0	49.6	9.9	2.5	37.2	169.9
2017	4.0	78.3	40.2	8.9	3.7	27.7	122.5
2018	W	65.9	W	W	W	W	108.8
2019	W	38.0	W	W	W	W	81.0
2020	W	40.0	W	W	W	W	87.0
2021	W	29.2	W	8.6	W	W	72.5
2022	9.4	22.2	53.1	11.4	5.4	36.4	84.7

Source: US Energy Information Administration, *Domestic Uranium Production Report*, 2022, Table 8

Notes: Expenditures are in nominal USD. Totals may not equal the sum of components because of independent rounding.

W = data withheld to avoid disclosure of individual company data

Drilling = all expenditures directly associated with exploration and development drilling

Production = all expenditures for mining, milling, processing of uranium, and facility expense

Total land and other = all expenditures for land; geological research; geochemical and geophysical surveys; costs incurred by field personnel during exploration, reclamation, and restoration work; and overhead and administrative charges directly associated with supervising and supporting field activities

United States uranium drilling activities, 2010–2022

Year	Exploration drilling		Development drilling		Exploration and development drilling	
	Number of holes	Metres (thousand)	Number of holes	Metres (thousand)	Number of holes	Metres (thousand)
2010	2 439	445	4 770	1 050	7 209	1 495
2011	5 441	1 013	5 156	915	10 597	1 928
2012	5 112	1 051	5 970	1 131	11 082	2 181
2013	1 231	280	4 013	892	5 244	1 172
2014	W	W	W	W	1 752	396
2015	W	W	W	W	1 518	268
2016	W	W	W	W	1 158	231
2017	W	W	W	W	420	60
2018	W	W	W	W	W	W
2019	W	W	W	W	W	W
2020	W	W	W	W	W	W
2021	W	W	W	W	W	W
2022	259	46	749	117	1 008	163

Source: US Energy Information Administration, *Domestic Uranium Production Report*, 2022, Table 1

Note: Totals may not equal the sum of components because of independent rounding.

W = data withheld to avoid disclosure of individual company data

Conventional and in situ recovery mine development

At the end of 2022, two US uranium in situ recovery (ISR) plants were operating with a combined capacity of 7.5 million pounds of uranium oxide (U_3O_8) (2 900 tU) per year (the Lost Creek Project and the Smith Ranch-Highland Operation in Wyoming). Production was residual from previously developed well fields, and no new well fields were developed during this period. Nine ISR plants were on standby at the end of 2022, and nine new ISR plants were planned across four states: New Mexico, South Dakota, Texas and Wyoming.

The United States has conventional and ISR-amenable mines and deposits with some degree of permitting or development. Most of these are indefinitely paused, awaiting more favourable market conditions. Although this is not a comprehensive review of the status of these uranium mines and properties, noteworthy activities or developments during 2021 and 2022 are described in this report. Developments not directly related to uranium production, such as property transfers, incremental permitting, resource updates and financial actions, are not included.

Texas

- Burke Hollow (ISR – Uranium Energy Corporation): In 2021 and 2022, resource delineation drilling and wellfield development were carried out at Burke Hollow. In 2022, 106 monitor wells were installed in the first wellfield (PAA-1), baseline sampling commenced, permitting continued, and delineation drilling was expanded throughout the deposit area.
- Rosita (ISR – enCore Energy Corp.): Work in 2021 and 2022 focused on updating the infrastructure of the processing plant, installing and sampling monitoring wells, and permitting for production in 2023.

Wyoming

- Nichols Ranch (ISR – Energy Fuels Inc.): The Nichols Ranch project has been on standby since 2018, with only minimal production in 2021 and 2022 from previously developed wellfields.
- Lance (ISR – Peninsula Energy Ltd.): This project produced uranium between 2015 and 2019 and has since been on standby. In October 2022, Strata Energy received an amendment to its radioactive materials licence from the Wyoming Department of Environmental Quality that allows them to use low pH lixiviants (natural ground water with sulphuric acid, hydrogen peroxide or oxygen, compressed air, or sodium chlorate) within certain parameters. Previously, only alkaline lixiviants (native groundwater with carbon dioxide, sodium carbonate or sodium bicarbonate, and hydrogen peroxide or oxygen) were allowed. Except for small pilot projects that occurred mostly in the 1980s, no low pH ISR mining had occurred in the United States, and this licensing action represents a marked shift in the direction of permitting.
- Lost Creek (ISR – Ur-Energy Inc.): New wellfields were not developed in 2021–22, but residual production from previously developed wellfields continued. The project includes infrastructure (header house) development and permitting in support of a rapid return to production if market conditions improve.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

At the end of 2022, estimated uranium reserves (in situ reasonably assured resources [RAR]) were 168 182 tU at a maximum forward cost of less than USD 45 per kilogram of uranium (kgU).

Private companies prepare the estimates of uranium resources. These estimates change each year due to production (resource depletion), changes in resource estimation, site boundary expansions and evolving production costs. Industry participants prepare the uranium resource estimates and report them to the US Energy Information Administration (EIA), which aliases the resources by tabulating them into states or regions without further analysis.

Undiscovered conventional resources (prognosticated and speculative resources)

A 1984 Memorandum of Understanding between the US Department of the Interior, US Geological Survey (USGS), and US Department of Energy (US DOE) assigns responsibilities for assessing potential or undiscovered uranium resources to the USGS. In 2021 and 2022, the USGS did not complete any undiscovered resource estimates due to staffing shortfalls. Progress was made towards completing some of the elements that are required for the USGS 3-part assessment. Specifically updated deposit models were completed for two prospective areas (the southern Appalachian and Colorado Plateau regions), and a grade and tonnage database was compiled for one region (the Colorado Plateau). The southern Appalachian deposit model was based on a comprehensive multiyear analysis of the Coles Hill metasomatite deposit and provides a model that predicts prospective trends in the southeastern US Piedmont region. The Colorado Plateau model includes new research that supports: 1) alternative sources for uranium, 2) a novel preservation mechanism, and 3) methods to predict the location of additional deposits in the Morrison and Chinle mineral systems in Utah, New Mexico and Colorado using analysis of paleogeography, paleoclimate and subsurface facies analysis. A database of uranium occurrences for the Colorado Plateau region was compiled using a "cluster method" of analysis. Because of the large number of occurrences in the region (over 4 000 occurrences, of which over 1 200 were mined), occurrences within the same host rock were compiled into circular 25-mile diameter areas for analysis. This work is published in peer-reviewed open-access journals1. An updated deposit model for breccia-pipe deposits in the Colorado Plateau is in preparation.

Uranium production

Historical review

Following the passage of the Atomic Energy Act of 1946 (AEA), designed to meet the US government's uranium procurement needs, the Atomic Energy Commission (AEC) fostered the development of a domestic uranium industry (chiefly in the western United States) from 1947 through 1970 through incentive programmes for exploration, development and production. To ensure the supply of uranium ore would be sufficient to meet future needs, the AEC, in April 1948, announced a domestic ore procurement programme designed to stimulate prospecting and build a domestic uranium mining industry. The AEC also negotiated concentrate procurement contracts, under the AEA (as amended in 1954), with guaranteed prices for source materials delivered within specified times. Contracts were structured to allow milling companies that built and operated mills the opportunity to repay plant costs during the procurement-contract period. By 1961, 27 mills were operating. Overall, 32 conventional mills and several pilot plants, concentrators, upgraders, heap leach, and solution-mining facilities were operating at various times. The AEC, as the sole government purchasing agent, provided the only US market for uranium. Although many of the mills closed soon after completing deliveries scheduled under AEC purchase contracts, several mills continued to produce concentrate for the commercial market after fulfilling their AEC commitments.

The AEA, as amended, legalised the private ownership of nuclear reactors for commercial electricity generation. By late 1957, domestic ore reserves and milling capacity were sufficient to meet government needs. In 1958, the AEC's procurement programmes were reduced in scope, and to foster atomic energy use for peaceful purposes, domestic ore and concentrate producers were allowed to sell uranium to private domestic and foreign buyers. The first US commercial-market contract was finalised in 1966. The AEC announced in 1962 an extension of its procurement programme that committed the government to take only set annual quantities of

1 Hall, S.M., J.S. Beard, C.J. Potter, R.J. Bodnar, L.A. Neymark, J.B. Paces, C.A. Johnson, G.N. Breit, R.A. Zielinksi and G.J. Aylor Jr. (2022), "The Coles Hill Uranium Deposit, Virginia, USA: Geology, Geochemistry, Geochronology, and Genetic Model", *Economic Geology* and the *Bulletin of the Society of Economic Geologists*, v. 117, no. 2, p. 273-304; Hall, S.M., B.S. Van Gosen and R.A. Zielinksi (2023), "Sandstone-hosted uranium deposits of the Colorado Plateau", United States, *Ore Geology Reviews*, v. 155, p. 39.

uranium from 1967 through 1970. This programme change also helped sustain a viable domestic uranium industry. The US government's natural uranium procurement programme ended in 1970, and the industry became a private sector, commercial enterprise with no government purchases. The government, however, continues to monitor private industry exploration and development activities to the extent of meeting federal information and data needs.

Exploration by the US uranium industry increased through the 1970s in response to rising prices and the projected large demand for uranium to be used to fuel an increasing number of commercial nuclear power plants that were under construction or planned. US production peaked in 1980 (16 809 tU) and generally declined until 2003. Beginning in 2004, production began increasing again in response to rising uranium prices. Production began decreasing in 2013 in response to an oversupply of uranium on the world market and the resulting lower uranium prices. In 2022, exploration and development drilling activities began to rise again, and the EIA released exploration and drilling activity data again, after four years of withholding them due to low levels of drilling activity.

Status of production facilities, production capability, recent and ongoing activities and other issues

US uranium mines produced 75 tU in 2022, a significant increase from 2021. Production in 2022 came from five facilities: four ISR plants in Nebraska and Wyoming (Crow Butte Operation, Ross CPP, Nichols Ranch, and Smith Ranch-Highland Operation) and the White Mesa Mill in Utah. Centres that produced uranium in 2022 are listed in the table below.

Ownership structure of the uranium industry

Uranium facilities that produced uranium in 2021 and 2022 are owned by public and privately held firms with both foreign and domestic participation.

Employment in the uranium industry

Employment in the raw materials sector (exploration, mining, milling and processing) of the US uranium industry generally declined from 1998 to 2003, and then steadily increased from 2004 to 2008. Employment in the uranium industry in 2009 decreased significantly for the first time after five years of gains, but from 2009 through 2012, total uranium employment made marginal gains. Since 2012, however, uranium employment has declined with the lower production. In 2022, total employment in the US uranium production industry was 196 person-years (including reclamation employment), a 5% decrease from the 2021 total of 207 person-years and the lowest on record. In 2022, employment in the uranium production industry spanned at least three states: Colorado, Texas and Wyoming.

Future production centres

Several future production centres are currently in either the permitting or licensing process or under development. Significant activities affecting these production centres are described in the previous sections on conventional and ISR mine development.

Uranium production centre technical details

(Centres that produced uranium between 1 July 2021 and 31 December 2022)

	Centre #1	Centre #2	Centre #3	Centre #4	Centre #5
Name of production centre	Crow Butte	White Mesa Mill	Smith Ranch-Highland and North Butte-Brown Ranch	Ross	Nichols Ranch
Production centre classification[1]	Existing	Existing	Existing	Existing	Existing
Date of first production	1991	1980	1988	2015	2014
Source of ore					
Deposit name	Crow Butte	Alternative feed material and pond returns	Smith Ranch, Highland, North Butte and Brown Ranch	Ross (Lance Projects)	Nichols Ranch, Jane Dough and Hank
Deposit type	Sandstone	Sandstone, breccia pipe	Sandstone	Sandstone	Sandstone
Recoverable resources (tU)	W	W	W	W	NA
Grade (% U)	W	W	W	W	NA
Mining operation					
Type (OP/UG/ISR)	ISR	UG and Other	ISR	ISR	ISR
Size (metric tonnes of ore/day)	NA	NA	NA	NA	NA
Average mining recovery (%)	NA	NA	NA	NA	NA
Processing plant					
Acid/alkaline	Alkaline	Acid	Alkaline	Alkaline	Alkaline
Type (IX/SX)	IX	SX	IX	IX	IX
Size (metric tonnes of ore/day)		1 538			
Average process recovery (%)	NA	NA	NA	NA	NA
Nominal production capacity (tU/year)[1]	385	NA	2 116	144	769
Plans for expansion	Deferred	Unknown	Deferred	Planned stage expansion, depending on market conditions	Unknown
Other remarks[2]	Operating: Q2 2016 – Production curtailed, and wellfield development deferred	Operating	Operating: Q2 2016 – Production curtailed, and wellfield development deferred	Operating	Operating (Placed on standby status Q1 2020)
State	Nebraska	Utah	Wyoming	Wyoming	Wyoming

Source: US Energy Information Administration, *Domestic Uranium Production Report*, 2022, Tables 4 and 5

NA = not available

W = data withheld to avoid disclosure of individual company data

Secondary sources of uranium

Production and/or use of mixed oxide fuels

There is no production or use of mixed oxide fuel.

Production and use of re-enriched tails

The DOE and the Bonneville Power Administration initiated a pilot project to re-enrich a portion of the DOE's tails inventory. This project produced approximately 1 940 metric tonnes of low-enriched uranium between 2005 and 2006 for Energy Northwest's 1 190-megawatt electric (MWe) Columbia Generating Station's use between 2007 and 2015. In mid-2012, Energy Northwest and the United States Enrichment Corp. (USEC), with the DOE, developed a new plan to re-enrich a portion of the DOE's high-assay tails. The 2013 project produced approximately 3 738 metric tonnes of natural uranium, which will be used through 2029 to fuel Energy Northwest and Tennessee Valley Authority (TVA) reactors.

In 2016, the DOE agreed to sell depleted uranium to GE-Hitachi Global Laser Enrichment, LLC, (GLE) for enrichment at a proposed GLE facility over a 40-year period. GLE will finance, construct, own, and operate the Paducah Laser Enrichment Facility (PLEF) next to the DOE site. Silex Systems Ltd, an Australian-owned company developing the laser enrichment technology, has licensed GLE to supply the depleted uranium.

In February 2019, Silex Systems Ltd and Cameco Corp. agreed to restructure ownership of GLE with a joint purchase of GE-Hitachi Nuclear Energy's (GEH) share of GLE. Silex holds the majority at 51% and Cameco increased its share to 49%.

Production and/or use of reprocessed uranium

There is no use or production of reprocessed uranium.

Environmental activities and socio-cultural issues

Remediation activities

Navajo Nation

Within the Colorado Plateau uranium province, an estimated 523 occurrences were mined between 1944 and 1986 in the Navajo Nation. Historic mining and mine remediation practices were not compatible with modern techniques and resulted in environmental contamination throughout the Nation. Funded by legal settlements with private companies who operated the mines and the US Atomic Energy Commission that promoted uranium mining in the area, assessment and environmental remediation of 230 of the mines is planned or in process. The priority is to remediate those mines or areas that pose the highest risk of radiation exposure to the Navajo people. In addition, legal action is progressing that targets companies that developed the additional uranium mines not covered in previous settlement agreements.

Piketon

Decommissioning and environmental remediation continues at the Portsmouth Gaseous Diffusion Plant in Piketon, Ohio, which closed in 2001. In 2015, the DOE created a comprehensive plan to demolish the process buildings and support structures at the Portsmouth Gaseous Diffusion Plant. Crews were still demolishing and conducting clean-up activities as of the end of 2022.

Defense-Related Uranium Mines (DRUM) Program

Federal land management agencies, state abandoned mine land programmes, and tribal governments created the US DOE Office of Legacy Management's Defense-Related Uranium Mines (DRUM) Program to locate and evaluate hazards of the mines that supplied uranium to the US Atomic Energy Commission for defence-related activities. Field crews are validating the locations of these mines and scanning them for health hazards to human populations and wildlife. The programme is divided into three campaigns:

- Campaign 1 (in progress) has evaluated 2 158 of an estimated 2 362 mines on public land and is scheduled for completion in March 2024.
- Campaign 2 (in progress) has evaluated 27 of an estimated 221 mines on tribal lands and is scheduled for completion by 2027.
- Campaign 3 focuses on mines on private land and is scheduled to begin in 2024.

Information on the hazards identified by the DRUM programme is shared with partner agencies who can work to safeguard physical hazardous mine features such as open mine entries, areas of subsidence, or unstable highwalls.

Legislation/policy

Federal

In 2018, the US Department of the Interior included uranium on a list of 35 minerals that are critical to the national security and economy of the United States. The USGS initiated the Earth Mapping Resources Initiative (Earth MRI) to identify focus areas that likely contain critical minerals and to fund geophysical and geochemical surveys and mapping to help identify additional resources. In 2020, as part of Earth MRI, the USGS identified over 60 high-priority uranium focus areas that could contain undiscovered uranium resources. State geological surveys evaluated these sites and applied for funding to initiate studies of the mineral potential of select focus areas. An updated list of critical minerals published by the USGS in 2022 did not include uranium. Because uranium was dropped from the list, funding for follow-on studies of uranium focus areas identified by Earth MRI is no longer prioritised.

Regulatory regime

The US Nuclear Regulatory Commission (NRC), the US Environmental Protection Agency (EPA), and individual states regulate uranium recovery, but mining regulations for federal lands are administered through the federal agency that controls the land (such as the Bureau of Land Management). Before mining begins, Environmental Impact Statements must be completed, adequate bonding must be posted, and additional regulatory requirements specified by federal and state agencies must be satisfied.

As of December 2020, the NRC was reviewing uranium recovery licence applications for two ISR facilities (one renewal and one expansion), and the agreement states were reviewing three ISR applications (two expansions and one renewal).

US NRC uranium recovery licence applications

Facility	Facility type	Applicant
Crownpoint	ISR – Renewal (NRC)	Hydro Resources, Inc.
North Trend	ISR – Expansion (NRC)	Crow Butte Resources
LC East/KM Horizon	ISR – Expansion	Lost Creek ISR LLC
Kendrick	ISR – Expansion	Stata Energy, Inc.
Smith Ranch-Highland	ISR – Renewal	Power Resources, Inc.

Uranium requirements

Annual US uranium requirements are projected to decrease from 16 886 tU in 2020 to 16 727 tU in 2040 (EIA high-case estimate). They are expected to remain steady through the early 2030s and then marginally decrease by 2040 (see annual reactor-related uranium requirements to 2040 [excluding mixed oxide fuel]). The EIA based this decrease on the possibility that some nuclear power plants may retire early due to economic challenges in unregulated or competitive electricity markets after existing federal and state financial clean energy subsidies expire. These estimates include the continued operations of Watts Bar unit 2 in Tennessee, Diablo Canyon Units 1 and 2 in California, and the construction expansion project of Plant Vogtle for units 3 and 4 in Georgia, which are expected to be completed in 2024. Once fully commissioned, Plant Vogtle will be the largest nuclear power plant in the United States and one of the 10 largest nuclear power plants worldwide.

In 2022, the US Congress passed the Inflation Reduction Act (IRA), which contains several key financial provisions for the nuclear industry. The zero-emission nuclear power production credit provides up to USD 15 per megawatt-hour for electricity produced by nuclear power plants. The credit is available for operating nuclear power plants in 2024 and would last through 2032.

The US Congress also enacted the Bipartisan Infrastructure Law (BIL) in 2021 that established the USD 6 billion Civil Nuclear Credit Program to be administered by the US DOE Office of Nuclear Energy. Under the new programme, owners or operators of commercial nuclear power plants can apply for certification to bid on credits to support their continued operations. Credits will be allocated to selected certified reactors over a four-year period, beginning on the date of the selection, and credits can be awarded through 30 September 2031, if funds remain available. In November 2021, the DOE announced a conditional award of credits valued at up to USD 1.1 billion to Diablo Canyon, effectively reversing plant owner-operator Pacific Gas and Electric's decision to retire the facility by August of 2025.

Supply and procurement strategy

In the fiscal year 2021, the US Congress allocated USD 150 million to purchase US-sourced uranium from US mines to help ensure the continued vitality of the front end of the US nuclear fuel cycle. These purchases are intended to be held in a national uranium reserve. Purchases are being administered by the US National Nuclear Security Administration (NNSA). In December 2022, Energy Fuels (~115 tU), Peninsula Energy Ltd. (~115 tU), enCore Uranium (~38 tU), Uranium Energy Corporation (~115 tU), and Ur-Energy Inc. (~38 tU) announced that they had contracted to sell US-sourced uranium from existing inventories to the US uranium reserve for prices that average USD 164/kgU. US miners are optimistic that this programme will revitalise the US mining industry.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Currently, most of the uranium oxide (U_3O_8) commodity and technology used in the uranium enrichment process in the United States comes from foreign sources. US-sourced material accounted for 5% of total deliveries in 2022. In July 2022, the government increased funding for the Strategic Uranium Reserve to USD 4.3 billion to purchase enriched uranium directly from domestic producers and decrease imports. The government intends to augment development of domestically enriched uranium and produce domestically fabricated light-water nuclear reactor fuel. The US DOE's National Nuclear Security Administration is overseeing the direct purchase of an estimated 385 tU of domestically produced uranium oxide (U_3O_8), in up to four separate awards. The first awards were approved in December 2022. The United States operates only one commercial enrichment facility, located in New Mexico, which is owned by the British-German-Dutch consortium Urenco. The plan to expand domestic enrichment capabilities could include firms such as Centrus Energy and ConverDyn.

Advanced small modular reactors (SMRs) are an increasing part of the DOE goal to develop clean energy technologies with nuclear power options. The US DOE envisions SMRs that vary in size from tens of megawatts up to hundreds of megawatts. The US DOE has provided substantial support for the development of light water-cooled SMRs, which are under licensing review by the US Nuclear Regulatory Commission (NRC) and are expected to initially deploy in the late 2020s to early 2030s.

The existing US fleet of traditional full-sized reactors uses uranium fuel that is enriched up to 5% with uranium-235 – the main fissile isotope that produces energy during a chain reaction. High assay low-enriched uranium (HALEU) is enriched between 5% and 20% and is required for most US advanced reactors to achieve smaller designs that get more power per unit of volume. HALEU is expected to allow developers to optimise generation systems for longer reactor core life, increased efficiencies, and better fuel utilisation.

A three-year demonstration project is underway to send a strong signal to potential vendors that there will be a proven domestic capability to produce HALEU to meet demand. The US DOE is partnering with Centrus to manufacture 16 advanced centrifuges for deployment at an enrichment facility in Piketon, Ohio. The company's AC-100M machine was developed through the years with support from DOE and will demonstrate enrichment of uranium hexafluoride gas to produce HALEU. The HALEU will be used for advanced reactor fuel qualification testing and reactor demonstration projects. The AC-100M technology will be available for commercial deployment at the conclusion of the demonstration.

Uranium stocks

As of 2022, total commercial inventories (producer and utility stocks) were 54 139 tU, a 1% decrease from the 54 775 tU of inventories held in 2021. Owners and operators of commercial reactors held 74% of commercial inventories, or 40 129 tU. This holding was a 4% decrease from the 41 955 tU owned by this group at the end of 2021. Enriched uranium inventories held by utilities (including fuel elements in storage) increased 10% from 2021 to 2022 (from 16 702 tU in 2021 to 18 342 tU in 2022), whereas natural uranium inventories held by utilities (including uranium hexafluoride [UF_6] in storage) decreased 11% from 2021 to 2022 (from 21 702 tU in 2021 to 19 313 tU in 2022).

Uranium prices

Owners and operators of US civilian nuclear power reactors (civilian owners and operators, or COOs) purchased 15 577 tU of deliveries from US suppliers and foreign suppliers during 2022 at a weighted-average price of USD 101.61/kgU. As stated above, most uranium delivered in 2022 was of foreign origin. Canada was the top source, at 27% of total deliveries, edging out Kazakhstan, which had 25% of total deliveries. Uzbekistan accounted for 11% of total deliveries and Australia was fourth at 9% of total deliveries.

Domestically sourced material accounted for 5% of total deliveries in 2022. COOs purchased three material types of uranium for 2022 deliveries from 31 sellers. During 2022, 15% of the uranium delivered was purchased under spot contracts at a weighted-average price of USD 105.82/kgU. The remaining 85% was purchased under long-term contracts at a weighted-average price of USD 100.90/kgU. Spot contracts are contracts that typically have a one-time uranium delivery for the entire contract, and the delivery typically occurs within one year of contract execution (signed date). Long-term contracts are contracts with one or more uranium deliveries.

In 2022, COOs signed 27 new purchase contracts, with deliveries in 2022 of 1 769 tU at a weighted-average price of USD 108.86/kgU, specifically USD 125.92/kgU for spot contracts and USD 94.77/kgU for long-term contracts. COOs report minimum and maximum quantities of future deliveries under contract to allow the option of either decreasing or increasing quantities. At the end of 2022, the maximum uranium deliveries for 2023 through 2032 under existing purchase contracts for COOs totalled 85 770 tU. Also at the end of 2022, unfilled uranium market requirements for 2023 through 2032 totalled 68 847 tU. These contracted deliveries and unfilled market requirements combined represent the maximum anticipated market requirements of 154 618 tU over the next 10 years for COOs.

Average US uranium prices, 2008–2022

(USD per kilogram U-equivalent)

Year	Spot contracts	Long-term contracts
2022	105.82	100.90
2021	79.45	90.24
2020	74.6	90.3
2019	72.5	98.1
2018	71.52	106.56
2017	58.13	108.10
2016	76.82	119.59
2015	95.45	119.41
2014	95.26	129.29
2013	113.95	140.39
2012	132.69	144.68
2011	142.18	145.33
2010	114.36	131.11
2009	120.76	118.91
2008	174.06	108.12

Source: US Energy Information Administration, Uranium Marketing Annual Report, 2022, Table 7.

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Underground mining (UG)	0	W	W	W	NA
Open-pit mining (OP)	0	W	W	W	NA
In situ leaching alkaline	0	W	W	W	NA
Unspecified	0	0	0	0	NA
Total	0	W	W	168 182	NA

Source: US Energy Information Administration, *Domestic Uranium Production Report, 2022*, Table 10.

Note: US reserves data do not draw a distinction between UG and OP; the combined value is assigned to UG.

kgU = kilogram of uranium; W = data withheld to avoid disclosure of individual company data; NA = not available.

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from UG	0	NA	NA	NA	NA
Conventional from OP	0	NA	NA	NA	NA
In situ leaching acid	0	NA	NA	NA	NA
In situ leaching alkaline	0	NA	NA	NA	NA
In-place leaching*	0	NA	NA	NA	NA
Heap leaching** from UG	0	NA	NA	NA	NA
Heap leaching** from OP	0	NA	NA	NA	NA
Unspecified	0	NA	NA	NA	NA
Total	0	W	W	168 182	NA

Source: US Energy Information Administration, *Domestic Uranium Production Report*, 2022, Table 10.

* Also known as stope leaching or block leaching.

** A subset of open-pit and underground mining because the category is used in conjunction with both.

NA = not available; kgU = kilogram of uranium; UG = underground mining; OP = open-pit mining.

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unconformity-related	0	0	0	0	NA
Sandstone	0	W	W	168 182	NA
Intrusive	0	0	W	W	NA
Volcanic and caldera-related	0	0	W	W	NA
Other*	0	0	W	W	NA
Total	0	W	W	168 182	NA

Source: US Energy Information Administration, *Domestic Uranium Production Report*, 2022, Table 10.

* Includes surficial, collapse breccia pipe, phosphorite, and other types of deposits, as well as rocks with elevated uranium content. Pegmatite, granites and black shale are not included.

NA = not available; kgU = kilogram of uranium.

Historical uranium production by production method

(tonnes U in concentrate)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Open-pit mining*	0	0	0	0	0
Underground mining*	NA	W	W	W	NA
In situ leaching	NA	W	W	W	NA
Co-product/by-product	NA	W	W	W	NA
Total**	376 990	8	75	377 073	NA

Source: US Energy Information Administration, *Domestic Uranium Production Report*, 2022, Table 2.

Note: Data are not available prior to 1968.

* Pre-2018 totals may include uranium recovered by heap and in-place leaching.

** also includes, in various years, mine water, mill site clean-up and mill tailings, and well field restoration as sources of uranium.

W = Data withheld to avoid disclosure of individual company data; NA = not available.

Historical uranium production by processing method[a]

(tonnes U in concentrate)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Conventional	NA	W	W	W	NA
In-place leaching*	NA	W	W	W	NA
In situ leaching	NA	W	W	W	NA
Other methods**	NA	W	W	W	NA
Total	376 990	8	75	377 073	NA

Source: US Energy Information Administration, *Domestic Uranium Production Report*, 2022, Table 3.

Note: Data are available from 1947 to present.

[a] May not equal production by method because it produces concentrates and may include ore mined and shipped to a mill during the same year, ore that was mined during a previous year and later shipped from mine-site stockpiles, or ore obtained from drawdowns of stockpiles maintained at a mill site. Uranium production by processing method may also include uranium from mill clean-up, mine water, tailings water, and other materials in various years.

* Also known as stope leaching or block leaching.

** Includes mine water treatment and environmental restoration.

W = data withheld to avoid disclosure of individual company data; NA = not available.

Historical uranium production by deposit type

(tonnes U in concentrate)

Deposit type	Total through end of 2019	2020	2021	2022	Total through end of 2022	2023 (expected)
Unconformity-related	NA	NA	NA	NA	NA	NA
Sandstone	NA	NA	NA	NA	NA	NA
Hematite breccia complex	NA	NA	NA	NA	NA	NA
Quartz-pebble conglomerate	NA	NA	NA	NA	NA	NA
Vein	NA	NA	NA	NA	NA	NA
Intrusive	NA	NA	NA	NA	NA	NA
Volcanic and caldera-related	NA	NA	NA	NA	NA	NA
Metasomatite	NA	NA	NA	NA	NA	NA
Other*	NA	NA	NA	NA	NA	NA
Total	NA	NA	NA	NA	NA	NA

* Includes surficial, collapse breccia pipe, phosphorite, and other types of deposits, as well as rocks with elevated uranium content. Pegmatite, granites and black shale are not included.

NA = not available.

Ownership of uranium production in 2022

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
0	0	W	W	0	0	W	W	W	W

Source: US Energy Information Administration, *Domestic Uranium Production Report*, 2022, Table 2.

W = data withheld to avoid disclosure of individual company data; tU = metric tonnes of uranium

Uranium industry employment at existing production centres

(person-years)

	2020	2021	2022	2023 (expected)
Total employment related to existing production centres[1]	W	125	91	NA
Employment directly related to uranium production[2]	W	83	W	NA

1. Source: US Energy Information Administration, *Domestic Uranium Production Report*, 2022, Table 6, all sectors except Reclamation.

2. Source: US Energy Information Administration, *Domestic Uranium Production Report*, 2022, Table 6, all sectors except Exploration and Reclamation.

NA = not available; W = data withheld to avoid disclosure of individual company data.

Short-term production capability

(tonnes U/year)

2025				2030				2035			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

2040				2045			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
NA	NA	NA	NA	NA	NA	NA	NA

NA = not available.

Re-enriched tails production and use[1]

(tonnes of natural U-equivalent)

Re-enriched tails	Total through end of 2019	2020	2021	2022	Total through end of 2022	2023 (expected)
Production	5 677.8	0	0	0	5 677.8	0
Use	1 939.8	0	0	0	1 939.8	0

1. 2017 and 2022 Data provided by Energy Northwest, owner-operator of the Columbia Generating Station.

Net nuclear electricity generation

(TWh net)

	2021	2022
Nuclear electricity generated	771.6	772.2

Installed nuclear generating capacity to 2040

(GWe net)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Annual reactor-related uranium requirements to 2040 (excluding mixed oxide fuel)

(metric tonnes U)

2021	2022	2025		2030		2035		2040		2045		2050	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	BA	NA	NA

Total uranium stocks

(tonnes natural U-equivalent)

Holder	Natural uranium stocks	Enriched uranium stocks	Depleted uranium stocks	LWR reprocessed uranium stocks[5]	Total
Government[1]	5 285	4 396	90 000	NA	99 681
Producer[2]	NA	NA	NA	NA	7 645
Utility[2]	24 072[3]	18 860[4]	NA	NA	42 933
Total	NA	NA	NA	NA	150 259

1. US government analysis of the *Potential Impacts of Uranium Transfers on the Domestic Uranium Mining, Conversion, and Enrichment Industries*, 2017.
2. US Energy Information Administration, *Uranium Marketing Annual Report*, 2018, Tables 22 and 23.
3. The value for natural uranium stocks in this table does not include natural uranium hexafluoride (UF6). Values for total utility natural uranium stocks in the text include natural UF_6.
4. The value for enriched uranium stocks in this table does not include fabricated fuel elements held in storage prior to loading in the reactor. Values for total utility enriched uranium in the text include fabricated fuel elements in storage.
5. Light water reactor (LWR).

Uzbekistan*

Uranium exploration and mine development

Historical review

Uranium exploration in Uzbekistan predates the 1945 start-up of uranium mining at the small vein ore deposits (Shakaptar, Uiguz Sai and others) in the Fergana Valley of Eastern Uzbekistan. Exploration conducted during the early 1950s, including airborne geophysical surveys, ground radiometry and underground work over the remote Kyzylkum desert in central Uzbekistan, led to the discovery of the Uchkuduk and Ketmenchi uranium deposits in 1952, the Bukinai deposit in 1959, the Sabyrsai deposit in 1960, and the South Bukinai, Sugraly and Lyavlyakan deposits in 1961. All deposits were discovered by the Krasnokholmskaya exploration company, which was renamed Kyzyltepageologia in 1990. Drilling confirmed the initial discovery and development of the first mine at the Uchkuduk deposit in 1959, followed by development of the Sabyrsai deposit. Both deposits were initially mined using open pit and underground mining methods until 1975.

In the early 1960s, development of the in situ leaching (ISL) mining technique for recovery of uranium from sandstone deposits led to the re-evaluation of previously ignored deposits including Lavlyakan and Ketmenchi and to an increase in exploration efforts in the sedimentary basins of the Kyzylkum desert. Three uranium districts with 24 sandstone-type deposits amenable to ISL mining have been established since the Uchkuduk discovery in 1952.

Several black shale type uranium deposits, including Dzhantuar, Rudnoye, Kostcheka, Voskhod and Dzitym, were identified during the 1960s in the Auminzatau Mountains district. Mineralisation is in black shale related to strata-structure-type and occurs in stratiform and stockwork lodes. Resources of individual deposits are relatively small, and grades range from 0.02 to 0.13% U, averaging 0.05% U.

Since 1994, the Navoiy Mining and Metallurgy Combinat (NMMC) has funded all uranium exploration activities in Uzbekistan. In 1995-1996, Kyzyltepageologia developed the known resources of the Severny (Northern) Kanimekh, Alendy, Kendykijube and Tokhumbet deposits. In addition, assessments of undiscovered resources were completed in the Kyzylkum, Bukhara-Khiva and Fergana Provinces.

Between 1997 and 2000, Kyzyltepageologia evaluated the known resources of the Kendyktyube, Severny, Kanimekh, Tokhumbet and Ulus deposits, some of which were handed over to NMMC for further investigation. Delineation drilling was carried out in 2002 on the Kendytyube and Tokhumbet deposits, then transferred to Mining Division No. 5 for commercial development.

From 2003 to 2004, Kyzyltepageologia completed exploration and evaluation works in the Kendyktyube and Tokhumbet deposits, the southwestern flanks of the Sugraly deposit, and the western and eastern flanks of the Ketmenchi deposit. Kyzyltepageologiya further explored the northern and southern areas of Central Kyzylkum with government funding.

* Report prepared by the NEA/IAEA, based on previous Red Books, a report submitted by the Navoiyuran and public data.

In August 2009, GoscomGeology (State Geology and Mineral Resources Committee) and the China Guangdong Nuclear Uranium Corp. (CGN-URC) set up a 50%-50% uranium exploration joint venture, Uz-China Uran, to focus on the black shale deposits in the Boztau area of the Central Kyzylkum Desert in the Navoi region. Approximately 5 500 tU resources have been reported. From 2011-2013, CGN-URC was to develop technology to produce uranium and vanadium from these black shale deposits. No activities have been reported since that time.

In July 2013, the Japan Oil, Gas and Metals National Corporation (JOGMEC) received a five-year licence for uranium exploration at two prospective areas in the country's Navoi region. JOGMEC indicated that they would implement geological exploration work in the Uchkuduk and Tamdiykuduk-Tulyantash prospective ore fields. Historical uranium resources discovered at the licensed sites total about 13 000 tU according to Uzbekistan government data. No activities have been reported since that time.

Development of Uzbekistan's black shale deposits was indefinitely delayed due to complicated processing technology and unfavourable uranium prices.

Recent and ongoing uranium exploration and mine development activities

In July 2022, Uzbekistan's President Shavkat Mirziyoyev signed a resolution to double the country's uranium production from 3 500 tU in 2021 to 7 100 tU in 2030 and increase uranium resources to 100 000 tU by 2030. Uzbekistan's ability to reach this target will depend on rapid expansion of its resource base to continue replacing deposits that are being exhausted.

The Navoiyuran subsidiary, Scientific and Production Center "Geology of Uranium and Rare Metals", is responsible for all uranium exploration activities in the country. It has three geological expeditions (Bukantau, Nuratinsk and Zirabulak) that conduct exploration within the Bukantau, Bukinai, Ziyavutdin-Zirabulak and Syrdaria uranium ore provinces, respectively. Exploration is focused on ISL amenable resources, expansion of known operating deposits and on resources identification at new prospective areas.

Navoiyuran reports on significant recent exploration drilling activities focused on the above-mentioned Presidental resolution execution. Navoiyuran drilled in a range of 1 539 to 1 734 holes annually during 2020-2022 and plans to increase drilling to 2 551 holes (more than 1 million metres of drilling) in 2023. Exploration expenditures have more than tripled during the past four years, from USD 11.32 million in 2020 to USD 38.2 million in 2023. Intensive exploration resulted in an additional 3 967 tU resources estimation in 2021 and 5 827 tU in 2022, about 95% of which are in the RAR category. Resources identified near to existing mines may be involved in rapid development.

Navoiyuran plans to proceed with active exploration in areas both near existing mines and at new prospective areas. The target is to estimate more resources, starting from 5 500 tU in 2023 and to increase that figure to 10 500 tU in 2030. The aggregated amount of targeted additional resources through this period is about 63 000 tU.

In December 2019, France and Uzbekistan established the French-Uzbek uranium joint venture, the Nurlikum Mining LLC, which is 51% owned by Orano (formerly Areva) and 49% by Uzbekistan's State Committee on Geological and Mineral Resources (GoscomGeology). Nurlikum Mining will conduct uranium exploration and mining operations throughout Uzbekistan, focusing on sandstone-type uranium mineralisation in the Djengeldi region of Kyzylkum province. Orano contributes to the joint venture capital and technology, while the Uzbekistan side contributes historical exploration results.

Nurlikum's first field exploration commenced in 2020 and consisted of 40 drill holes. At the end of 2022, Nurlikum Mining had carried out more than 50 000 metres of hydrogeological and exploratory drilling. In June 2023, the company commissioned and launched the pilot plant at the Dzhengeldi deposit in order to confirm the feasibility of ISL mining. In November 2023, Orano reported that it had extracted its first 350 kgU from the Dzhengeldi deposit. Nurlikum Mining reported indicated resources of 4 070 tU and inferred resources of 2 813 tU. Information about Nurlikum exploration and development expenditures is not available.

Navoiyuran uranium exploration drilling effort – domestic (USD millions)

	2020	2021	2022	2023
Government exploration expenditures	11.32	11.41	13.73	38.22
Total expenditures	11.32	11.41	13.73	38.22
Government exploration drilling (m)	573 009	588 544	697 479	1 046 750
Government exploration holes drilled	1 734	1 539	1 647	2 551

Navoiyuran 2021-2022 uranium exploration results (estimated additional resources, tU)

	2021	2022
At existing deposits		
RAR	2 682	2 642
Inferred	214	0
At new areas		
RAR	1 071	2 854
Inferred	0	331
TOTAL		
RAR	3 753	5 496
Inferred	214	331
Identified	**3 967**	**5 827**

Uranium resources

Uzbekistan's uranium resources occur primarily in sandstone-type and black shale type deposits. All sandstone roll-front type uranium resources are found in the Central Kyzylkum area, comprising a 125 km-wide belt extending over about 400 km from Uchkuduk in the northwest, to Nurabad in the southeast. Only sandstone-type deposits have been exploited.

As of 1 January 2023, Uzbekistan's total identified in situ uranium resources reported by Navoiyuran amounted to 90 903 tU (63 633 tU recoverable resources assuming a 70% recovery factor), with about 85% of these belonging to the RAR category. About 82% of the total are sandstone-type resources amenable to ISL mining, while the remaining 18% refer to black shale type deposits requiring open pit or underground mining. About 70% of total resources (64 256 tU) are in the <USD 130/kgU cost category. The table below gives resources of deposits that were under Navoiyuran development in 2022 with a breakdown by categories and mining units. More than half (33 741 tU) of resources in cost category <USD 130/kgU are from existing mining operations.

Compared with the data as of 1 January 2021, this is a significant decrease of 79 382 tU in total identified in situ resources (an increase of 15 692 tU in the RAR category and a decrease of 95 074 tU in the inferred category). The main reason of the decrease is a write-off of high cost (above USD 260/kgU) inferred resources, including about 44 000 tU of black shales and 45 000 tU of sandstone type resources, which are not economically feasible for mining. Other change factors include inferred resources conversion to the reasonably assured category, addition of resources from favourable exploration results and annual depletion by mining. Some inconsistency in resources numbers with previous Red Books may be also explained by a long interval when Uzbekistan did not officially report to the IAEA on their uranium resources and production.

Prognosticated resources (P1 in national classification) are estimated at about 20 000 tU and speculative (P2) resources at 45 000 tU.

In situ resources of sandstone type deposits presently mined by the Navoiyuran

(tonnes U as of 1 January 2023)

Deposit	Resources category *		
	C_1 + B	C_2	B+C_1+C_2
Uchkuduk Mining Unit			
Uchkuduk	17	0	17
Kendyk-Tyube	394	0	394
Mejlisaj	2 699	28	2 727
Total Uchkuduk Mining Unit	**3 110**	**28**	**3 138**
Zafarobod Mining Unit			
Shimolij Bukinoi	3 262	147	3 409
Istiklol	2 686	109	2 795
Kukhnur	2 478	83	2 561
Aulbek	2 778	0	2 778
Karakata Aksai area	391	0	391
Zhanubij Bukinoi	24	0	24
North Kanimekh	4 075	2 005	6 080
Ketmonchi	1 096	44	1 140
Maibulok	548	0	548
Aksaj-1	126	0	126
Terekuduk	120	146	266
Dzhengeldy South East	733	0	733
Sugrali	157	3 292	3 450
Zhanubij Sugrali	1 706	0	1 706
Aktau	2 694	0	2 694
Total Zafarobod Mining Unit	**22 873**	**5 826**	**28 701**
Nurobod Mining Unit			
Shark	472	0	472
East Agron	631	0	631
Ingichki	802	0	802
Total Nurobod Mining Unit	**1 905**	**0**	**1 905**
TOTAL Navoiyuran	**27 888**	**5 854**	**33 744**

* Resource categories according to the national Uzbekistan classification system. B and C1 resources correlate with RAR and C2 with Inferred resources (see Appendix 3, Figure A3.1). Minor differences in totals are possible due to rounding.

Uranium production

Historical review

Uranium production in Uzbekistan began in 1946 at several small volcanic vein deposits in the Fergana valley and Kazamazar uranium district. The two largest deposits, Alatanga and Chauli, contained 4 500 tU each. Underground mining was undertaken from the late 1940s to the early 1960s. Cumulative production is estimated in the order of several thousand tU. The ore was processed in the Leninabad uranium production centre in Tajikistan.

The mining operator for the sandstone-type Uchkuduk and Sabyrsai deposits was Mining Complex No. 2, which was established in September 1958. In 1967, it was renamed the Navoi Mining and Metallurgy Combinat (NMMC). NMMC is part of the Uzbekistan state holding company Kyzylkumredmetzoloto, which undertakes all uranium mining in the country.

In the late 1950s, NMMC commenced operation, focusing on uranium and gold production in the desert region of Central Kyzylkum province. Early uranium mining was by underground (to 1990) and open pit (to 1994).

The first ISL tests occurred at the Uchkuduk deposit in 1963, followed by ISL tests at the Sabyrsai, South Bukinai and Ketmenchi deposits in 1968. Commercial ISL mining in Uzbekistan began in 1975. In 1980, ISL accounted for 29% of total uranium production and by 1985 ISL comprised 56% of total production. Since 1995, NMMC has been producing uranium using only ISL technology. Annual production peaked in the 1980s, when 3 700 to 3 800 tU were recovered.

In 2008, NMMC started mining the major new Northern Kanimekh deposit, northwest of Navoi. Northern Kanimekh ore occurs 260-600 m below the surface, with 77% of the uranium resources present at a depth of 400-500 m. NMMC has also started building a pilot plant for ISL at the Alendy and Yarkuduk deposits, and began operating the Aulbek ISL mine in Central Kyzylkum, as well as developing the Meilysai deposit. The Aulbek mine at the deposit of the same name commenced production in 2013.

NMMC has developed and implemented two new technologies of acid ISL for ores with high carbonate content. The first is a bicarbonate-acid method that is used for ores with a carbonate content above 2%. It is based on bicarbonate ion generation during the soft acidification stage, which oxidises and dissolves uranium minerals. This method reduces the kinetics of the leaching process, but chemical plugging may occur at the final leaching stage. The repair and restoration procedures for wells is reduced by 2.5-3 times using this method.

The second method uses a mini-reagent technology that is applied for ores with a carbonate content >0.5% located in an artesian aquifer. At the first stage, a preliminary ore oxidation occurs by pumping compressed air into the aquifer. At the second stage, slightly acidic solutions, formed during aquifer saturation with atmospheric oxygen, dissolve the contained uranium.

The implementation of these two technologies has significantly reduced acid consumption and in turn operating costs by 20-30%. Another important advantage has been the low impact of ISL mining on the total mineralisation and chemical composition of productive aquifers during and after the leaching process.

Status of production capability and recent and ongoing activities

In January 2022, NMMC was split into three independent entities – the Navoi Mining and Metallurgical Plant (production of precious metals such as gold), Navoiyuran (mining and processing of natural uranium and rare earth metals), and the Navoi Mining and Metallurgical Plant Foundation.

Navoiyuran produces uranium by ISL at three mining divisions:

- Uchkuduk Mining Unit (former Northern Unit) operates the Kendyktube and Mailisai deposits.
- Nurabad the Southern Mining Unit (former Southern Unit) operates the Sabyrsai deposit.
- Zafarabad Mining Unit (former Unit No. 5) is the largest division of the three, and operates the Northern Bukinai, Istikol, Beshkak, Ketmenchi, Sugraly, Tokhumbet, Kanimekh and other deposits.

All mining units produce "yellowcake" uranium concentrates on-site and send it by rail to the hydrometallurgical plant located in Navoi for further processing and purification. Navoiyuran exports all produced uranium to Canada, China, France, India, Korea and the United States.

In 2022, Navoiyuran was among the top six uranium mining companies in the world. It is the sole state uranium mining company in Uzbekistan. Annual production amounted to approximately 3 500 tU from 2019 to 2022. In 2022, 18 uranium deposits were in operation by ISL method and 4 more deposits are planned for development during 2022-2026. Mineralisation occurs at depths between 120 and 500 metres.

In July 2022, Uzbekistan's President signed a resolution to increase the country's uranium production from 3 500 tU in 2021 to 7 100 tU by 2030. Navoiyuran's ability to reach this target will depend on its ability to rapidly increase its resource base for ISL mining to continue replacing deposits that are being exhausted. Current identified resources are not sufficient to maintain current production levels in the long-term.

From 2025 to 2030, Navoiyuran plans to modernise operating mines, conduct technical and technological re-equipment, and expand existing uranium production facilities. To meet these plans, investment projects will be launched to construct new ISL mining and processing complexes at new sandstone-type uranium deposits.

Navoiyuran will also consider, in future, black shale-type uranium deposits development by open pit and underground methods. These deposits were explored in the 1970s and contain REE and vanadium as by-products to uranium. However, the known processing flowsheet for this type of ore is not effective and Navoiyuran is conducting research for its improvement.

Environmental activities

Navoiyuran promotes monitoring of working conditions and environmental protection. The local and central divisions of the national health monitoring authority, the National Committee for Nature Protection and the National Mining Monitoring Authority conduct radiation monitoring of all of Navoiyuran's activities. Monitoring data from peripheral observation wells shows that for productive aquifers at all ISL sites, the natural geochemical background of the formation water is unchanged at 200-300 m from the ore body boundary, regardless of the leaching technology used (sulphuric acid, bicarbonate-acid or mini-reagent). Radiation monitoring at work locations, supervised areas and the environment shows that the average annual effective radiation dose does not exceed permitted levels. For example, for a critical group of the population, radiation does not exceed one millisievert per year, which corresponds to the basic limit adopted by the International Commission on Radiological Protection (ICRP).

Ownership structure of the uranium industry

All uranium produced by Navoiyuran is owned by the government of Uzbekistan. In 2019, Uzbekistan began a major reorganisation of NMMC, separating the uranium mining division from gold enterprises. In March 2020, a presidential decree outlined official plans to create State Enterprise Navoiyuran, which will focus on uranium and rare earth metals, while NMMC will focus on gold, and state company NMMC Fund will manage non-core assets. The uranium business transformation to Navoiyuran was completed in 2022 and currently Navoiyuran is the sole enterprise in Uzbekistan that mines and exports uranium.

Employment in the uranium industry

Four towns support uranium production activities: mining divisions are based in Uchkuduk, Zafarabad and Nurabad, while the main processing plant for yellowcake purification and administrative staff are based in Navoi. Uranium industry employment in 2020 was about 7 500 and increased to 8 372 in 2022 after NMMC reorganisation completion.

Reasonably assured conventional resources by production method
(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
In situ leaching acid	0	35 570	57 358	66 331	70
Open pit	0	0	0	2 412	70
Underground	0	0	0	8 709	70
Total	0	35 570	57 358	77 452	

Reasonably assured conventional resources by processing method
(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
In situ leaching acid	0	35 570	57 358	66 331	70
Unspecified	0	0	0	11 121	70
Total	0	35 570	57 358	77 452	

Reasonably assured conventional resources by deposit type
(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Sandstone	0	35 570	57 358	66 331	70
Black shales	0	0	0	11 121	70
Total	0	35 570	57 358	77 452	

Inferred conventional resources by production method
(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
In situ leaching acid	0	5 181	6 898	7 841	70
Open pit	0	0	0	3 323	70
Underground	0	0	0	2 287	70
Total	0	5 181	6 898	13 451	

Inferred conventional resources by processing method
(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
In situ leaching acid	0	5 181	6 898	7 841	70
Unspecified	0	0	0	5 610	70
Total	0	5 181	6 898	13 451	

Inferred conventional resources by deposit type
(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Sandstone	0	5 181	6 898	7 841	70
Black shales	0	0	0	5 610	70
Total	0	5 181	6 898	13 451	

Prognosticated conventional resources
(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
20 000	20 000	20 000

Speculative conventional resources
(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
NA	NA	45 000

Historical uranium production by production method
(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Open pit mining*	36 249	0	0	36 249	0
Underground mining*	19 719	0	0	19 719	0
In situ leaching	91 510	3 526	3 561	98 597	4 000
Total	147 478	3 526	3 561	154 565	4 000

* Pre-2018 totals may include uranium recovered by heap and in-place leaching.

Ownership of uranium production in 2022

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
3 561	100	0	0	0	0	0	0	3 561	100

Uranium industry employment at existing production centres

(Person-years)

	2020	2021	2022	2023 (expected)
Employment directly related to uranium production	7 500	7 700	8 372	8 750

Short-term production capability

(tonnes U/year)

2025				2030			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
3 500	3 500	3 500	3 500	2 000	2 000	3 500	3 500

2035				2040			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
1 000	1 000	2 500	3 500	0	0	0	1 500

Viet Nam

Uranium exploration and mine development

Historical review

Uranium mineralisation in Viet Nam is associated with rare earth element deposits (Lao Cai province), phosphate deposits (Cao Bang province), and sandstone and coal deposits (Quang Nam province). The first exploration programmes were initiated before 1955 by French geologists of the Geological Department of Indochina. Beginning in 1978, a systematic regional exploration programme was conducted over the entire country using radiometric methods combined with geological observations. About 25% of the country was also covered by airborne radiometric and magnetic surveys at a scale of 1:25 000 and 1:50 000, respectively. This led to the discovery of several promising areas in the provinces of Cao Bang, Lao Cai, Yen Bai and Quang Nam. Between 1997 and 2002, the Geological Division for Radioactive and Rare Elements (GDRRE) of the Ministry of Natural Resources and Environment carried out detailed uranium exploration and evaluation (including drilling, trenching, and bulk sampling) in the Palau and Parong areas of the Quang Nam province. Uranium exploration activities have been continuing and now focus on the recovery of thorium and uranium from rare earth concentrates.

Recent and ongoing uranium exploration and mine development activities

Since 2010, the GDRRE has been carrying out uranium exploration in the Parong area in the Quang Nam province of central Viet Nam. The project consists of an investigation and evaluation of Triassic sandstone-type uranium deposits.

Exploration activities on the Parong deposit, covering an area of 1.9 km^2, consist of geophysical and geological surveys, trenching, drilling, and mining tests. Over the main part of the deposit, 712 holes (60 954 m) have been drilled on a 25 x 25 m grid to depths of between 30 and 150 m. Extensions of the deposit have also been drilled on a more widely spaced grid (between 50 x 50 m and 50 x 25 m). A mining test was conducted via a 130 m adit from which 3 holes were drilled to 300 m for hydrogeological tests. Results showed a limited amount of water in the formations.

Mineralisation at Parong is associated with medium- to coarse-grained sandstone with organic matter. Three main levels of mineralisation in reduced formations have been defined, separated by oxidised sandstones. Mineralisation over a lateral extension of 200-300 m has been intersected and varies in thickness from a few centimetres to a few metres.

In support of this exploration project, the Institute for Technology of Radioactive and Rare Elements (ITRRE) has carried out research on ore leaching treatment methods, laboratory, and pilot-scale tests, as well as investigations on the management of mining wastes and tailings. The results show that the heap leach method is suitable for the low-grade Parong ore, with uranium recovery of over 75%.

Current uranium exploration activities are focused on the recovery of thorium and uranium from rare earth concentrates. Research has been carried out by the ITRRE. A continuous counter-current extraction process for the simultaneous recovery of thorium and uranium from the Yen Phu rare earth concentrate leach solutions was developed. Separation of thorium and uranium from xenotime leach solutions was achieved by solvent extraction using primary and tertiary amines. The results show that the extraction method is suitable for the recovery of thorium and uranium from rare earth concentrate with thorium and uranium purities of greater than 99%. Uranium exploration and research on uranium extraction from uranium ores are continuing.

Uranium resources

Identified conventional resources

In 2011-2012, the uranium potential of part "A" of the Parong area (drilled at a 25 x 25 m grid) was assessed. Uranium resources, estimated using a 0.0085% U cut-off grade, amounted to 1 200 tU at an average grade of 0.034% U. These resources are classified as reasonably assured resources in the highest cost category (<USD 260/kgU or <USD 100/lb U_3O_8).

From 2013 to 2015, the uranium potential of part "G" of the Parong-Palua area was assessed. Inferred uranium resources are estimated at 1 081 tU.

From 2016 to 2019, estimates of the uranium potential of the remaining parts "B", "C", "D" and "F" of the Palua-Parong area were also completed.

Results of a previous evaluation of uranium resources as of 31 December 2008 in the main area of the Quang Nam province showed that:

- The Palua deposit consists of five deposits with total resources amounting to 4 596 tU, including 984 tU inferred resources and 3 612 tU prognosticated.
- The Parong deposit consists of seven deposits with total resources amounting to 3 867 tU, including 1 200 tU inferred resources and 2 667 tU prognosticated.
- The Khehoa-Khecao deposit consists of four deposits with total resources amounting to 5 803 tU, including 1 125 tU inferred resources and 4 678 tU prognosticated.
- The Dong Nam Ben Giang deposit consists of eight deposits with total resources amounting to 1 556 tU, including 337 tU inferred resources and 1 219 tU prognosticated.
- Resources of the An Diem deposit amount to 1 853 tU, including 354 tU inferred and 1 499 tU prognosticated.

The deposits of the Quang Nam province described above amount to a total of 4 000 tU inferred resources, 13 675 tU prognosticated resources and 17 675 tU combined inferred and prognosticated resources.

Undiscovered conventional resources (prognosticated and speculative resources)

The results of geological exploration conducted by the GDRRE show that there are more than ten uranium occurrences and deposits located in the northern provinces (Lai Chau, Lao Cai, Yen Bai, Son La, Ha Giang, Cao Bang, PhuTho, and Thai Nguyen), as well as in the highlands and central provinces.

Uranium deposits in the Lai Chau province are associated with rare earth element deposits. In the Cao Bang province, uranium mineralisation is associated with phosphate deposits, and in the Quang Nam province, uranium is associated with sandstones, and coal deposits.

The undiscovered conventional uranium resources as of 31 December 2008 amounted to a total of 81 200 tU prognosticated and 321 600 tU speculative resources. Some of the prognosticated resources include: 3 612 tU at Palua; 2 667 tU at Parong; 4 678 tU at Khehoa-Khecao; 1 219 tU at Dong Nam Ben Giang; and 1 499 tU at An Diem.

Unconventional resources and other materials

Uranium exploration activities associated with rare earth element ores (Dong Pao bastnaesites, Namxe bastnaesite, YenPhu xenotime and beach sand monazite, etc.) continue.

Uranium production

No uranium has been produced in Viet Nam.

Future production centres

The objective of the current uranium exploration programme is to increase the resource base to a total of 5 500 tU_3O_8 (4 665 tU) inferred and 8 000 tU_3O_8 (6 780 tU) prognosticated, as well as to determine the feasibility of mining these deposits. The ITRRE has researched ore processing and has started to survey the environmental conditions of future mining operations. A future production centre is being considered.

Environmental activities and socio-cultural issues

Environmental activities, such as monitoring the environmental impacts of exploration, are being carried out.

Uranium requirements

Viet Nam had a plan to develop several nuclear power plants with up to 14 nuclear reactors for a total net nuclear electricity generating capacity of about 15 000 MWe to 16 000 MWe by the year 2030. Seven potential build sites had been selected, with each site having the potential to accommodate four to six units.

In March 2010, the Prime Minister of Viet Nam approved the plan for the implementation of the NinhThuan Nuclear Power Project, which included the PhuocDinh and Vinh Hai Nuclear Power Plants.

Under this plan, the first nuclear power plant would have consisted of two VVER-type pressurised water reactors (PWRs) with a total net nuclear electricity generating capacity of about 2 000 MWe, built in co-operation with Rosatom. This plant would have been located in the PhuocDinh commune, Thuan Nam district, NinhThuan province. The second nuclear power plant, to have been built in co-operation with Japan Atomic Power Co., would have had the same generating capacity (2 x 1 000 MWe) and been located in the Vinh Hai commune, Ninh Hai district, NinhThuan province. The expected annual reactor-related uranium requirements would have been satisfied by imports and domestic production.

Because of a lack of funding at the end of 2016, the Viet Nam government decided to abandon plans to build the NinhThuan Nuclear Power Project.

Reasonably assured conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Underground mining (UG)	0	0	0	1 200
Total	0	0	0	1 200

Reasonably assured conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Heap leaching*	0	0	0	1 200
Total	0	0	0	1 200

* From open-pit and underground mining.

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	0	1 200
Total	0	0	0	1 200

Inferred conventional resources by production method

(in situ tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Unspecified	0	0	0	4 000
Total	0	0	0	4 000

Inferred conventional resources by processing method

(in situ tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Unspecified	0	0	0	4 000
Total	0	0	0	4 000

Inferred conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	0	4 000
Total	0	0	0	4 000

Prognosticated conventional resources

(in situ tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
NA	NA	81 200

Speculative conventional resources

(in situ tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
NA	NA	321 600

Zambia

Uranium exploration and mine development

Historical review

Uranium was first identified in Zambia (then Northern Rhodesia) at the site of the Mindola copper mine in Kitwe, leading to the mining of this small deposit between 1957 and 1959. A total of 102 tU_3O_8 (86 tU) was produced. Although no uranium has been produced from that mine or any other in Zambia since then, exploration activity has been carried out periodically by the government and by private companies.

Sporadic uranium exploration activities took place during the 1980s-1990s, but attention was primarily focused on copper. It was only in the mid-2000s that interest in uranium was stimulated by the dramatic rise in the spot market price for uranium. The exploration environment in Zambia underwent a fundamental change in 1969, when all mineral rights, which were then held privately, reverted to the state. That same year, the state also effectively nationalised mining by becoming a majority shareholder in all mining companies active in the country (principally copper). Financial realities, including a decline in copper prices, along with recommendations from external bodies, such as the World Bank and International Monetary Fund, encouraged the state to enter into a process of privatisation. This became a reality in 1997 with the primary objective of encouraging foreign investment in the country.

During the 1980s, active exploration for uranium by government and private companies within the Katanga metasediments revealed small, isolated medium-grade deposits in the Dome areas of North-Western Province. The Karoo sediments were also prospected by private companies and revealed some small low-grade deposits at shallow depths. Speculative resources were estimated at 35 000 tU.

The initial identification of uranium mineralisation in the Siavonga District occurred in 1957, with further exploration activities revealing that the majority of the uranium mineral resources are made up of three main deposits, Mutanga, Dibwe, and Dibwe East, with additional smaller deposits also discovered. Mutanga is a sandstone-type deposit, which formed in permeable sandstone aquifers, below the water table at low temperatures. The majority of the uranium found at Mutanga is contained within uranium-calcite-potassium minerals of autunite and minor meta-autunite, with approximately 2% of the U-bearing mineralisation comprised of brannerite and coffinite.

The discovery and exploration of the Mutanga Project is as follows:

1957	Uranium was identified after a ground survey at Bungua hill.
1958-1959	Low-grade uranium was found over an 800 m strike extent.
1974	Additional uranium mineralisation was defined by regional airborne magnetic and radiometric surveys.
1973-1977	Geological Survey Department conducted ground investigations.
1974-1984	AGIP discovered and drilled the Muntanga and Njame deposits.
2004	AGIP's prospecting licence was granted to Okurusu Flourspar Pty Lte.
2005	Licence transferred to OMEGA Corp.
2006	OMEGA Corp. drilled 11 holes to confirm the Muntanga deposit.
2007	Denison acquired OMEGA and drilled 45 598 m at the Muntanga and Dibwe deposits and 27 341 m of exploration drilling on 12 previously untested prospects.
2011	Discovery and delineation of the Dibwe East deposit.

In June 2016, GoviEx acquired Denison's Mutanga Project, and in October 2017 completed the acquisition of Africa Energy's Chirundu uranium project. GoviEx is a mineral resource company focused on the exploration and development of uranium properties in Zambia. The principal objective is to become a significant uranium producer through the continued exploration and development of its Muntanga Project in Zambia, among other projects in Africa. The company holds three mining licences granted by the Ministry of Mines and Minerals Development to mine uranium in the Siavonga and Chirundu Districts. Additionally, the company has three exploration licences. GoviEx has not started mining and is expanding on the feasibility studies for costing and mine design.

Recent and ongoing uranium exploration and mine development activities

In mid-2011, Equinox Minerals was taken over by Barrick Gold Corp. for CAD 7.3 billion. At that time, a total of 4.2 Mt of uraniferous ore at a grade of 0.118% U_3O_8 (0.1% U) was stockpiled at the Lumwana copper mine, which could be processed in the future if Barrick decided to build a uranium mill for an estimated cost of USD 200 to 230 million.

In 2012, drilling programmes at Lumwana were focused on resource definition at Chimiwungo, reserve delineation at Chimiwungo and Malundwe, extension exploration drilling at Chimiwungo, and condemnation drilling to test for economic mineralisation in areas of planned mining infrastructure. A total of 237 277 m of diamond drilling and 49 029 m of reverse circulation drilling was completed during 2012 in order to better define the limits of mineralisation and develop an updated, more comprehensive block model of the ore body for mine planning purposes. Total uranium resources, including the uranium ore stockpiled at Malundwe, amounted to 7 492 tU at an average grade of 0.07% U. However, the ore body did not meet economic expectations. The drilling defined significant additional mineralisation, some at higher grades. Much of the mineralisation was deep and would therefore require a significant amount of waste stripping, making it uneconomic based on the expected operating costs and current market copper prices.

In 2019, the reclamation process of the stockpiled copper at Malundwe and Chimiwungo, which covered an approximate area of 148 000 m^2 and a volume of 6 409 969 billion cubic metres, began. The stockpiles contained about 0.5% Sulphur, 0.79% copper and 920 ppm uranium. The waste with elevated uranium was channelled to an existing Tailing Storage Facility (TSF) with a capacity of 600 million tonnes; only 20 million tonnes of waste have been deposited there. The waste with elevated uranium covered about 4 million tonnes representing 0.7% of the total capacity of the TSF.

In 2021 and 2022, GoviEx conducted an extensive infill drilling program in the Dibbwi East deposit, which targeted conversion of the 29 million pounds U_3O_8 from inferred into indicated resources. A total of 5 980 m were drilled in 2021, and 27 634 m in 2022 (for a 2-year total of 33 614 m in 262 holes). Over four tonnes of ore have been delivered to Zambia's Copperbelt University, where confirmatory metallurgical test work is ongoing. This will be used to support the feasibility study process, design and costing. Analysis of the 2022 drilling results has highlighted that the Dibbwi East deposit is open both up and down dip, as several sections have not closed off the uranium resource.

In 2023 GoviEx plans to conduct 7 000 metres of rotary mud drilling to target these areas of open mineralisation at the Dibbwi East deposit and further enhance its understanding of the deposit's potential. The objective is to expand its feasibility study to include detailed engineering and design. The company will also complete the Environmental and Social Impact Assessment and undertake additional drilling to target mineralisation extensions along sections at the Dibbwi East deposit.

Uranium exploration and development expenditures and drilling effort – domestic

(USD)

	2020	2021	2022	2023 (preliminary)
Private* exploration expenditures	536 000	974 000	3 751 000	690 000
Government exploration expenditures				
Private* development expenditures				
Government development expenditures				
Total expenditures	536 000	974 000	3 751 000	690 000
Private* exploration drilling (metres)	-	**5 980**	27 684	7 000
Private* exploration holes drilled	-	-	**262***	82
Private exploration trenches (metres)				
Private trenches (number)				
Government exploration drilling (metres)				
Government exploration holes drilled				
Government exploration trenches (metres)				
Government trenches (number)				
Private development drilling (metres)				
Private development holes drilled				
Government development drilling (metres)				
Government development holes drilled				
Subtotal exploration drilling (metres)				
Subtotal exploration holes drilled				
Subtotal development drilling (metres)				
Subtotal development holes drilled				
Total drilling (metres)	-	5 980	27 634	7 000
Total number of holes drilled	-	-	262*	82

* Also includes holes drilled in 2021.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

In October 2017, GoviEx published an NI 43-101 technical report on a preliminary economic assessment of the Mutanga Project. GoviEx's Mutanga and Chirundu deposits were estimated to hold 21.6 Mt of measured ore resources grading 269 ppm U (0.0269% U) and containing 5 810 tU. Inferred resources were estimated to be 74.6 Mt of ore grading 231 ppm U (0.0231% U) and containing 17 270 tU. In June 2023, GoviEx released a new NI 43-101 compliant resource estimate for the Mutanga Project, including the results from extensive drilling completed in 2021 (5 980 m) and 2022 (27 634 m), for a total of 33 614 m in 262 holes. Based on this updated resource estimate, the Mutanga Project is estimated to contain 42.6 Mt of ore at an average grade of 304 ppm U (measured and indicated resources), and 15.0 Mt tonnes at 289 ppm U (inferred resources). These resources are contained in five deposits (Mutanga, Dibbwi East, Dibbwi, Gwabi, and Njame) located over a 65 km strike. Compared to the 2017 resource estimate, the 2023 estimate shows an increase of 7 150 tU in the measured and indicated categories, and a decrease of 13 070 tU in the inferred category.

Identified conventional resources by deposit

Deposit	Category	Ore (Mt)	Grade (ppmU)	Uranium (tU)
Mutanga	Indicated	7.5	305	2 270
Dibbwi East	Indicated	25.2	317	8 000
Dibbwi	Indicated	3.1	216	690
Gwabi	Measured	1.1	215	230
	Indicated	2.7	317	850
Njame	Measured	2.2	317	690
	Indicated	0.8	272	230
Total measured and indicated		42.6	307	12 960
Mutanga	Inferred	4.0	271	1 080
Dibbwi East	Inferred	9.1	292	2 650
Dibbwi	Inferred	0.6	212	120
Gwabi	Inferred	0.2	237	40
Njame	Inferred	1.1	276	310
Total inferred		15.0	280	4 200

The Lumwana copper mine, where resources are hosted by mica-quartz-kyanite schists of the Katangan Supergroup, contains identified recoverable uranium resources of 6 967 tU.

Potential for the discovery of additional uranium resources exists in various parts of the country that have been poorly explored. Of particular interest is the Copperbelt, where many copper orebodies are associated with uranium mineralisation.

Uranium production

Historical review

A total of 102 tU_3O_8 (86 tU) was produced at the Mindola mine in Kitwe during the late 1950s. Production ceased in 1960 and no uranium has been produced since. Uraniferous ore was stockpiled at Lumwana while mining the higher-grade Malundwe copper deposit. As of May 2019, the stockpile amounted to 4 Mt of ore grading 910 ppm U (3 640 tU). Copper was reclaimed from the stockpile in 2020 and the material with elevated uranium, considered as waste, was channelled into the Tailings Storage Facility.

Future projects

GoviEx is planning to develop a USD 123 million project at Mutanga and Chirundu with estimated cash operating costs of USD 31.1/lb U_3O_8 (USD 80.85/kgU), excluding royalties, when uranium prices have improved to >USD 55/lb U_3O_8 (USD 143/kgU). Following a successful licence renewal, a preliminary economic study of the Mutanga deposit was undertaken for an open-pit mine with acid heap leaching. Most of the mineralisation occurs within 125 m of the surface and is considered to have a reasonable prospect for economic mining. The project holds a 25-year mining licence, environmental approval, and a radioactive materials licence. The project is forecast to produce 920 tU/yr for 11 years. On 25 June 2020, the Mining Cadastre Department of Zambia issued a letter to GoviEx revoking the Chirundu mining permit due to failure to develop the permitted mining areas and carry out mining operations. However, on 10 May 2021, the Chirundu mining permit was reinstalled, subject to the completion of exploration and development milestones to advance the project towards a feasibility study.

Uranium production centre technical details

(as of 1 January 2021)

	Centre #1	Centre #2
Name of production centre	Lumwana	Mutanga
Production centre classification	Planned	Planned
Date of first production (year)	NA	NA
Source of ore:		
Deposit name(s)	Malundwe-Chimiwungo	Dibwe-Mutanga-Gwabe-Njame
Deposit type(s)	Metasomatic (metamorphosed schists)	Sandstone
Recoverable resources (tU)	6 967	15 100
Grade (% U)	0.07	0.029
Mining operation:		
Type (OP/UG/ISL)	OP	OP
Size (tonnes ore/day)	2 800	11 000
Average mining recovery (%)	NA	NA
Processing plant:		
Acid/alkaline	Acid	Acid
Type (IX/SX/HL)	SX	HL
Size (tonnes ore/day)		
Average process recovery (%)	93	88
Nominal production capacity (tU/year)	650	920
Plans for expansion (yes/no)		
Other remarks	Mine currently operated by Barrick	Mine construction on hold until uranium price increases

Environmental activities and socio-cultural issues

Waste rock management

Equinox Minerals' original plan in 2003 was to excavate, stockpile and return the uraniferous ore to the Malundwe pit at the Lumwana copper mine, following completion of mining, as it was considered uneconomic at the time to recover the uranium. However, in 2006, with a uranium spot price in excess of USD 50 lb/U_3O_8 (USD 130/kgU), the project was re-evaluated. In January 2011, Equinox Minerals reported that the portion of the stockpile containing 0.09% U and 0.8% Cu could be treated at a later date, if and when a uranium plant is built. The stockpile is currently classified and expensed as "waste" in the copper project.

In May 2019, Lumwana Mining Company (LMC) presented an Environmental and Social Impact Assessment Report for the proposed Stockpile Reclamation Project within the Lumwana Mining Licences. LMC has been mining from the Malundwe open pit since 2007. Initially, LMC investigated the feasibility of processing the stockpile for both copper and uranium. The uranium project was shelved in 2009/2010 following the decline of the uranium price and low availability of uranium ore. The proposed stockpile for reclamation covers an area of approximately 148 000 m^2 and contains about 4 Mt of "ore". The stockpiles contain about 0.5% sulphur, 0.79% copper and 920 ppm uranium (3 640 tU). The Chimuwungo resource contains less than 0.5% of copper and less than 200 ppm of uranium. Copper was reclaimed from the stockpile in 2020 and the waste with elevated uranium was channelled to the Tailing Storage Facility within the Lumwana Mine premises.

Environmental activities and socio-cultural issues

The Mines and Minerals Development Act (1995) makes provision for the preparation of a project brief when applying for a mining licence. This must include an environmental impact statement detailing all potential impacts of the project. Annual environmental audits must be carried out to ensure compliance and contributions must be made to an environmental management fund for rehabilitation.

Local inhabitants around the Mutanga Project were involved in public hearings organised by the Environmental Council of Zambia. Agreements were reached regarding the displacement of 107 families in two villages to allow for the construction of the mine infrastructure.

Denison/GoviEx has been providing funding to several communities and sustainability projects, including the construction of schools and clinics, water boreholes, and agricultural programmes.

African Energy assisted with the construction of a community health post and completed a water borehole at Sikoongo Village near their Chirundu Project.

Barrick invested in a wide range of sustainable development initiatives in 2012, including funding for infrastructures (such as schools and health centres), literacy and agricultural programmes, community sports and recreation, and an initiative to provide microcredit and small business loans to women.

Uranium requirements

Zambia has no nuclear generating capacity. In May 2016, Russia's Rosatom signed an intergovernmental agreement on co-operation on the peaceful uses of nuclear energy that provides a framework for opportunities to construct nuclear power facilities. Further co-operation agreements were signed with Rosatom in December 2016 and in June 2017. The agreements include training of Zambian specialists in Russia so that within 15 years, Russia will assist Zambia with training young nuclear energy engineers, planning for nuclear power plant personnel, developing a nuclear energy regulator, and building a research reactor. Zambia sent students to Russia to be trained in nuclear energy and a number of students graduated in 2020.

Zambia aims to become a regional centre for nuclear medicine. With respect to energy, nuclear power is needed to prevent load shedding due to unreliable supply. Zambia also developed the Nuclear Energy Policy and the National Nuclear and Radiation Safety Bill, which is the comprehensive nuclear law for the peaceful, safe, and secure use of nuclear science and technology.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Mining activities, in general, were regulated until 2008 by the Mines and Minerals Act (1995), but until recently there was no legislation specifically relating to the exploration and mining of uranium. The act was repealed in 2008 following widespread criticism of what was perceived to be excessive scope for granting tax concessions. This act was replaced by the Mines and Minerals Development Act 2008, which ruled that no special agreements should be entered into by the government for the development of large-scale mining licences. It also effectively ended development agreements concluded under the previous act. The Mines and Minerals Development (Prospecting, Mining, and Milling of Uranium Ores and Other Radioactive Mineral Ores) and Regulations of 2008 deal with the mining, storage and export of uranium. Mining and export licences will only be granted when the Radiation Protection Authority is satisfied that the operations pose no environmental and health hazards. Applicants for export licences will also have to prove the authenticity of the importers in terms of International Atomic Energy Agency (IAEA) guidelines.

A study by the Council of Churches concluded that current legislation and enforcement was inadequate for uranium mining. It recommended that current regulations be revised to address the concerns of local communities and that education and awareness programmes be initiated prior to any uranium exploration and mining activities.

In 2011, Zambia and Finland signed co-operation projects aimed at helping Zambia review regulations on uranium mining as well as the management of the mineral. The two projects are aimed at evaluating current regulations on uranium and other radioactive minerals as well as developing a modern geographical information infrastructure. These projects are designed to help the country evaluate, update and review regulations regarding the safety of uranium mining.

Zambia has upgraded its mining legislation to include uranium, following detailed consultations with the IAEA. It started issuing uranium mining licences late in 2008, and in 2017 was undertaking a further revision of regulations regarding uranium exploration and mining.

Zambia, through the Radiation Protection Authority, uses the Ionising Radiation Protection Act No. 16 of 2005 and its amendments No. 19 of 2011, the Ionising Radiation Protection (General) Regulations No. 98 of 2011, and its amendments, and Statutory Instrument No. 58 of 2014 to regulate all activities involving ionising radiation. The Radiation Protection Authority developed the Nuclear Energy Policy and the National Nuclear and Radiation Safety Bill, which is the comprehensive nuclear law that will cover uranium mining, exploration and prospecting activities. The Nuclear Energy Policy and Nuclear and Radiation Safety bill are still in draft form.

Reasonably assured conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	18 372	18 372	88-93
Total	0	0	18 372	18 372	88-93

Reasonably assured conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	0	0	18 372	18 372	88-93
Total	0	0	18 372	18 372	88-93

Reasonably assured conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	11 405	11 405
Metasomatite	0	0	6 967	6 967
Total	0	0	18 372	18 372

Inferred conventional resources by production method

(recoverable tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	0	0	4 647	4 647	88-93
Total	0	0	4 647	4 647	88-93

Inferred conventional resources by processing method

(recoverable tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Conventional from OP	0	0	4 647	4 647	88-93
Total	0	0	4 647	4 647	88-93

Inferred conventional resources by deposit type

(recoverable tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	3 696	3 696
Metasomatite	0		951	951
Total	0	0	4 647	4 647

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Underground mining[1]	86	0	0	86	0
Total	86	0	0	86	0

1. Pre-2020 totals may include uranium recovered by heap and in-place leaching.

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Conventional	86	0	0	86	0
Total	86	0	0	86	0

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2020	2021	2022	Total through end of 2022	2023 (expected)
Metasomatite	86	0	0	86	0
Total	86	0	0	86	0

Short-term production capabilities

(tonnes U/year)

2025				2030			
A-I	A-II	B-I	B-II	A-I	A-II	B-I	B-II
0	0	0	0	NA	NA	NA	NA

2035				2040			
A-I	A-II	B-I	B-II	A-I	A-II	B-I	B-II
NA	NA	NA	NA	NA	NA	NA	NA

Zimbabwe

Uranium exploration and development

Historical review

Exploration for uranium in Zimbabwe began in the 1950s when the United Kingdom Atomic Energy Agency embarked on exploration for radioactive minerals throughout the country. Several anomalies were identified but most of them were found to be the result of monazite, a rare earth element bearing mineral, and hence were considered to be insignificant for uranium.

However, the regional airborne surveys carried out over the Karoo rocks in the Zambezi Valley in the mid-1980s by Saarberg Interplan Uran Gmbh of Germany identified several anomalies, of which Kanyemba was targeted for detailed studies. Several deposits were identified at Kanyemba. Only Kanyemba 1 was explored in detail giving a resource of 450 000 tonnes at 0.7% U_3O_8 and 1.4% V_2O_5. Based on this, Saarberg carried out a detailed feasibility for the opening of a mine before the project was abandoned due to plummeting uranium prices at the end of the Cold War.

Recent and ongoing uranium exploration activities

There have been no recent exploration activities for uranium in Zimbabwe.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Several deposits were identified at Kanyemba. Only Kanyemba 1 was explored in detail, giving an in situ resource of 450 000 tonnes at 0.7% U_3O_8 (2 670 tU at 0.6% U) and 1.4% V_2O_5.

In the previous country report (Red Book 1997), these resources were classified as reasonably assured at a cost category of <USD 80/kgU. For this edition of the Red Book, the Secretariat has assigned the highest cost category for those resources.

Undiscovered conventional resources (prognosticated and speculative resources)

Several anomalies in the mid-Zambezi valley with similar sedimentological environments to those at Kanyemba were identified, but were not followed up in detail, as no uranium minerals were detected at the surface. In the <USD 260/kgU cost category, 25 000 tU can be reported as speculative resources.

Uranium production

Historical review

Saarberg carried out a detailed feasibility assessment for the opening of a mine before the project was abandoned due to plummeting uranium prices at the end of the Cold War. No uranium production has taken place to date.

Regulatory regime

Zimbabwe has legislation (Mines and Minerals Act Chapter 21:05) for nuclear energy source material exploration and mining. The Ministry of Mines and Mining Development administers the Mines and Minerals Act. As part of the uranium policy currently being drafted, there is scope to include stringent requirements of mine decommissioning plans and financial guarantees or decommissioning funds.

National policies relating to uranium

The Ministry of Mines and Mining Development is currently developing a Minerals Development Policy that incorporates policies to develop all minerals in the country. A comprehensive policy for uranium exploration and mining will also be incorporated in the Minerals Development Policy. At present the Mines and Minerals Act provides guidance on exploration and mining of nuclear energy material.

Reasonably assured conventional resources by deposit type

(in situ tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	0	2 670
Total	0	0	0	2 670

Appendix 1. List of reporting organisations and contact persons

NEA	OECD Nuclear Energy Agency – Division of Nuclear Technology Development and Economics, Paris Contact person: Mr Franco Michel-Sendis (Scientific Secretary)
IAEA	International Atomic Energy Agency, Division of Nuclear Fuel Cycle and Waste Technology, Vienna Contact person: Mr Mark Mihalasky (Scientific Secretary)
Algeria	Commissariat à l'Energie Atomique (COMENA), Centre de Recherche Nucléaire de Draria, BP 43, Sebala, Draria, Alger 16003 Algérie Contact person: Mr Jamel Eddine Nacer
Argentina	Comisión Nacional de Energía Atómica (CNEA), División Gestión de Proyectos, Avenida del Libertador 8250, (C1429BNP) Ciudad, Buenos Aires Contact person: Mr Luis López
Armenia	Ministry Territorial Administration and Infrastructure, Energy Department, Atomic Energy Division, Government House 3, Republic Square, Yerevan Contact person: Ms Margarita Balayan
Australia	Geoscience Australia, Cnr Jerrabomberra Avenue and Hindmarsh Drive, Symonston, ACT 2609, Canberra Contact person: Mr Andrew Cross
Bangladesh	Institute of Nuclear Minerals (IBN), Bangladesh Atomic Energy Commission, Atomic Energy Research Establishment, Ganakbari, Savar-1349, Dhaka Contact person: Mr Golam Rasul
	Bangladesh Atomic Energy Commission, Paramanu Bhaban, E-12/A, Sher-E-Banglanagar Dhaka-1207, Bangladesh Contact person: Office of the Chairman
Belgium	SYNATOM, Fuel Supply Department, ENGIE TOWER – 6th Floor, 36 Boulevard Simon Bolivar, 1000 Brussels Contact person: Ms Françoise Renneboog
	Service Public Fédéral – Économie, PME, Classes Moyennes & Énergie, 16 Bd du Roi Albert II, 1000 Brussels Contact person: Mr Alberto Fernàndez Fernàndez
Bolivia	Electricity And Nuclear Technology Supervision Authority, Nuclear Technology Department, Av. 16 de Julio N°1571 Zona Central (El Prado), La Paz, Bolivia Contact person: Mr Juan Francisco Valdez Rodriguez
Brazil	Indústrias Núcleares do Brasil, Av Rio Branco 1, 19th floor – Centro, Rio de Janeiro Contact person: Mr Leonardo Bernardino de Carvalho

Bulgaria	Ministry of Energy, Natural Resources, Concession and Control Direcorate, 8 Triaditsa Str., 1000 Sofia Contact person: Ms Valeri Trendafilov
Cameroon	Research Centre for Nuclear Science and Technology, Rue Monseigneur VOGT, P.O. Box 4110 Yaoundé Contact person: Mr SAIDOU
Canada	Natural Resources Canada, Uranium and Radioactive Waste Division, 580 Booth Street, Ottawa, Ontario K1A OE4 Contact persons: Mr Tom Calvert, Mr Jamie Fairchild
China	Permanent Mission of China to the IAEA, Hohe Warte 3, 1190 Vienna, Austria Contact person: Mr Qingming Wei
Czechia	DIAMO State Enterprise, Máchova 201, 471 27 Stráz Pod Ralskem Contact person: Mr Pavel Vostarek
Denmark/ Greenland	Geological Survey of Denmark and Greenland, Danish Ministery of Climate, Energy and Utilities, Øster Volgade 10, 1350 Copenhagen, Denmark Contact person: Ms Kristine Thrane
Ecuador	Geological and Energy Research Institute, Innovation Directorate, Sky Building, Planta Baja, Av, de la República E7-263, Quito 170503 Contact person: Mr Francisco Herrera
Egypt	Nuclear Materials Authority of Egypt, P.O. Box 530, El-Maadi, Cairo Contact persons: Mr Amer Hussien Amer Bishr
Finland	Ministry of Economic Affairs and Employment, Energy Department, Geological Survey of Finland, Vuorimiehentie 5 P.O. Box 96, FI-02151, Espoo Contact person: Mr Esa Pohjolainen
France	Commissariat à l'énergie atomique et aux énergies alternatives, Centre de Saclay, 91191 Gif-sur-Yvette Cedex Contact person: Ms Sophie Gabriel
Germany	Federal Institute for Geosciences and Natural Resources (BGR), Stilleweg 2, D-30655 Hannover Contact person: Mr Michael Schauer
Ghana	Ghana Atomic Energy Commission, National Nuclear Research Institute, P. O. Box LG 80, Atomic Street – Kwabenya, Legon Accra – Greater Accra Contact persons: Mr William Osei-Mensah, Mr Samuel Boakye Dampare
Guyana	Guyana Geology and Mines Commission, Main Office, Upper Brickdam, Georgetown Contact persons: Ms Xiomara Griffith, Ms Amanda O'Neil, Ms Shri Devi Ramkarran, Ms Darcy Walrond
Hungary	Hungarian Atomic Energy Authority, 4 Fényes Adolf Street, H-1036 Budapest Contact person: Mr András Barabás
India	Atomic Minerals Directorate for Exploration and Research, Department of Atomic Energy (DAE), AMD Complex, 1-10-153-156, Begumpet, Hyderabad 500 016, Telangana Contact person: Mr Baskaran Saravanan

Indonesia	Research Center for Nuclear Fuel Cycle and Radioactive Waste Technology, Research Organization for Nuclear Energy, National Research and Innovation Agency, 720 Building, KST BJ Habibie, Serpong, Tangerang Selatan, Banten Province, 15314 Contact persons: Mr Syaiful Bakhri, Mr Heri Syaeful
Japan	Office for International Nuclear Energy, Ministry of Economy, Trade and Industry, 1-3-1 Kasumigaseki, Chiyoda-ku, Tokyo Contact persons: Mr Urara Kida
Jordan	Jordanian Uranium Mining Company, Al Madena Al Munawarah Str., Building No. 269, Amman 11953 Contact person: Mr Mohammad Al-Shannag
Kazakhstan	National Atomic Company Kazatomprom JSC NAC, 17/12, Syganak Street, Z05T1X3 Astana Contact person: Ms Aliya Akzholova
Kenya	Nuclear Power & Energy Agency, Kawi Complex, off Red Cross Road, P.O. Box 26374-00100, Nairobi Contact person: Ms Hilda Mpakany
Madagascar	Office des Mines Nationales et des Industries Strategiques, 21, Rue Razanakombana Ambohijatovo Antananarivo Contact person: Ms Dinamalala Julia Ranaivosaona
Malawi	Atomic Energy Regulatory Authority, Chief M'Mbelwa Building, Robert Mugabe Crescent, City Center, Private Bag 368, Lilongwe 3 Contact person: Mr Winford Kanyika
Mexico	Ministry of Energy of Mexico, General Direction of International Affairs, 890 Insurgentes Sur, Del Valle, PC 03100, Benito Juarez, Mexico City Contact person: Ms. Velvet Rosemberg Fuentes
Mongolia	Government of Mongolia Executive office of the Nuclear Energy Commission, Executive Office of Nuclear Energy Commission, 17032 Uildverchdiin street 2, 20th khoroo, Khan-Uul district, Ulaanbaatar Contact person: Mr Baatartsogt Baldorj
Nepal	Department of Mines and Geology, Lainchaur, Kathmandu Contact person: Mr Dharma Raj Khadka
Peru	Instituto Geológico, Minero y Metalúrgico, 1470 Canada Av., San Borja, Lima 15034 Contact person: Mr Michael Valencia Muñoz
Poland	Ministry of Climate and Environment, Nuclear Energy Department, 52/54 Wawelska Street, 00-922 Warsaw Contact person: Mr Andrzej Chwas
Portugal	Empresa de Desenvolvimento Mineiro, S.A., Rua Sampaio e Pina, 1-3° Dt° 1070-248, Lisboa Contact person: Mr Zélia Estêvão Direção Geral de Energia e Geologia, Av. 5 de Outubro 208, 1069-039, Lisboa Contact person: Ms Paula Dinis
Russia	Rosatom State Corporation, TENEX Joint-Stock Company, 28/3 Ozerkovskaya nab., Moscow, 115184 Contact person: Mr Alexander Boytsov

Saudi Arabia	Ministry of Energy, 5 Nakhiel Neighbourhood, 6744 Riyadh, 21382 Contact person: Mr Fahad Al Sayyari (National Liaison Officer)
Senegal	Ministry of Energy and Mining, Regulatory Body, Experts Comity, Allée Papa Gueye Fall, Immeuble Adja Fatou Nourou Diop, Dakar Contact person: Mr Mamadou Kanoute
Slovakia	Štátny geologický ústav Dionýza Štúra, Mlynská dolina 1, 817 04 Bratislava 11 Contact persons: Mr Stanislav Šoltés
Slovenia	Slovenian Nuclear Safety Administration, Litostrojska cesta 54, 1000 Ljubljana Contact person: Ms Vesna Logar Zorn
Spain	ENUSA Industrias Avanzadas, S. A. S.M.E., Santiago Rusiñol, 12, E- 28040, Madrid Contact person: Ms Lourdes Guzmán
Tajikistan	Chemical, Biological, Radiological And Nuclear Safety And Security Agency, 734025, 33 Rudaki Ave, Dushanbe Contact persons: Mr Ilhom Mirsaidzoda, Mr Matin Akhmedov
Thailand	Department of Mining and Petroleum Engineering, Chulalongkorn University, Bangkok, 10330 Contact person: Mr Pipat Laowattanabandit
Türkiye	Ministry of Energy and Natural Resources, General Directorate of Nuclear Energy and International Projects, Türk Ocağı Street No:2 06520 Çankaya, Ankara Contact persons: Ms Çisem Tuba Ünaldi
Ukraine	Ministry of Energy, Department of Nuclear Energy and Atomic Industry, 30 Khreschatyk Street Kiev, 01601 Contact persons: Mr Yuri Bakarzhiyev, Mr Anatoliy Bakarzhiyev
	State Enterprise Kirovgeology, 8/9 Boychuka Street, Kiev, 01103 Contact person: Ms Svitlana Kulchytska
United States	Energy Information Administration, US Department of Energy, Washington, D.C. 20585 Contact persons: Mr Slade Johnson
	US Geological Survey, Denver Federal Center, Denver, Colorado 80225 Contact person: Ms Susan Hall
Uzbekistan	Ministry of Mining and Geology, Inspectorate on Control of Mining, Geological, and Industrial Safety, 10001, Toshkent sh., M-14, 27-uy Contact person: Mr Bakhtiyor Gulyamov
Viet Nam	Institute for Technology of Radioactive and Rare Elements, Vietnam Atomic Energy Institute (VNATOM), 48 Langha Street, Dongda District, Hanoi Contact person: Mr Nguyen Trong Hung
Zambia	Radiation Protection Authority of Zambia, P.O Box 50002, Exploration Houise, Government Road, Ridgeway, Lusaka Contact persons: Ms Linda Kumwenda, Mr Brian Kashimu
Zimbabwe	Ministry of Mines and Mining Development, Zimre Center Building, Kwame Nkrumah Avenue, Harare Contact persons: Mr Leon Dudzayi Godza, Mr Simbarashe Michael Mbokochena

Appendix 2. **Members of the Joint NEA-IAEA Uranium Group participating in 2023-2024 meetings**

IAEA	Mr Mark Mihalasky *(Uranium Group Scientific Secretary)*	Division of Nuclear Fuel Cycle and Waste Technology, Vienna
NEA	Mr. Franco Michel-Sendis (*Uranium Group Scientific Secretary*)	Division of Nuclear Technology Development and Economics, Paris
Algeria	Ms Assia Badani	Commissariat à l'énergie atomique (COMENA); Centre de recherche nucléaire de Draria, Draria
Argentina	Mr Luis Eduardo López (*Uranium Group Vice-Chair)*	Comisión Nacional de Energía Atómica, Buenos Aires
Armenia	Mr Ernest Tshagharyan	Armenian Nuclear Power Plant CJSC, Metsamor
Armenia	Ms Balayan Margarita	Minisrty of Energy Infrastructures and Natural Resources of the Republic of Armenia, Energy Department, Yerevan
Australia	Mr Andrew Cross (*Uranium Group Vice-Chair*)	Geoscience Australia, Canberra
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Belgium	Ms Françoise Renneboog	SYNATOM Market Analysis Division, Brussels
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Appendix 3. Glossary of definitions and terminology

Units

Metric units are used in all tabulations and statements. Resources and production quantities are expressed in terms of tonnes (t) contained uranium (U) rather than uranium oxide (U_3O_8).

1 short ton U_3O_8	=	0.769 tU
1% U_3O_8	=	0.848% U
1 USD/lb U_3O_8	=	USD 2.6/kg U
1 tonne	=	1 metric ton

Resource terminology

Resource estimates are divided into separate categories reflecting different levels of confidence in the quantities reported. The resources are further separated into categories based on the cost of production.

Definitions of resource categories

Uranium resources are broadly classified as either conventional or unconventional. Conventional resources are those that have an established history of production where uranium is a primary product, co-product or an important by-product (e.g., from the mining of copper and gold). Very low-grade resources, or those from which uranium is only recoverable as a minor by-product, are considered unconventional resources. In some instances, however, unconventional resources that are of atypical uranium grades (i.e., higher than what is normally a very low-grade for deposit types such as phosphate-hosted or black shale-hosted uranium) may, by some countries, be regarded as an important by-product and therefore considered to be conventional.

Conventional resources, as well as unconventional resources when sufficient data are available, are further divided according to different confidence levels of occurrence into four categories:

1. Reasonably assured resources (RAR)
2. Inferred resources (IR)
3. Prognosticated resources (PR)
4. Speculative resources (SR)

The correlation between these resource categories and those used in selected national resource classification systems is shown in Figure A3.1.

Reasonably assured resources (RAR) refers to uranium that occurs in known mineral deposits of delineated size, grade and configuration such that the quantities, which could be recovered within the given production cost ranges with currently proven mining and processing technology, can be specified. Estimates of tonnage and grade are based on specific sample data and measurements of the deposits and on knowledge of deposit characteristics. Reasonably assured resources have a high assurance of existence. Unless otherwise noted, RAR are expressed in terms of quantities of uranium recoverable from mineable ore (see: recoverable resources).

Inferred resources (IR) refers to uranium, in addition to RAR, that is inferred to occur based on direct geological evidence, in extensions of well-explored deposits, or in deposits in which geological continuity has been established but where specific data, including measurements of the deposits, and knowledge of the deposit's characteristics, are considered to be inadequate to classify the resource as RAR. Estimates of tonnage, grade and cost of further delineation and recovery are based on such sampling as is available and on knowledge of the deposit characteristics as determined in the best known parts of the deposit or in similar deposits. Less reliance can be placed on the estimates in this category than on those for RAR. Unless otherwise noted, inferred resources are expressed in terms of quantities of uranium recoverable from mineable ore (see: recoverable resources).

Figure A3.1. **Approximate correlation of terms used in major resources classification systems**

	Identified resources			Undiscovered resources		
Red Book (NEA/IAEA)	Reasonably assured		Inferred	Prognosticated	Speculative	
Australia	Demonstrated		Inferred	Undiscovered		
	Measured	Indicated				
Canada (NRCan)	Measured	Indicated	Inferred	Prognosticated	Speculative	
United States (DOE, USGS)	Reasonably assured		Inferred	Undiscovered		
Russia, Kazakhstan, Ukraine, Uzbekistan	A + B + C1	C2	C2+P1	P1	P2	P3

The terms illustrated are not strictly comparable as the criteria used in the various systems are not identical. "Grey zones" in correlation are therefore unavoidable, particularly as the resources become less assured. Nonetheless, the chart presents a reasonable approximation of the comparability of terms.

Work to align the NEA/IAEA and national resource classification systems outlined above with the United Nations Framework Classification system remains under consideration. (For a summary of recent efforts, see: www.unece.org/fileadmin/DAM/energy/se/pdfs/egrc/egrc5_apr2014/ECE.ENERGY.GE.3.2014.L1_e.pdf.)

Prognosticated resources (PR) refers to uranium, in addition to inferred resources, that is expected to occur in deposits for which the evidence is mainly indirect and which are believed to exist in well-defined geological trends or areas of mineralisation with known deposits. Estimates of tonnage, grade and cost of discovery, delineation and recovery are based primarily on knowledge of deposit characteristics in known deposits within the respective trends or areas and on such sampling, geological, geophysical or geochemical evidence as may be available. Less reliance can be placed on the estimates in this category than on those for inferred resources. Prognosticated resources are normally expressed in terms of uranium contained in mineable ore (i.e., in situ quantities).

Speculative resources (SR) refers to uranium, in addition to prognosticated resources, that is thought to exist, mostly on the basis of indirect evidence and geological extrapolations, in deposits discoverable with existing exploration techniques. The location of deposits envisaged in this category could generally be specified only as being somewhere within a given region or geological trend. As the term implies, the existence and size of such resources are speculative. SR are normally expressed in terms of uranium contained in mineable ore (i.e., in situ quantities).

Cost categories

The cost categories, in United States dollars (USD), used in this report are defined as: <USD 40/kgU (<USD 15/lbs U_3O_8), <USD 80/kgU (<USD 30/lbs U_3O_8), <USD 130/kgU (<USD 50/lbs U_3O_8), and <USD 260/kgU (<USD 100/lbs U_3O_8). The resource tonnages across the cost categories are cumulative, from lowest cost to highest cost category. This means that uranium resource tonnage for any cost category also includes uranium resource tonnage from the lower cost categories:

- Resources categorised at <USD 40/kgU are the lowest cost, most economically attractive to recover.
- Resources categorised at <USD 80/kgU include those recoverable at <USD 40/kgU, plus resources that are more expensive to recover, up to USD 80/kgU.
- Resources categorised at <USD 130/kgU include those recoverable at <USD 80/kgU and <USD 40/kgU, plus resources that are more expensive to recover, up to USD 130/kgU.
- Resources categorised at <USD 260/kgU include those recoverable at all lower cost categories, plus resources that are more expensive, up to USD 260/kgU.

All resource categories are defined in terms of costs of uranium recovered at the ore processing plant.

Note: It is not intended that the cost categories should follow fluctuations in market conditions.

Conversion of costs from other currencies into USD is done using an average exchange rate for the month of June in that year except for the projected costs for the year of the report.

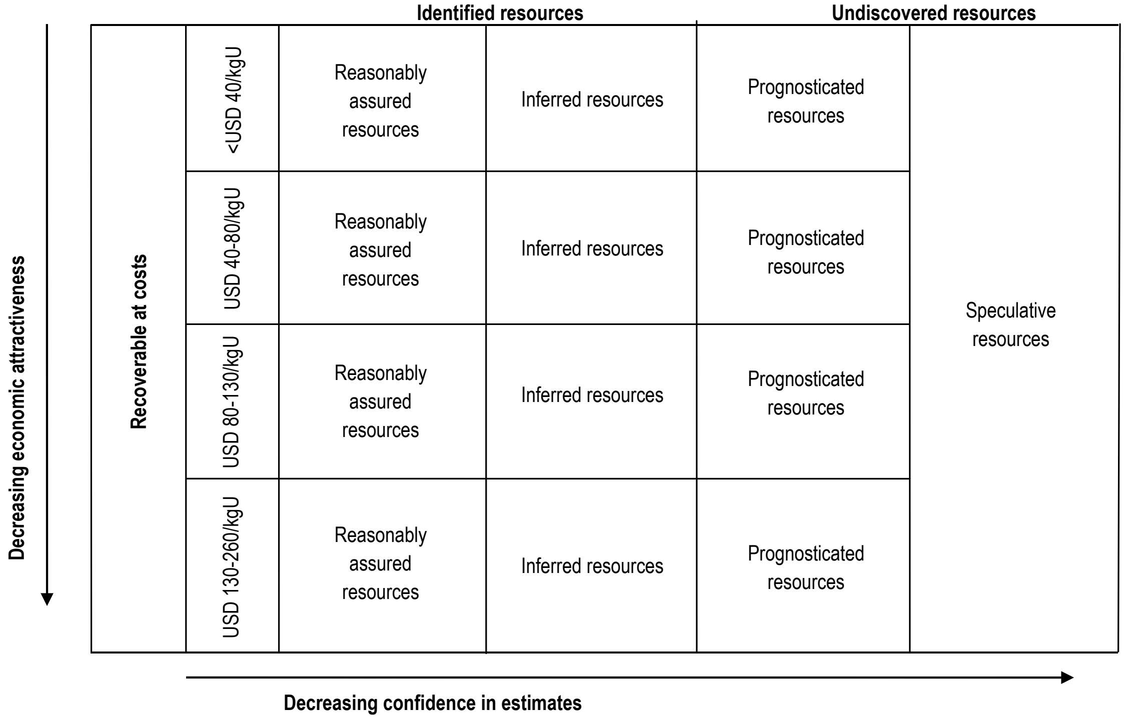
When estimating the cost of production for assigning resources within these cost categories, account has been taken of the following costs:

- the direct costs of mining, transporting and processing the uranium ore;
- the costs of associated environmental and waste management during and after mining;
- the costs of maintaining non-operating production units where applicable;
- in the case of ongoing projects, those capital costs that remain non-amortised;
- the capital cost of providing new production units where applicable, including the cost of financing;
- indirect costs such as office overheads, taxes and royalties where applicable;
- future exploration and development costs wherever required for further ore delineation to the stage where it is ready to be mined;
- sunk costs are not normally taken into consideration.

Relationship between resource categories

Figure A3.2 illustrates the inter-relationship between the different resource categories. The horizontal axis expresses the level of assurance about the actual existence of a given tonnage based on varying degrees of geologic knowledge while the vertical axis expresses the economic feasibility of exploitation by the division into cost categories.

Figure A3.2. **NEA/IAEA classification scheme for uranium resources**



Recoverable resources

RAR and IR estimates are expressed in terms of recoverable tonnes of uranium (i.e., quantities of uranium recoverable from mineable ore), as opposed to quantities contained in mineable ore, or quantities in situ (i.e., not taking into account mining and milling losses). Therefore, both expected mining and ore processing losses have been deducted in most cases. If a country reports its resources as in situ and the country does not provide a recovery factor, the NEA/IAEA assigns a recovery factor to those resources based on geology and projected mining and processing methods to determine recoverable resources. The recovery factors that have been applied are:

Mining and milling method	Overall recovery factor (%)
Open-pit mining with conventional milling	80
Underground mining with conventional milling	75
In situ leaching (acid)	85
In situ leaching (alkaline)	70
Heap leaching	70
Block and stope leaching	75
Co-product or by-product	65
Unspecified method	75

Secondary sources of uranium terminology

Mixed oxide fuel (MOX): MOX is the abbreviation for a fuel for nuclear power plants that consists of a mixture of uranium oxide and plutonium oxide. Current practice is to use a mixture of depleted uranium oxide and plutonium oxide.

Depleted uranium: Uranium where the ^{235}U assay is below the naturally occurring 0.7110%. Natural uranium is a mixture of three isotopes, uranium-238 – accounting for 99.2836%, uranium-235 – 0.7110%, and uranium-234 – 0.0054%. Depleted uranium is a by-product of the enrichment process, where enriched uranium is produced from initial natural uranium feed material.

Production terminology[1]

Production centres

A production centre, as referred to in this report, is a production unit consisting of one or more ore processing plants, one or more associated mines and uranium resources that are tributary to these facilities. For the purpose of describing production centres, they have been divided into four classes, as follows:

- Existing production centres are those that currently exist in operational condition. Production projections continue until the identified resources (costs < USD 130/kgU) are exhausted.
- Committed production centres are those that are either under construction or are firmly committed for construction.
- Planned production centres are those for which feasibility studies are completed and regulatory approvals are at advanced stage.
- Prospective production centres are those for which some level of feasibility study has been completed and the centres are supported by tributary RAR and Inferred resources. Indicative start-up dates should have been announced.

Production, production capacity, and production capability

Production: Denotes the amount of uranium output, in tonnes U contained in concentrate, from an ore processing plant or production centre (with milling losses deducted).

Production capacity: Denotes the nominal level of output, based on the design of the plant and facilities over an extended period, under normal commercial operating practices.

Production capability: Refers to an estimate of the level of production that could be practically and realistically achieved under favourable circumstances from the plant and facilities at any of the types of production centres described above, given the nature of mined ore flow to them. Projections of production capability are supported only by RAR and/or IR. Production capability is divided into two scenarios: **Scenario A** is based on **EXISTING** and **COMMITTED** production centres; **Scenario B** is based on **EXISTING**, **COMMITTED**, **PLANNED** and **PROSPECTIVE** production centres. The A and B scenarios are further subdivided based on cost category:

- The **A-I** scenario reflects production capability that is supported only by Reasonably Assured Resources (RAR) and Inferred Resources (IR) recoverable at costs **<USD 80/kgU** which are available to feed and be processed at **EXISTING** and **COMMITTED** production centres.

1. IAEA (1984), *Manual on the Projection of Uranium Production Capability,* General Guidelines, Technical Report Series No. 238, IAEA, Vienna.

- The **A-II** scenario reflects production capability that is supported only by Reasonably Assured Resources (RAR) and Inferred Resources (IR) recoverable at costs **<USD 130/kgU** which are available to feed and be processed at **EXISTING** and **COMMITTED** production centres.
- The **B-I** scenario reflects production capability that is supported by Reasonably Assured Resources (RAR) and Inferred Resources (IR) recoverable at costs **<USD 80/kgU** which are available to feed and be processed at **EXISTING**, **COMMITTED**, **PLANNED**, and **PROSPECTIVE** production centres.
- The **B-II** scenario reflects production capability that is supported by Reasonably Assured Resources (RAR) and Inferred Resources (IR) recoverable at costs **<USD 130/kgU** which are available to feed and be processed at **EXISTING**, **COMMITTED**, **PLANNED**, and **PROSPECTIVE** production centres.

The unit used for production capability is tonnes U/year.

Mining and milling

Open-pit mining: The extraction of near-surface uranium-bearing rock (ore) from an exposed pit open to the air, typically excavated as a series of benches or steps cut into the pit walls using drilling, blasting, and heavy machinery.

Underground mining: The extraction beneath the surface of uranium-bearing rock (ore) through horizontal, sub-horizontal, and vertical tunnels (shafts, slopes, adits, declines and other openings that access the ore body) using drilling, blasting, and various types of specialized heavy machinery. More commonly applied to high-grade, low-tonnage deposits where the ore body is too deep to be mined economically by open pit methods.

In situ leaching mining (ISL, sometimes referred to as in situ recovery, or ISR): The extraction of uranium from sandstone using chemical solutions and the recovery of uranium at the surface. ISL extraction is conducted by injecting a suitable uranium-dissolving leach solution (acid or alkaline) into the ore zone below the water table thereby oxidising, complexing and mobilising the uranium; then recovering the pregnant solutions through production wells, and finally pumping the uranium bearing solution to the surface for further processing.

Heap leaching (HL): Heaps of ore are formed over a collecting system underlain by an impervious membrane. Dilute sulphuric acid solutions are distributed over the top surface of the ore. As the solutions seep down through the heap, they dissolve a significant (50-75%) amount of the uranium in the ore. The uranium is recovered from the heap leach product liquor by ion exchange or solvent extraction.

In-place leaching (IPL): involves leaching of broken ore without removing it from an underground mine. This is also sometimes referred to as stope leaching or block leaching.

Co-product: Uranium is a co-product when it is one of two commodities that must be produced to make a mine economic. Both commodities influence output, for example, uranium and copper are co-produced at Olympic Dam in Australia. Co-product uranium is produced using either the open-pit or underground mining methods.

By-product: Uranium is considered a by-product when it is a secondary or additional product. By-product uranium can be produced in association with a main product or with co-products (e.g., uranium recovered from the Palabora copper mining operations in South Africa). By-product uranium is produced using either the open-pit or underground mining methods.

Uranium from phosphate rocks: Uranium has been recovered as a by-product of phosphoric acid production. Uranium is separated from phosphoric acid by a solvent extraction process. The most frequently used reagent is a synergetic mixture of tri-n-octyl phosphine oxide (TOPO) and di 2-ethylhexyl phosphoric acid (DEPA).

Ion exchange (IX): Reversible exchange of ions contained in a host material for different ions in solution without destruction of the host material or disturbance of electrical neutrality. The process is accomplished by diffusion and occurs typically in crystals possessing – one or two – dimensional channels where ions are weakly bonded. It also occurs in resins consisting of three-dimensional hydrocarbon networks to which are attached many ionisable groups. Ion exchange is used for recovering uranium from leaching solutions.

Solvent extraction (SX): A method of separation in which a generally aqueous solution is mixed with an immiscible solvent to transfer one or more components into the solvent. This method is used to recover uranium from leaching solutions.

Idled mine: A temporarily closed operation. Idled mines are those with associated identified uranium resources and processing facilities that have all necessary licenses, permits and agreements for operation and have produced commercially in the past, but were not producing as of the middle to end of the second year of the current Red Book reporting period. Annual production capacity of an idled mine could be potentially increased relatively rapidly if the operation is brought back into service. Although each mine operation is unique in terms of operational costs and a threshold price for reopening, the ability to raise capital as required to resume operation and to meet regulatory requirements, idled mines could be returned to production in roughly one year, given that all permits and licences remain in place.

Demand terminology

Reactor-related requirements: Refers to natural uranium acquisitions *not* necessarily consumption during a calendar year.

Environmental terminology[2]

Close-out: In the context of uranium mill tailings impoundment, the operational, regulatory and administrative actions required to place a tailings impoundment into long-term conditions such that little or no future surveillance and maintenance are required.

Decommissioning: Actions taken at the end of the operating life of a uranium mill or other uranium facility in retiring it from service with adequate regard for the health and safety of workers and members of the public and protection of the environment. The time period to achieve decommissioning may range from a few to several hundred years.

Decontamination: The removal or reduction of radioactive or toxic chemical contamination using physical, chemical, or biological processes.

Dismantling: The disassembly and removal of any structure, system or component during decommissioning. Dismantling may be performed immediately after permanent retirement of a mine or mill facility or may be deferred.

Environmental restoration: Clean-up and restoration, according to predefined criteria, of sites contaminated with radioactive and/or hazardous substances during past uranium production activities.

Environmental impact statement: A set of documents recording the results of an evaluation of the physical, ecological, cultural and socio-economic effects of a planned installation, facility, or technology.

Groundwater restoration: The process of returning affected groundwater to acceptable quality and quantity levels for future use.

2. Definitions based on those published in OECD (2002), *Environmental Remediation of Uranium Production Facilities*, Paris.

Reclamation: The process of restoring a site to predefined conditions, which allows new uses.

Restricted release (or use): A designation, by the regulatory body of a country, that restricts the release or use of equipment, buildings, materials or the site because of its potential radiological or other hazards.

Tailings: The remaining portion of a metal-bearing ore consisting of finely ground rock and process liquids after some or all of the metal, such as uranium, has been extracted.

Tailings impoundment: A structure in which the tailings are deposited to prevent their release into the environment.

Unrestricted release (or use): A designation, by the regulatory body of a country, that enables the release or use of equipment, buildings, materials or the site without any restriction.

Geological terminology

Uranium occurrence: A naturally occurring, anomalous concentration of uranium.

Uranium deposit: A mass of naturally occurring mineral from which uranium could be economically exploited at present or in the future.

Geologic types of uranium deposits[3]: uranium resources can be assigned on the basis of the following 15 major categories of uranium ore deposit types (arranged according to their approximate economic significance):

1. Sandstone deposits
2. Proterozoic unconformity deposits
3. Polymetallic Fe-oxide breccia complex deposits
4. Paleo-quartz-pebble conglomerate deposits
5. Granite-related
6. Metamorphite
7. Intrusive deposits
8. Volcanic-related deposits
9. Metasomatite deposits
10. Surficial deposits
11. Carbonate deposits
12. Collapse breccia-type deposits
13. Phosphate deposits
14. Lignite and coal
15. Black shale

Detailed descriptions with examples follow. Note that for Red Book reporting purposes only the major categories are used. However, descriptions of the sub-types for sandstone and Proterozoic unconformity deposits have also been included because of their importance.

1. Sandstone deposits: Sandstone-hosted uranium deposits occur in medium- to coarse-grained sandstones deposited in a continental fluvial or marginal marine sedimentary environment. Uranium is precipitated under reducing conditions caused by a variety of reducing agents within the sandstone, such as carbonaceous material, sulphides (pyrite), hydrocarbons and ferro-magnesian minerals (chlorite), bacterial activity, migrated fluids from underlying hydrocarbon reservoirs, and others. Sandstone uranium deposits can be divided into five main sub-types (with frequent transitional types between them):

   - Basal channel deposits: Paleodrainage systems consist of wide channels filled with thick, permeable alluvial-fluvial sediments. The uranium is predominantly associated with detrital plant debris in orebodies that display, in a plan view, an elongated lens or ribbon-like configuration and, in a section-view, a lenticular or, more rarely, a roll shape. Individual deposits can range from several hundred to 20 000 t of uranium, at grades ranging from 0.01% to 3%. Examples are the deposits of Dalmatovskoye (Transural Region), Malinovskoye (West Siberia), Khiagdinskoye (Vitim District) in the Russia, deposits of the Tono District (Japan), Blizzard (Canada) and Beverley (Australia).

3. This classification of the geological types of uranium deposits was updated in 2011-2012 through a number of IAEA consultancies that included an update of the World Distribution of Uranium Deposits (UDEPO).

- Tabular deposits consist of uranium matrix impregnations that form irregularly shaped lenticular masses within reduced sediments. The mineralised zones are largely oriented parallel to the depositional trend. Individual deposits can contain several hundred tons up to 150 000 tons of uranium, at average grades ranging from 0.05% to 0.5%, occasionally up to 1%. Examples of deposits include Hamr-Stráz (Czech Republic), Akouta, Arlit, and Imouraren (Niger) and those of the Colorado Plateau (United States).
- Roll-front deposits: The mineralised zones are convex in shape, oriented down the hydrologic gradient. They display diffuse boundaries with reduced sandstone on the down-gradient side and sharp contacts with oxidised sandstone on the up-gradient side. The mineralised zones are elongate and sinuous approximately parallel to the strike, and perpendicular to the direction of deposition and groundwater flow. Resources can range from a few hundred tons to several thousands of tons of uranium, at grades averaging 0.05% to 0.25%. Examples are Budenovskoye, Tortkuduk, Moynkum, Inkai and Mynkuduk (Kazakhstan); Crow Butte and Smith Ranch (United States) and Bukinay, Sugraly and Uchkuduk (Uzbekistan).
- Tectonic/lithologic deposits are discordant to strata. They occur in permeable fault zones and adjacent sandstone beds in reducing environments created by hydrocarbons and/or detrital organic matter. Uranium is precipitated in fracture or fault zones related to tectonic extension. Individual deposits contain a few hundred tons up to 5 000 tons of uranium at average grades ranging from 0.1-0.5%. Examples include the deposits of the Lodève District (France) and the Franceville basin (Gabon).
- Mafic dykes/sills in Proterozoic sandstones: mineralisation is associated with mafic dykes and sills that are interlayered with or crosscut Proterozoic sandstone formations. Deposits can be subvertical along the dyke's borders, sometime within the dykes, or stratabound within the sandstones along lithological contacts (Westmoreland District, Australia; Matoush, Canada). Deposits are small to medium (300-10 000 t) with grades low to medium (0.05-0.40%).

2. Proterozoic unconformity deposits: Unconformity-related deposits are associated with and occur immediately below and above an unconformable contact that separates Archean to Paleoproterozoic crystalline basement from overlying, redbed clastic sediments of Proterozoic age. In most cases, the basement rocks immediately below the unconformity are strongly hematised and clay altered, possibly as a result of paleoweathering and/or diagenetic/hydrothermal alteration. Deposits consist of pods, veins and semimassive replacements consisting of mainly pitchblende. They are preferentially located in two major districts, the Athabasca Basin (Canada) and the Pine Creek Orogen (Australia). The unconformity-related deposits include three sub-types:

   - Unconformity-contact deposits: Except for the low-grade Karku deposit (Russia), these all occur in the Athabasca Basin (Canada). Deposits develop at the base of the sedimentary cover directly above the unconformity. They form elongate pods to flattened linear orebodies typically characterised by a high-grade core surrounded by a lower grade halo. Most of the orebodies have root-like extensions into the basement. While some mineralisation is open space infill, much of it is replacement style. Often, mineralisation also extends up into the sandstone cover within breccias and fault zones forming "perched mineralisation". Deposits can be monometallic (McArthur River) or polymetallic (Cigar Lake). Deposits are medium to large to very large (1 000-200 000 t) and are characterised by their high grades (1-20%).
   - Basement-hosted deposits are strata-structure bound in metasediments below the unconformity on which the basinal clastic sediments rest. The basement ore typically occupies moderately to steeply dipping brittle shear, fracture and breccia zones hundreds of metres in strike length that can extend down-dip for several tens to more than 500 m into basement rocks below the unconformity. Disseminated and vein uraninite/pitchblende occupies fractures and breccia matrix but may also replace the host rock. High-grade ore is associated with brecciated graphitic schists. These deposits have small to very large resources (300-200 000 t), at medium grade (0.10-0.50%).

Examples are Kintyre, Jabiluka and Ranger in Australia, Millennium and Eagle Point in the Athabasca Basin and Kiggavik and Andrew Lake in the Thelon Basin (Canada).

- Stratiform structure-controlled deposits: low-grade (0.05-0.10%), stratabound, thin (1-5 m) zones of mineralisation are located along the unconformity between Archean, U-Th-rich granites and Proterozoic metasediments with minor enrichments along fractures. This type of deposit (Chitrial and Lambapur) has only been observed in the Cuddapah basin (India). Resources of individual deposits range between 1 000-8 000 t.

3. Polymetallic iron-oxide breccia complex deposits: This type of deposit has been attributed to a broad category of worldwide iron oxide-copper-gold deposits. Olympic Dam (Australia) is the only known representative of this type with significant by-product uranium resources. The deposit contains the world's largest uranium resources with more than 2 Mt of uranium. Deposits of this group occur in hematite-rich granite breccias and contain disseminated uranium in association with copper, gold, silver and rare earth elements. At Olympic Dam, this breccia is hosted within a Mesoproterozoic highly potassic granite intrusion that exhibits regional Fe-K-metasomatism. Significant deposits and prospects of this type occur in the same region, including Prominent Hill, Wirrda Well, Carrapeteena, Acropolis and Oak Dam as well as some younger breccia-hosted deposits in the Mount Painter area.

4. Paleo-quartz pebble conglomerate deposits: Deposits of this type contain detrital uranium oxide ores, which are found in quartz pebble conglomerates deposited as basal units in fluvial to lacustrine braided stream systems older than 2 400-2 300 Ma. The conglomerate matrix is pyritic and contains gold, as well as other accessory and oxide and sulphide detrital minerals that are often present in minor amounts. Examples include deposits in the Witwatersrand basin, South Africa, where uranium is mined as a by-product of gold as well as deposits in the Blind River/Elliot Lake area of Canada.

5. Granite-related deposits include: i) true veins composed of ore and gangue minerals in granite or adjacent (meta-) sediments and ii) disseminated mineralisation in granite as episyenite bodies. Uranium mineralisation occurs within, at the contact or peripheral to the intrusion. In the Hercynian belt of Europe, these deposits are associated with large, peraluminous two-mica granite complexes (leucogranites). Resources range from small to large and grades are variable, from low to high.

6. Metamorphite deposits correspond to disseminations, impregnations, veins and shear zones within or affecting metamorphic rocks of various ages. These deposits are highly variable in sizes, resources and grades.

7. Intrusive deposits are contained in intrusive or anatectic igneous rocks of many different petrochemical compositions (granite, pegmatite, monzonite, peralkaline syenite and carbonatite). Examples include the Rossing and Rossing South (Husab) deposits (Namibia), the deposits in the Bancroft area (Canada), the uranium occurrences in the porphyry copper deposits of Bingham Canyon and Twin Butte (United States), the Kvanefjeld and Sorensen deposits (Greenland) and the Palabora carbonatite complex (South Africa).

8. Volcanic-related deposits are located within and near volcanic calderas filled by mafic to felsic, effusive and intrusive volcanic rocks and intercalated clastic sediments. Uranium mineralisation is largely controlled by structures as veins and stockworks with minor stratiform lodes. This mineralisation occurs at several stratigraphic levels of the volcanic and sedimentary units and may extend into the basement where it is found in fractured granite and metamorphic rocks. Uranium minerals (pitchblende, coffinite, U_6+ minerals, less commonly brannerite) are associated with Mo-bearing sulphides and pyrite. Other anomalous elements include As, Bi, Ag, Li, Pb, Sb, Sn and W. Associated gangue minerals comprise violet fluorite, carbonates, barite and quartz. The most significant deposits are located within the Streltsovska caldera in Russia. Other examples are known in China (Xiangshan District), Mongolia (Dornot and Gurvanbulag Districts), the United States (McDermitt caldera) and Mexico (Pena Blanca District).

9. Metasomatite deposits are confined to Precambrian shields in areas of tectono-magmatic activity affected by intense Na-metasomatism or K-metasomatism, which produced albitised or illitised facies along deeply rooted fault systems. In Ukraine, these deposits are developed within a variety of basement rocks, including granites, migmatites, gneisses and ferruginous quartzites, which produced albitites, aegirinites, alkali-amphibolic, as well as carbonate and ferruginous rocks. Principal uranium phases are uraninite, brannerite and other Ti-U-bearing minerals, coffinite and hexavalent uranium minerals. The reserves are usually medium to large. Examples include Michurinskoye, Vatutinskoye, Severinskoye, Zheltorechenskoye, Novokonstantinovskoye and Pervomayskoye deposits (Ukraine), deposits of the Elkon District (Russia), Espinharas and Lagoa Real (Brazil), Valhalla (Australia), Kurupung (Guyana), Coles Hill (US), Lianshanguan (China), Michelin (Canada) and small deposits of the Arjeplog region in the north of Sweden.

10. Surficial deposits are broadly defined as young (Tertiary to Recent), near-surface uranium concentrations in sediments and soils. The largest of the surficial uranium deposits are in calcrete (calcium and magnesium carbonates) found mainly in Australia (Yeelirrie deposit) and Namibia (Langer Heinrich deposit). These calcrete-hosted deposits mainly occur in valley-fill sediments along Tertiary drainage channels and in playa lake sediments in areas of deeply weathered, uranium-rich granites. Carnotite is the main uraniferous mineral. Surficial deposits also occur less commonly in peat bogs, karst caverns and soils.

11. Carbonate deposits are hosted in carbonate rocks (limestone, dolostone). Mineralisation can be syngenetic stratabound or more commonly structure-related within karsts, fractures, faults and folds. The only example of a stratabound carbonate deposits is the Tummalapalledeposit in India, which is hosted in phosphatic dolostone. At Mailuu-Suu, Kyrgyzstan and Todilto, United States. Another example includes deposits developed in solution collapse breccias occurring in limestone with intercalations of carbonaceous shale such as the Sanbaqi deposit, China.

12. Collapse breccia-type deposits occur in cylindrical, vertical pipes filled with down-dropped fragments developed from karstic dissolution cavities in underlying thick carbonate layers. The uranium is concentrated as primary uranium ore, mainly uraninite, in the permeable breccia matrix, and in the arcuate, ring-fracture zone surrounding the pipe. The pitchblende is intergrown with numerous sulphide and oxide minerals variably containing Cu, Fe, V, Zn, Pb, Ag, Mo, Ni, Co, As and Se. Type examples are the deposits in the Arizona Strip north of the Grand Canyon and those immediately south of the Grand Canyon in the United States. Resources are small to medium (300-2 500 t) with grades around 0.20-0.80%.

13. Phosphate deposits are principally represented by marine phosphorite of continental-shelf origin containing syn-sedimentary, stratiform, disseminated uranium in fine-grained apatite. Phosphorite deposits constitute large uranium resources (millions of tons), but at a very low grade (0.005-0.015%). Uranium can be recovered as a by-product of phosphate production. Examples include the Land Pebble District, Florida (land-pebble phosphate) (US), Gantour (Morocco) and Al-Abiad (Jordan). Another type of phosphorite deposits consists of organic phosphate, including argillaceous marine sediments enriched in fish remains that are uraniferous (Melovoye, Kazakhstan). Deposits in continental phosphates are not common.

14. Lignite-coal deposits consist of elevated uranium contents in lignite/coal mixed with mineral detritus (silt, clay), and in immediately adjacent carbonaceous mud and silt/sandstone beds. Pyrite and ash contents are high. Lignite-coal seams are often interbedded or overlain by felsic pyroclastic rocks. Examples are deposits of the south-western Williston basin, North and South Dakota (US), Koldjat and Nizhne Iliyskoe (Kazakhstan), Freital (Germany), Ambassador (Australia) and the Serres basin (Greece).

15. Black shale deposits include marine, organic-rich shale or coal-rich pyritic shale, containing synsedimentary, disseminated uranium adsorbed onto organic material, and fracture-controlled mineralisation within or adjacent to black shale horizons. Examples include the uraniferous alum shale in Sweden and Estonia, the Chattanooga shale (United States), the Chanziping deposit (China) and the Gera-Ronneburg deposit (Germany).

Appendix 4. List of abbreviations and acronyms

ARMZ	Atomredmetzoloto
BHP	BHP Billiton
CAREM	Central Argentina de Elementos Modulares
CCHEN	Chilean Nuclear Energy Commission
CGNPC	China General Nuclear Power Corporation
CEA	Commissariat à l'Energie Atomique et aux Energies Alternatives
CNEA	National Atomic Energy Commission (Argentina)
CNEN	National Nuclear Energy Commission (Brazil)
CNNC	China National Nuclear Corporation
CNPC	China National Petroleum Corporation
CNSC	Canadian Nuclear Safety Commission
COGEMA	Compagnie Générale des Matières Nucléaires
CRA	Conzinc Riotinto of Australia
DFS	Definitive feasibility study
DOE	Department of Energy (United States)
DU	Depleted uranium
EC	European Commission
EDF	Électricité de France
EIA	Environmental impact assessments
EPA	Environmental Protection Authority (United States)
EPL	Exclusive prospecting licence
EPR	European pressurised reactor
ENAMI	National Mining Company of Chile
ENUSA	Industrias Avanzadas, S.A. S.M.E. (Spain)
ERA	Energy Resources of Australia
ESA	Euratom Supply Agency
EU	European Union
Ga	Giga-years
GAC	Global Atomic Corporation
GDR	German Democratic Republic
GDRRE	Geological Division for Radioactive and Rare Elements

GWe	Gigawatt electric
ha	Hectare
HEU	Highly enriched uranium
HL	Heap leaching
IAEA	International Atomic Energy Agency
IBAMA	Brazilian Institute for the Environment and Renewable Natural Resources
INB	Industrias Núcleares do Brasil S.A
IPEN	Peruvian Institute Nuclear Energy
IPL	In-place leaching
IR	Inferred resources
ISL	In situ leaching
ISR	In situ recovery
IX	Ion exchange
JAEA	Japan Atomic Energy Agency
JAEC	Jordan Atomic Energy Commission
JOGMEC	Japan Oil, Gas and Metals National Corporation
JORC	Joint Ore Reserves Committee
KEPCO	Korea Electric Power Corporation
kg	Kilogram
km	Kilometre
lb	Pound
LEU	Low-enriched uranium
MOX	mixed oxide fuel
MRE	Mineral resource estimate
MTA	General Directorate of Mineral Research and Exploration (Turkey)
MWe	Megawatt electric
NatU	Natural uranium
NEA	Nuclear Energy Agency
NMMC	Navoi Mining and Metallurgical Complex
NNSA	National Nuclear Security Administration (United States)
NPP	Nuclear power plant
NRC	Nuclear Regulatory Commission (United States)
NUA	Namibian Uranium Association
NWMO	Nuclear Waste Management Organization (Canada)
OECD	Organisation for Economic Co-operation and Development
OP	Open pit
ppm	Parts per million

PMCPA	Priargunsky Mining-Chemical Production Association
PR	Prognosticated resources
Pu	Plutonium
RAR	Reasonably assured resources
REE	Rare earth elements
RepU	Reprocessed uranium
RMRE	Reptile Mineral Resources & Exploration (Namibia)
SDAG	Sowjetisch-Deutsche Aktiengesellschaft
SMR	Small modular reactors
SR	Speculative resources
STUK	Radiation and Nuclear Safety Authority (Finland)
SWU	Separative work unit
SX	Solvent extraction
t	Tonnes (metric tons)
TAEK	Turkish Atomic Energy Authority
TENEX	Techsnabexport
Th	Thorium
tHM	Tonnes heavy metal
TOE	Tonnes oil equivalent
tU	Tonnes uranium
tU_3O_8	Tonnes triuranium octoxide
tUnat	Tonnes natural uranium equivalent
TVA	Tennessee Valley Authority
TVEL	TVEL Fuel Company
TVO	Teollisuuden Voima Oyj
TWh	Terawatt-hour
U	Uranium
UCIL	Uranium Corporation of India Limited
UDEPO	World Distribution of Uranium Deposits database (IAEA)
UEC	Uranium Energy Corporation
UG	Underground
USEC	United States Enrichment Corporation
USGS	US Geological Survey
US EIA	US Energy Information Administration
VostGOK	Vostochnyi Mining-process Combinat (Ukraine)
VVER	Water-water energetic reactor
WNA	World Nuclear Association

Appendix 5. Energy conversion factors

The need to establish a set of factors to convert quantities of uranium into common units of energy has become increasingly evident with the growing frequency of requests in recent years in relation to the various types of reactors.

Conversion factors and energy equivalence for fossil fuel for comparison

1 cal	=	4.1868 J
1 J	=	0.239 cal
1 tonne of oil equivalent (TOE) (net, lower heating value [LHV])	=	42 GJ * = 1 TOE
1 tonne of coal equivalent (TCE) (standard, LHV)	=	29.3 GJ* = 1 TCE
1 000 m^3 of natural gas (standard, LHV)	=	36 GJ
1 tonne of crude oil	=	approx. 7.3 barrels
1 tonne of liquid natural gas (LNG)	=	45 GJ
1 000 kWh (primary energy)	=	9.36 MJ
1 TOE	=	10 034 Mcal
1 TCE	=	7 000 Mcal
1 000 m^3 natural gas (atmospheric pressure)	=	8 600 Mcal
1 tonne LNG	=	11 000 Mcal
1 000 kWh (primary energy)	=	2 236 Mcal **
1 TCE	=	0.698 TOE
1 000 m^3 natural gas (atmospheric pressure)	=	0.857 TOE
1 tonne LNG	=	1.096 TOE
1 000 kWh (primary energy)	=	0.223 TOE
1 tonne of fuelwood	=	0.3215 TOE
1 tonne of uranium: light-water reactors	=	10 000-16 000 TOE
open cycle	=	14 000-23 000 TCE

* World Energy Council standard conversion factors (from WEC, 1998 Survey of Energy Resources, 18th Edition).

** With 1 000 kWh (final consumption) = 860 Mcal as WEC conversion factor.

Appendix 6. List of all Red Book editions (1965-2024) and national reports

Listing of Red Book editions (1965-2024)

OECD/ENEA*	World Uranium and Thorium Resources, Paris, 1965
OECD/ENEA	Uranium Resources, Revised Estimates, Paris, 1967
OECD/ENEA-IAEA	Uranium Production and Short-Term Demand, Paris, 1969
OECD/ENEA-IAEA	Uranium Resources, Production and Demand, Paris, 1970
OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1973
OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1976
OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1977
OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1979
OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1982
OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1983
OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1986
OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1988
OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1990
OECD/NEA-IAEA	Uranium 1991: Resources, Production and Demand, Paris, 1992
OECD/NEA-IAEA	Uranium 1993: Resources, Production and Demand, Paris, 1994
OECD/NEA-IAEA	Uranium 1995: Resources, Production and Demand, Paris, 1996
OECD/NEA-IAEA	Uranium 1997: Resources, Production and Demand, Paris, 1998
OECD/NEA-IAEA	Uranium 1999: Resources, Production and Demand, Paris, 2000
OECD/NEA-IAEA	Uranium 2001: Resources, Production and Demand, Paris, 2002
OECD/NEA-IAEA	Uranium 2003: Resources, Production and Demand, Paris, 2004
OECD/NEA-IAEA	Uranium 2005: Resources, Production and Demand, Paris, 2006
OECD/NEA-IAEA	Uranium 2007: Resources, Production and Demand, Paris, 2008
OECD/NEA-IAEA	Uranium 2009: Resources, Production and Demand, Paris, 2010
OECD/NEA-IAEA	Uranium 2011: Resources, Production and Demand, Paris, 2012
OECD/NEA-IAEA	Uranium 2014: Resources, Production and Demand, Paris, 2014
OECD/NEA-IAEA	Uranium 2016: Resources, Production and Demand, Paris, 2016
OECD/NEA-IAEA	Uranium 2018: Resources, Production and Demand, Paris, 2018
OECD/NEA-IAEA	Uranium 2020: Resources, Production and Demand, Paris, 2020
OECD/NEA-IAEA	Uranium 2022: Resources, Production and Demand, Paris, 2023
OECD/NEA-IAEA	Uranium 2024: Resources, Production and Demand, Paris, 2025

* ENEA: European Nuclear Energy Agency; former name of the Nuclear Energy Agency (NEA).

Index of national reports in Red Books

(The following index lists all national reports by the year in which these reports were published in the Red Books)

	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
Algeria						1976	1977	1979	1982						
Argentina		1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
Armenia															
Australia		1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
Austria							1977								
Bangladesh											1986	1988			
Belgium									1982	1983	1986	1988	1990	1992	1994
Benin													1990		
Bolivia							1977	1979	1982	1983	1986				
Bophuthatswana [1]									1982						
Botswana								1979		1983	1986	1988			
Brazil				1970	1973	1976	1977	1979	1982	1983	1986			1992	1994
Bulgaria													1990	1992	1994
Cameroon							1977		1982	1983					
Canada	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
Central African Republic				1970	1973		1977	1979			1986				
Chad															
Chile							1977	1979	1982	1983	1986	1988		1992	1994
China													1990	1992	1994
Colombia							1977	1979	1982	1983	1986	1988	1990		
Congo		1967													
Costa Rica									1982	1983	1986	1988	1990		
Côte d'Ivoire									1982						
Cuba												1988		1992	
Czechia															1994
Czech and Slovak Rep.													1990		
Denmark (Greenland)	1965	1967		1970	1973	1976	1977	1979	1982	1983	1986		1990	1992	
Dominican Republic									1982						
Ecuador							1977		1982	1983	1986	1988			
Egypt							1977	1979			1986	1988	1990	1992	1994
El Salvador										1983	1986				
Estonia															
Ethiopia								1979		1983	1986				
Finland					1973	1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
France	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
Gabon		1967		1970	1973				1982	1983	1986				
Germany				1970		1976	1977	1979	1982	1983	1986	1988	1990	1992	1994

1. Bophuthatswana is a former republic, dissolved in 1994, in the north-western region of South Africa.

Index of national reports in Red Books (*cont'd*)

1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	
			2002	2004	2006	2008		2012	2014	2016	2018	2020	2022	2024	Algeria
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Argentina
		2000	2002	2004	2006		2010	2012	2014	2016	2018	2020	2022	2024	Armenia
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Australia
															Austria
													2022	2024	Bangladesh
1996	1998	2000	2002	2004	2006	2008									Belgium
															Benin
											2018		2022	2024	Bolivia
															Bophuthatswana
							2010	2012	2014	2016		2020	2022	2024	Botswana
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Brazil
1996	1998					2008	2010						2022	2024	Bulgaria
														2024	Cameroon
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Canada
													2022	2024	Central African Republic
									2014	2016					Chad
1996	1998	2000	2002	2004	2006	2008		2012	2014	2016	2018	2020	2022	2024	Chile
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	China
1996	1998					2008									Colombia
															Congo
															Costa Rica
															Côte d'Ivoire
1996	1998														Cuba
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Czechia
															Czech and Slovak Rep.
1996	1998			2004			2010	2012	2014	2016	2018	2020	2022	2024	Denmark (Greenland)
															Dominican Republic
													2022	2024	Ecuador
1996	1998	2000		2004	2006	2008	2010					2020	2022	2024	Egypt
															El Salvador
	1998			2004											Estonia
								2012							Ethiopia
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Finland
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	France
1996	1998	2000	2002	2004	2006										Gabon
1996	1998	2000	2002		2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Germany

Index of national reports in Red Books *(cont'd)*

	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
Ghana							1977			1983					
Greece							1977	1979	1982	1983	1986	1988	1990	1992	1994
Guatemala											1986	1988			
Guyana								1979	1982	1983	1986				
Hungary														1992	1994
India	1965	1967		1970	1973	1976	1977	1979	1982	1983	1986		1990	1992	1994
Indonesia							1977				1986	1988	1990	1992	1994
Iran, Islamic Republic of							1977								
Iraq															
Ireland								1979	1982	1983	1986			1992	
Italy		1967		1970	1973	1976	1977	1979	1982	1983	1986	1988		1992	1994
Jamaica									1982	1983					
Japan	1965	1967		1970	1973	1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
Jordan							1977				1986	1988	1990	1992	1994
Kazakhstan															1994
Kenya															
Korea						1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
Kyrgyzstan															
Lesotho												1988			
Liberia							1977			1983					
Libyan Arab Jamahiriya[2]										1983					
Lithuania															1994
Madagascar						1976	1977	1979	1982	1983	1986	1988			
Malawi															
Malaysia										1983	1986	1988	1990	1992	1994
Mali											1986	1988			
Mauritania													1990		
Mexico				1970	1973	1976	1977	1979	1982		1986		1990	1992	1994
Mongolia															1994
Morocco	1965	1967				1976	1977	1979	1982	1983	1986	1988	1990		
Namibia								1979	1982	1983	1986	1988	1990		1994
Nepal															
Netherlands									1982	1983	1986		1990	1992	1994
New Zealand		1967					1977	1979							
Niger		1967		1970	1973		1977				1986	1988	1990	1992	1994
Nigeria								1979							
Norway								1979	1982	1983				1992	
Pakistan		1967													1994
Panama										1983		1988			
Paraguay										1983	1986				
Peru							1977	1979		1983	1986	1988	1990	1992	1994
Philippines							1977		1982	1983	1986		1990		1994
Poland															

2. Libya as of 2011.

Index of national reports in Red Books *(cont'd)*

1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	
														2024	Ghana
1996	1998														Greece
															Guatemala
													2022	2024	Guyana
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Hungary
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	India
1996	1998	2000	2002	2004	2006		2010	2012	2014	2016	2018	2020	2022	2024	Indonesia
	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Iran, Islamic Republic of
										2016					Iraq
	1998														Ireland
1996	1998	2000						2012	2014	2016					Italy
															Jamaica
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018		2022	2024	Japan
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Jordan
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Kazakhstan
														2024	Kenya
1996	1998	2000	2002	2004	2006	2008	2010								Korea
1996			2002												Kyrgyzstan
															Lesotho
															Liberia
															Libyan Arab Jamahiriya
1996	1998	2000	2002	2004	2006	2008									Lithuania
												2020		2024	Madagascar
		2000				2008	2010	2012	2014	2016		2020	2022	2024	Malawi
1996	1998	2000	2002												Malaysia
									2014	2016	2018	2020	2022	2024	Mali
										2016		2020	2022	2024	Mauritania
1996	1998	2000						2012		2016	2018	2020	2022	2024	Mexico
1996	1998						2010	2012	2014	2016	2018	2020	2022	2024	Mongolia
	1998														Morocco
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Namibia
													2022	2024	Nepal
1996	1998	2000	2002												Netherlands
															New Zealand
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Niger
															Nigeria
1996	1998														Norway
	1998	2000												2024	Pakistan
															Panama
											2018		2022	2024	Paraguay
1996	1998	2000		2004	2006	2008	2010	2012	2014	2016	2018		2022	2024	Peru
1996	1998	2000	2002	2004	2006										Philippines
		2000	2002			2008	2010	2012	2014	2016			2022	2024	Poland

Index of national reports in Red Books *(cont'd)*

	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
Portugal	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
Romania														1992	1994
Russia															1994
Rwanda											1986				
Saudi Arabia															
Senegal									1982						
Slovak Republic															1994
Slovenia															1994
Somalia							1977	1979							
South Africa	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986			1992	1994
Spain	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
Sri Lanka							1977		1982	1983	1986	1988			
Sudan							1977								
Surinam									1982	1983					
Sweden	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
Switzerland						1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
Syrian Arab Republic									1982	1983	1986	1988	1990		1994
Tajikistan															
Tanzania													1990		
Thailand							1977	1979	1982	1983	1986	1988	1990	1992	1994
Togo								1979							
Türkiye					1973	1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
Turkmenistan															
Ukraine															1994
United Kingdom						1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
United States	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990	1992	1994
Uruguay							1977		1982	1983	1986	1988	1990		
USSR (former)														1992	
Uzbekistan															1994
Venezuela											1986	1988			
Viet Nam														1992	1994
Yugoslavia					1973	1976	1977		1982				1990	1992	
Zaire[3]					1973		1977					1988			
Zambia											1986	1988	1990	1992	1994
Zimbabwe									1982			1988		1992	1994

3. Zaire is the former name – between 1971 and 1997 – of the Democratic Republic of the Congo.

Index of national reports in Red Books *(cont'd)*

1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016		2020	2022	2024	Portugal
1996	1998	2000	2002												Romania
	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Russia
															Rwanda
													2022	2024	Saudi Arabia
											2018	2020	2022	2024	Senegal
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016			2022	2024	Slovak Republic
1996	1998		2002	2004	2006	2008	2010		2014	2016	2018	2020	2022	2024	Slovenia
															Somalia
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016		2020	2022	2024	South Africa
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Spain
												2020			Sri Lanka
															Sudan
															Surinam
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016		2020			Sweden
1996	1998	2000	2002	2004	2006	2008									Switzerland
															Syrian Arab Republic
			2002											2024	Tajikistan
							2010	2012	2014	2016	2018	2020	2022	2024	Tanzania
1996	1998	2000	2002		2006				2014	2016	2018	2020		2024	Thailand
															Togo
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Türkiye
				2004											Turkmenistan
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	Ukraine
1996	1998	2000	2002	2004	2006	2008	2010		2014	2016	2018				United Kingdom
1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020	2022	2024	United States
															Uruguay
															USSR (former)
1996	1998	2000	2002	2004	2006			2012		2016	2018	2020	2022	2024	Uzbekistan
															Venezuela
1996	1998	2000	2002	2004	2006	2008			2014	2016	2018	2020	2022	2024	Viet Nam
															Yugoslavia
															Zaire
1996	1998							2012	2014	2016	2018	2020	2022	2024	Zambia
1996	1998													2024	Zimbabwe

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BETTER POLICIES FOR BETTER LIVES

Uranium 2024: Resources, Production and Demand

Uranium is the primary raw material fuelling all nuclear fission reactors today. Countries around the world rely on it to generate low-carbon electricity, process heat and hydrogen as part of their strategies to reduce carbon emissions and increase energy security and supply. No form of nuclear fission power – of any kind – is possible without relying on uranium.

This 30th edition of *Uranium Resources, Production and Demand*, also commonly known as the "Red Book" marks the 60th anniversary of its establishment as a recognised global reference on uranium. Jointly prepared by the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), it provides analyses and insights from 62 uranium-producing and consuming countries – some participating for the first time. The present edition reviews world uranium market fundamentals and presents data on global uranium exploration, resources, production and reactor-related requirements. It offers updated information on established uranium production centres and mine development plans, as well as projections of nuclear generating capacity and reactor-related requirements through 2050.

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