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

Uranium 2018
Resources, Production and Demand




IAEA
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NEA
NUCLEAR ENERGY AGENCY

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Uranium 2018: Resources, Production and Demand

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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 33 countries: Argentina, Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, Romania, Russia, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, 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 a 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 competence of the NEA 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.

Cover photos: Olkiluoto nuclear site, units 1, 2 and 3, Finland (TVO); uranium ore: uranophane (Orano); Somaïr open-pit mine, Niger (Orano, M. Ascani).

Preface

Since the mid-1960s, with the co-operation of their member countries and states, the OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA) have jointly prepared periodic updates (currently every two years) on world uranium resources, production and demand. Such updates have been published in what are commonly known as the "Red Books".

This 27th edition features a comprehensive assessment of uranium supply and demand and projections as of 1 January 2017 to the year 2035. The basis of this assessment is a comparison of uranium resource estimates (according to categories of geological certainty and production cost) and mine production capability with anticipated uranium requirements arising from projected installed nuclear capacity. Current data on resources, exploration, production and uranium stocks are also presented, along with historical summaries of exploration and production, and plans for future mine development. Available information on uranium secondary supply is provided and the potential impact of secondary sources on the market is assessed. Individual country reports offer detailed information on recent developments in uranium exploration and production, on environmental activities, regulatory requirements and on relevant national uranium policies.

This publication has been prepared on the basis of data obtained through questionnaires sent by the NEA to OECD member countries and by the IAEA to other countries. It contains official data provided by 36 countries and 5 national reports prepared by the NEA and the IAEA. This report is published under the responsibility of the OECD Secretary-General.

Acknowledgements

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Executive summary

In addition to updated resource figures, *Uranium 2018: Resources, Production and Demand* presents the results of the most recent review of world uranium market fundamentals and offers a statistical profile of the world uranium industry. It contains official data provided by 36 countries and 5 national reports prepared by the NEA and IAEA Scientific Secretaries on uranium exploration, resources, production and reactor-related requirements. Projections of nuclear generating capacity and reactor-related uranium requirements through 2035 are presented, as well as a discussion of long-term uranium supply and demand issues.

Resources [1]

The overall picture shows an increase in identified uranium resources. Though a portion of these increases relate to new discoveries, the majority result from re-evaluations of previously identified uranium resources. However, additional investment is required to ensure these resources can be brought into production in a timely manner.

Total identified resources recoverable (reasonably assured and inferred) as of 1 January 2017 amounted to 6 142 200 tonnes of uranium metal (tU) in the <USD 130/kgU (<USD 50/lb U_3O_8) category, an increase of 7.4% compared to 2015. In the highest cost category (<USD 260/kgU or <USD 100/lb U_3O_8), total identified resources amounted to 7 988 600 tU, an increase of 4.5% compared to the total reported for the previous edition.

Reasonably assured resources (RAR) reported for this edition increased in all cost categories. In comparison, inferred resources decreased overall from 3 255 100 tU in 2015 to 3 173 000 tU in 2017, mainly due to the re-evaluation of resources, with Kazakhstan and the Russian Federation reporting the most significant decreases. The most notable change is reported in the <USD 40/kgU category, with an increase of 49.1% in RAR and 104.5% in inferred resources, compared to values reported in 2015. This can be primarily attributed to currency devaluation in Kazakhstan, which shifted the national resources into the lowest cost category.

1. 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*) refer to uranium deposits delineated by sufficient direct measurement to conduct pre-feasibility and sometimes feasibility studies. For *RAR*, 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 (*prognosticated* and *speculative*) 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.

At the 2016 level of uranium requirements, identified recoverable resources are sufficient for over 130 years of supply for the global nuclear power fleet. Moreover, an additional 73 230 tU of resources have been identified by the NEA/IAEA as resources reported by companies that are not yet included in national resource totals.

A summary has been prepared of worldwide in situ identified resources. Overall, there is a 22% to 33% increase in the resources when they are reported as in situ. The total identified in situ resources increased from 10 188 700 tU reported in 2016 to 10 652 900 tU for this edition. Reporting in situ resources provides a more optimistic view of the available resource base and gives some indication of how the resource base could increase with improvements in mining and processing methods, which would lead to better recovery.

Additions to the conventional resource base in the future could come from undiscovered resources (prognosticated resources and speculative resources), which as of 1 January 2017 amounted to 7 530 600 tU, a 1.5% increase from the 7 422 700 tU reported in the previous edition (NEA/IAEA, 2016). Unconventional resources are another source of potential future supply and currently amount to over 28.5 million tU. It is important to note that in some cases, including those of major producing countries with large identified resource inventories (e.g. Australia, Canada and the United States), 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 volume are a snapshot of the situation as of 1 January 2017. Readers should keep in mind that resource figures are dynamic and related to commodity prices.

Exploration and mining development

Uranium exploration and mine development expenditures declined from over USD 2 billion in 2014 to USD 663 678 million in 2016. Total expenditures continue to decrease in response to a sustained depressed uranium market since mid-2011.

Worldwide exploration and mine development expenditures as of 1 January 2017 totalled USD 663 678 million, a large, 59% decrease over 2014 figures. This substantial decrease can be partially attributed to the expenditures that were associated with the development of the Cigar Lake mine in Canada and Husab mine in Namibia. However, in addition, significant decreases were reported for Australia, Canada, the People's Republic of China (China), the Czech Republic, Namibia, Russia and the United States. Kazahkstan reported an increase in expenditures from USD 34.7 million to USD 60.9 million from 2014 to 2015 but this was followed by a sharp decline to USD 23.9 million in 2016. The decline in exploration and development expenditures for this reporting period reflects an adjustment within the industry in response to oversupply, which began with the depressed uranium market in the middle of 2011.

Non-domestic exploration and development expenditures are a subset of worldwide exploration and development expenditures. Only four countries – China, France, Japan and Russia – report their out-of-country (non-domestic) expenditures and this decreased from USD 801 million in 2014 to USD 419 million in 2016. This is mainly due to decreased non-domestic development expenses for China following the completion of the major development and investment in the Husab mine in Namibia.

From 2016 to 2017, Canada had the highest uranium and exploration development expenditures, followed by China and India.

Production

Global uranium mine production increased by 3% from 2015 to 2016. However, production has started to decline with 59 342 tU produced in 2017 and further reductions are expected in 2018 as major producing countries, including Canada and Kazakhstan, limit total production in response to the sustained low price of uranium.

Overall, world uranium production increased by 3% from 60 291 tU in 2015 to 62 071 tU as of 1 January 2017. The changes are principally the result of increased production in Australia, Canada and Kazakhstan along with some other more modest increases reported for China and Namibia. However, production has since declined to 59 342 tU in 2017 and is expected to decline even further in 2018 as major producers are limiting production in response to a depressed uranium market.

Within OECD countries, production increased from 16 217 tU in 2014 to 21 521 tU in 2016, primarily as a result of increased production in Australia and Canada.

In 2016, uranium was produced in 19 different countries, which is two less than the last reporting period as Romania stopped production in 2016 and the Kayelekera mine in Malawi was placed on care and maintenance in May 2014. Production also ceased in December 2016 at the Rozná underground mine in the Czech Republic. Out of the 19 producing countries, 16 are primary producers as France, Germany and Hungary produced uranium only as a result of mine remediation activities. Kazakhstan's growth in production continued, but at a much slower pace, and it remains the world's largest producer reporting production of 23 806 tU in 2015 and 24 689 tU in 2016. Production from Kazakhstan totals more than the combined production reported in 2016 from both Canada and Australia, the second and third largest producers of uranium, respectively. Canada and Kazakhstan will produce less in 2018 as both countries announced plans to limit production in response to the depressed uranium market.

In situ leaching (ISL, sometimes referred to as in situ recovery [ISR] production) continued to dominate uranium production accounting for 50% of world production as of 1 January 2017, largely due to continued production increases from Kazakhstan and other projects in Australia and China. Underground mining (31%), open-pit mining (13%) and co-product and by-product recovery from copper and gold operations (6%), heap leaching (<1%) and other methods (<1%) accounted for the remaining uranium production shares.

Environmental and social aspects of uranium exploration and production

With uranium production projected to expand in a mid-term perspective, efforts are being made to develop safe mining practices and to continue to minimise environmental impacts. Brief country overviews indicate the status of site remediation and decommissioning projects and highlight 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 gaining increasing importance and, as in the last few editions, updates on activities in this area are included in the national reports. With uranium production ready to expand, in some cases, to countries hosting uranium production for the first time, the continued development of transparent, safe and well-regulated operations that minimise environmental impacts is crucial.

Several countries provided updates for this edition on activities related to environmental aspects of uranium exploration and production including Argentina, Australia, Canada, Finland, Greenland, Kazakhstan, Mali, Namibia, Spain, Tanzania, Ukraine, Viet Nam and Zambia. For several countries with closed uranium production facilities (i.e. Brazil, Canada, the Czech Republic, France, Hungary, Slovenia, Spain, Ukraine and the United States), updates of remedial and monitoring activities are provided in the respective country reports.

For example, Namibia continues to make progress in a number of environmental and social issues, building on the establishment of the Rössing Foundation in 1978. The foundation's activities focus on education, health care, environmental management and radiation safety in the uranium industry. With the development of the Husab mine, Swakop Uranium has engaged in social responsibility programmes, including committing itself to local procurement, recruitment and employment, training, education and responsible environmental management practices.

Additional information on environmental aspects of uranium production may be found in *Managing Environmental and Health Impacts of Uranium Mining* (NEA, 2014), which outlines significant improvements that have been undertaken in these areas since the early strategic period of uranium mining to the present day. More recently, the IAEA Bulletin, *Uranium from Exploration to Remediation* (IAEA, 2018) includes some information on this topic.

Uranium demand

The outlook for nuclear power has decreased since the 2016 report. However, demand for uranium is expected to continue to rise for the foreseeable future as nuclear power is projected to grow in regulated electricity markets with increasing electricity demand and a growing need for low-carbon electricity generation. Promoting incentives for all types of low-carbon electricity production are key conditions for a greater projected growth in nuclear capacity.

As of 1 January 2017, a total of 449 commercial nuclear reactors were connected to the grid globally, with a net generating capacity of 391 GWe requiring about 62 825 tU annually. Taking into account changes in policies announced in several countries and revised nuclear programmes, world nuclear capacity is projected to grow to between 331 GWe net in the low demand case and 568 GWe net in the high demand case by 2035. The low case represents a decrease of about 15% from 2016 nuclear generating capacity, while the high case represents an increase of about 45%. Accordingly, world annual reactor-related uranium requirements (excluding mixed oxide fuel [MOX]) are projected to rise to between 53 010 tU and 90 820 tU by 2035.

Nuclear capacity projections vary considerably from region to region. The East Asia region is projected to experience the largest increase, which, by the year 2035, could result in the installation of between 30 GWe and 120 GWe of new capacity in the low and high cases, respectively, representing increases of more than 30% and 122% over 2016 capacity. Nuclear capacity in non-EU member countries on the European continent is also projected to increase considerably, with between 47.5 and 67.8 GWe of capacity projected by 2035 (increases of about 9% and 56% over 2016 capacity, respectively). Other regions projected to experience significant nuclear capacity growth include the Middle East, Central and Southern Asia, with more modest growth projected in Africa, the Central and South American, and the South-eastern Asia regions.

For North America, the projections see nuclear generating capacity decreasing by 2035 in both the low and high cases, depending largely on future electricity demand, lifetime extension of existing reactors and government policies with respect to greenhouse gas emissions. The reality of financial losses in several reactors in the United States has resulted in a larger number of premature shutdowns to be assumed. In the European Union (EU), nuclear capacity in 2035 is projected to decrease by 48% in the low case scenario and decrease by 3% in the high case.

Key factors influencing future nuclear energy capacity include projected electricity demand, the economic competitiveness of nuclear power plants, as well as funding arrangements for such capital-intensive projects, the cost of fuel for other electricity generating technologies, proposed waste management strategies and public acceptance of nuclear energy. Concerns about longer-term security of fossil fuel supply and the extent to which nuclear energy is seen to be beneficial in climate change mitigation could contribute to even greater projected growth in nuclear capacity and, consequently, in uranium demand. Recognising the security of supply, reliability and predictability that nuclear power offers and promoting incentives for all types of low-carbon electricity production are key conditions for a faster deployment of nuclear power.

Supply and demand relationship

The currently defined resource base is more than adequate to meet high case uranium demand through 2035, but doing so will depend upon timely investments to turn resources into refined uranium ready for nuclear fuel production. Challenges remain in the global uranium market with high levels of oversupply and inventories, resulting in continuing pricing pressures. Other concerns in mine development include geopolitical factors, technical challenges and legal and regulatory frameworks.

As of 1 January 2017, world uranium production (62 071 tU) provided about 99.9% of world reactor requirements (62 285 tU), whereas in 2017, global primary production provided about 95% of requirements, with the remainder supplied by so-called secondary sources. The secondary supply includes excess government and commercial inventories, spent fuel reprocessing, underfeeding and uranium produced by the re-enrichment of depleted uranium tails, as well as low-enriched uranium (LEU) produced by blending down highly enriched uranium (HEU).

Uranium miners vigorously responded to the market signal of increased prices and projections of rapidly rising demand prior to the Fukushima Daiichi accident. However, the continued decline in uranium market prices following the accident and lingering uncertainty about nuclear power development in some countries has at least temporarily reduced uranium requirements, further depressed prices and slowed the pace of mine production and development. The uranium market is currently well supplied and projected primary uranium *production capabilities* including existing, committed, planned and prospective production centres would satisfy projected low and high case requirements through 2035 if developments proceed as planned. Meeting high case demand requirements to 2035 would consume less than 25% of the total 2017 identified resource base (resources recoverable at a cost of <USD 130/kg). Nonetheless, significant investment and technical expertise will be required to bring these resources to the market. Producers will have to overcome a number of significant and, at times, unpredictable issues in bringing new production facilities on stream, including geopolitical and local factors, technical challenges and legal and regulatory frameworks. To do so, strong market conditions will be fundamental to bringing the required investment to the industry.

Although information on secondary sources is incomplete, the availability of these sources is generally expected to decline somewhat after 2018. However, available information indicates that there remains a significant amount of previously mined uranium, some of which could feasibly be brought to the market in the coming years. With the successful transition from gas diffusion to centrifuge enrichment and capacity at least temporarily in excess of requirements, enrichment providers are well-positioned to reduce tails assays below contractual requirements and thereby create additional uranium supply. In the longer term, alternative fuel cycles (e.g. based on the utilisation of uranium-238 or thorium), if successfully developed and implemented, could have a significant impact on the uranium market, but it is far too early to say how cost-effective and widely implemented these proposed alternative fuel cycles could be.

Although declining market prices have led to significant reductions in uranium production and a delay in some mine development projects, other projects have advanced through regulatory and further stages of development. Finally, the overall time frame for mine development should be reduced if market conditions warrant renewed development activity. The current global network of uranium mine facilities is, at the same time, relatively sparse, creating the potential for supply vulnerability should several key facilities be put out of operation. Nevertheless, utilities have been building significant inventory over the last few years at reduced prices, which should help to protect them from such events.

Conclusions

Despite recent declines in electricity demand in some developed countries, global uranium demand is expected to continue to increase in the next several decades to meet large population needs, particularly in developing countries. Since nuclear power plants produce competitively priced, low-carbon baseload electricity, and the deployment of nuclear power enhances the security of energy supply, it is projected to remain an important component of energy supply. However, the Fukushima Daiichi accident has eroded public confidence in nuclear power in some countries, and prospects for growth in nuclear generating capacity are thus being reduced and are subject to even greater uncertainty than usual. In addition, the abundance of low-cost natural gas in North America and the risk-averse investment climate have reduced the competitiveness of nuclear power plants in liberalised electricity markets. Government and market policies that recognise the benefits of low-carbon electricity production and the security of energy supply provided by nuclear power plants could help alleviate these competitive pressures. Nuclear power nonetheless is projected to grow in regulated electricity markets with increasing electricity demand and a rising need for clean air electricity generation.

Regardless of the role that nuclear energy ultimately plays in meeting future electricity demand and moving towards global climate objectives, the uranium resource base described in this publication is more than adequate to meet projected requirements for the foreseeable future. In the wake of recent significant reductions in uranium production, the coming challenges are likely to be those associated with constrained investment capabilities, as a result of depressed market conditions that will push the industry to optimise its activities still further.

Chapter 1. **Uranium supply**

This chapter summarises the status of worldwide uranium resources, exploration and production.

Uranium resources

Identified conventional resources

Identified resources consist of *reasonably assured resources* (RAR) and *inferred resources* (IR) recoverable at a cost of less than USD 260/kgU. Relative changes in different resource and cost categories of identified resources between this edition and the 2016 edition of the Red Book are summarised in Table 1.1. The overall picture is one of resources increasing, with the main increase noted in the reasonably assured resource category, while inferred resources decreased overall. Identified resources recoverable at costs <USD 260/kgU increased by 4.5% to 7 988 600 tU.

Identified resources recoverable at costs of <USD 130/kgU increased by 7.4% from 5 718 400 tU in 2015 to a total of 6 142 200 tU in 2017.

A decrease in the <USD 80/kgU category by 2.1% from 2 124 700 tU to 2 079 500 tU between 2015 and 2017 is largely a result of a decrease in inferred resources and the transfer of resources to the lowest cost category. A significant 63.5% increase in the lowest cost category (<USD 40/kgU) was reported, amounting to a change from 646 900 tU in 2015 to 1 057 700 tU in 2017. This mainly reflects the low-cost resources reported by Kazakhstan, with a major shift of their resources into this category because of local currency fluctuations during this reporting period.

Table 1.1. **Changes in identified resources (recoverable) 2015-2017**

Resource category	2015	2017	Change (1 000 tU)[(a)]	% change
Identified (total)				
<USD 260/kgU	7 641.6	7 988.6	347.0	4.5
<USD 130/kgU	5 718.4	6 142.2	423.8	7.4
<USD 80/kgU	2 124.7	2 079.5	-45.2	-2.1
<USD 40/kgU[(b)]	646.9	1 057.7	410.8	63.5
RAR				
<USD 260/kgU	4 386.4	4 815.0	428.6	9.8
<USD 130/kgU	3 458.4	3 865.0	406.6	11.8
<USD 80/kgU	1 223.6	1 279.9	56.3	4.6
<USD 40/kgU[(b)]	478.5	713.4	234.9	49.1
Inferred resources				
<USD 260/kgU	3 255.1	3 173.0	-82.1	-2.5
<USD 130/kgU	2 260.1	2 277.0	16.9	0.7
<USD 80/kgU	901.1	799.9	-101.2	-11.2
<USD 40/kgU[(b)]	168.4	344.4	176.0	104.5

(a) Changes might not equal differences between 2015 and 2017 because of independent rounding.

(b) Resources in the cost category of <USD 40/kgU are likely higher than reported because some countries have indicated that detailed estimates are not available, or the data are confidential.

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, respectively. Table 1.5 summarises major changes in resources between 2015 and 2017 in selected countries.

The most significant changes during this reporting period are observed in the reasonably assured resources category with increases of 9.8%, 11.8% and 4.6% reported in the <USD 260/kgU, <USD 130/kgU and <USD 80/kgU categories, respectively. In the lowest cost category (<USD 40/kgU) significant increases were reported of 49.1% and 104.5% in the RAR and inferred resources, respectively. Reasonably assured resources comprise 66% of the identified resource total, an 8% increase over the last reporting period.

Argentina, Australia, Canada, China, Namibia and Zambia reported increases in both reasonably assured and inferred resources. India, Jordan, Kazakhstan, Niger, Turkey and Uzbekistan reported only an increase in RAR with a concomitant decrease in inferred resources as a result of re-evaluation of their resources and while Turkey reported an increase in RAR there was no change in inferred resources. Paraguay reported resources to the Red Book for the first time in over two decades. The Czech Republic, Mali, Spain and Russia also reported decreases in both RAR and inferred resources due to re-evaluation of deposits and adjustments made for mining depletion and increased mining costs. The Islamic Republic of Iran, Mexico and Mongolia reported increases to inferred resources and no changes or small decreases to RAR while Mexico reported an overall increase in the higher cost categories due to re-evaluation of existing deposits. Ukraine reported a decrease in RAR and no change to inferred resources. Indonesia reported an increase in inferred resources and no change to RAR.

Niger reported an increase in RAR in the highest cost category (<USD 260/kgU) and decreases in both RAR and inferred resources in the lower cost categories.

Kazakhstan reported a significant increase in RAR due to exploration activities and transferring of some resources from the inferred category to the RAR category. Significant increases to the <USD 40/kgU are a result of the devaluation of the national currency.

Australia still dominates the world’s uranium resources with about 30% of the total identified resources (<USD 130/kgU) and 25% of identified resources in the highest cost category (<USD 260/kgU). A total of 74% of Australia’s uranium resources are attributed to the world-class polymetallic Fe-oxide breccia complex, the Olympic Dam deposit. Kazakhstan is a distant second with approximately 14% in the <USD 130/kgU and 11% in the <USD 260/kgU cost category. Canada has increased its share since the last reporting period to about 11% in the <USD 260/kgU category. All other countries have less than a 10% share in the highest cost categories. Only 15 countries represent approximately 95% of the total resources in the <USD 130/kgU cost category (see Figure 1.1). In the lower cost categories, Australia did not report any resources and thus Kazakhstan leads with 31%, followed by Canada with 15%, and South Africa and Brazil each with 11% of the total resources in the <USD 80/kgU category. Only seven countries reported resources in the <USD 40/kgU category with Kazakhstan having the largest share at 45%, followed by Canada at 25%, Brazil at 13%, China at 10%, Uzbekistan with 6%, and Spain and Argentina both having less than 1% each of the total in this cost range.

Starting in the 2016 edition, a summary has been prepared of worldwide in situ identified 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 22% to 33% increase in the resources when they are reported as in situ. This corresponds to average recoveries ranging from approximately 67% to 78%. The total identified in situ resources increased from 10 188 700 tU reported in the last edition to 10 652 900 tU for this edition.

Reporting in situ resources provides a more optimistic view of the available resource base and gives some indication of how the resource base could increase with improvements in mining and processing methods, which would lead to better recovery. However, recoverable resources still provide the best and more realistic estimate of uranium supply.

Figure 1.1. **Global distribution of identified resources**
(<USD 130/kgU as of 1 January 2017)

The global distribution of identified resources among 15 countries that 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 95% of the identified global resource base in this cost category (the remaining 5% are distributed among another 22 countries). The widespread distribution of uranium resources is an important geographic aspect of nuclear energy in light of security of energy supply.

Table 1.2a. **Identified resources (recoverable)**

(as of 1 January 2017, tonnes U, rounded to nearest 100 tonnes)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Algeria(c, d)	0	0	0	19 500
Argentina	2 400	9 100	30 000	31 000
Australia	NA	NA	1 818 300	2 054 800
Botswana*	0	0	73 500	73 500
Brazil(d)	138 100	229 400	276 800	276 800
Canada	263 500	310 400	514 400	846 400
Central African Republic*(a, c)	0	0	32 000	32 000
Chad*(a, c, d, e)	0	0	0	2 400
Chile	0	0	0	1 500
China (People's Republic of)(d)	101 200	222 500	290 400	290 400
Congo, Dem. Rep.*(a, c, d)	0	0	0	2 700
Czech Republic	0	0	1 200	118 900
Egypt(a, c, d)	0	0	0	1 900
Finland(c, d)	0	0	1 200	1 200
Gabon(a, c)	0	0	4 800	5 800
Germany(c)	0	0	0	7 000
Greece(a, c)	0	0	0	7 000
Greenland(d, f)	0	0	0	148 200
Hungary(c, d)	0	0	0	13 500
India(d, e)	NA	NA	NA	157 000
Indonesia(b, d)	0	1 500	7 600	7 600
Iran, Islamic Republic of(b, d)	0	0	6 100	6 100
Italy(a, c)	0	6 100	6 100	6 100
Japan(c)	0	0	6 600	6 600
Jordan(d)	0	0	43 500	43 500
Kazakhstan(d)	481 000	639 500	842 200	904 500
Malawi*	0	0	6 200	14 300
Mali(d)	0	0	8 900	8 900
Mauritania*	0	0	16 400	23 800
Mexico(d)	0	0	3 800	5 000
Mongolia	0	113 500	113 500	113 500
Namibia*	0	0	442 100	541 700
Niger*	0		280 000	425 600
Paraguay*	0	0	0	3 600
Peru(d)	0	33 400	33 400	33 400
Portugal(a, c)	0	5 500	7 000	7 000
Romania*(a, c)	0	0	6 600	6 600
Russia(b)	0	39 800	485 600	656 900
Slovak Republic(b, d)	0	12 700	15 500	15 500
Slovenia(c, d)	0	5 400	9 200	9 200
Somalia*(a ,c, d)	0	0	0	7 600
South Africa(a)	0	229 500	322 400	449 300
Spain	9 800	34 300	34 300	34 300
Sweden*(a, c, d)	0	0	9 600	9 600
Tanzania*(b)	0	46 800	58 200	58 200
Turkey(b, d)	0	7 000	7 000	7 000
Ukraine	0	58 300	114 100	219 100
United States(d, f)	0	13 100	47 200	100 800
Uzbekistan*	61 700	61 700	139 200	139 200
Viet Nam(d)	0	0	0	3 900
Zambia*	0	0	27 300	27 300
Zimbabwe(a ,c, d)	0	0	0	1 400
Total(g)	1 057 700	2 079 500	6 142 200	7 988 600

* Secretariat estimate. (a) Not reported in 2017 responses; data from previous Red Book. (b) Assessment partially made within the last five years. (c) Assessment not made within the last five years. (d) In situ resources were adjusted by the Secretariat to estimate recoverable resources using recovery factors provided by countries or estimated by the Secretariat. (e) Cost data not provided, therefore resources are reported in the <USD 260/kgU category. (f) Updated to report recoverable resources. (g) Totals related to cost ranges <USD 40/kgU and <USD 80/kgU are higher than reported in the tables because certain countries do not report low-cost resource estimates, mainly for reasons of confidentiality.

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

(as of 1 January 2017, tonnes U, rounded to nearest 100 tonnes)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Algeria[c]	0	0	0	26 000
Argentina[d]	3 400	12 700	41 700	43 100
Australia[d]	NA	NA	2 668 500	3 007 200
Botswana*	0	0	118 600	118 600
Brazil	184 300	314 600	382 300	382 300
Canada[d]	351 300	413 800	680 700	1 119 800
Central African Republic*	0	0	42 700	42 700
Chad*[a, e]	0	0	0	3 200
Chile[d]	0	0	0	1 900
China (People's Republic of)	127 800	284 200	370 900	370 900
Congo, Dem. Rep.* [a, c]	0	0	0	3 600
Czech Republic[d]	0	0	1 900	197 100
Egypt[a, c]	0	0	0	2 500
Finland[c]	0	0	1 500	1 500
Gabon[a, c, d]	0	0	6 400	7 700
Germany[c, d]	0	0	0	9 300
Greece[a, c, d]	0	0	0	9 300
Greenland[f]	0	0	0	227 900
Hungary[c]	0	0	0	17 900
India[e]	NA	NA	NA	207 700
Indonesia[b]	0	2 000	10 100	10 100
Iran, Islamic Republic of[b]	0	0	8 100	8 100
Italy[a, c, d]	0	8 100	8 100	8 100
Japan[c, d, f]	0	0	7 800	7 800
Jordan	0	0	62 100	62 100
Kazakhstan	540 500	719 100	956 200	1 031 300
Malawi*[d, f]	0	0	8 300	19 000
Mali	0	0	11 900	11 900
Mauritania*[f]	0	0	18 900	28 700
Mexico	0	0	5 000	6 700
Mongolia[d]	0	144 200	144 200	144 200
Namibia*	0	0	552 500	676 700
Niger*	0	0	341 200	519 400
Paraguay*	0	0	0	4 300
Peru	0	47 700	47 700	47 700
Portugal[a, c, d, f]	0	7 300	9 300	9 300
Romania*[a, c, d]	0	0	8 800	8 800
Russia[b, d]	0	53 100	590 200	840 600
Slovak Republic[b]	0	15 800	19 300	19 300
Slovenia[c]	0	7 200	12 200	12 200
Somalia*[a, c, d]	0	0	0	10 200
South Africa[a, d]	0	322 000	450 300	630 600
Spain[d]	10 300	36 100	36 100	36 100
Sweden*[a, c]	0	0	12 800	12 800
Tanzania*[b]	0	58 500	72 800	72 800
Turkey[b]	0	9 700	9 700	9 700
Ukraine[d]	0	67 400	130 500	249 100
United States[f]	0	17 400	62 900	138 200
Uzbekistan*	77 100	77 100	179 800	179 800
Viet Nam	0	0	0	5 200
Zambia*	0	0	30 100	30 100
Zimbabwe[a, c]	0	0	0	1 800
Total[g]	1 294 700	2 618 000	8 122 100	10 652 900

* Secretariat estimate. ** In situ resources do not take into account mining and milling losses. (a) Not reported in 2017 responses; data from previous Red Book. (b) Assessment partially made within the last five years. (c) Assessment not made within the last five years. (d) 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). (e) Cost data not provided, therefore resources are reported in the <USD 260/kgU category. (f) Updated from previous report. (g) Totals related to cost ranges <USD 40/kgU and <USD 80/kgU are higher than reported in the tables because certain countries do not report low-cost resource estimates, mainly for reasons of confidentiality.

Table 1.2c. **Comparison of in situ and recoverable identified resources**

(as of 1 January 2017)

Identified resources	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Total in situ (tU)	1 294 700	2 618 000	8 122 100	10 652 900
Total recoverable (tU)	1 057 700	2 079 500	6 142 200	7 988 600
Difference (tU)	237 000	538 500	1 979 900	2 664 300
% difference	22.4	25.9	32.2	33.4

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

(as of 1 January 2017, tonnes U, rounded to nearest 100 tonnes)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Algeria[c, d]	0	0	0	19 500
Argentina	0	5 100	11 000	11 000
Australia	NA	NA	1 269 800	1 400 600
Botswana*	0	0	13 700	13 700
Brazil[d]	138 100	155 900	155 900	155 900
Canada	255 900	275 200	409 700	592 900
Central African Republic*[a, c]	0	0	32 000	32 000
Chile	0	0	0	600
China (People's Republic of)[d]	44 300	102 200	136 700	136 700
Congo, Dem. Rep.*[a, c, d]	0	0	0	1 400
Czech Republic	0	0	1 200	50 700
Finland[c, d]	0	0	1 200	1 200
Gabon[a, c]	0	0	4 800	4 800
Germany[c]	0	0	0	3 000
Greece[a, c]	0	0	0	1 000
Greenland[d, f]	0	0	0	66 800
India[d, e]	NA	NA	NA	149 000
Indonesia[b, d]	0	1 500	5 300	5 300
Iran, Islamic Republic of [b, d]	0	0	1 100	1 100
Italy[a, c]	0	4 800	4 800	4 800
Japan[c]	0	0	6 600	6 600
Jordan[d]	0	0	4 800	4 800
Kazakhstan[d]	227 900	304 400	415 200	434 800
Malawi*	0	0	4 400	9 700
Mali[d]	0	0	5 000	5 000
Mauritania*	NA	NA	700	1 000
Mexico[d]	0	0	1 800	1 800
Mongolia	0	49 800	49 800	49 800
Namibia*	0	0	335 300	368 500
Niger*	0	0	237 400	336 400
Paraguay*	0	0	0	2 900
Peru[d]	0	14 000	14 000	14 000
Portugal[a, c]	0	4 500	6 000	6 000
Romania*[a, c]	0	0	3 000	3 000
Russia[b]	0	24 500	214 500	260 000
Slovak Republic[b, d]	0	8 800	8 800	8 800
Slovenia[c, d]	0	1 700	1 700	1 700
Somalia*[a, c, d]	0	0	0	5 000
South Africa[a]	0	167 900	237 600	259 600
Spain	9 800	23 000	23 000	23 000
Sweden*[a, c, d]	0	0	4 900	4 900
Tanzania*[b]	0	38 300	39 700	39 700
Turkey[b, d]	0	6 500	6 500	6 500
Ukraine	0	41 300	81 200	137 700
United States[d, f]	0	13 100	47 200	100 800
Uzbekistan*	37 400	37 400	57 600	57 600
Viet Nam[d]	0	0	0	900
Zambia*	0	0	11 100	11 100
Zimbabwe[a, c, d]	0	0	0	1 400
Total[g]	713 400	1 279 900	3 865 000	4 815 000

See notes on page 21.

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

(as of 1 January 2017, tonnes U, rounded to nearest 100 tonnes)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Algeria(c)	0	0	0	26 000
Argentina(d)	0	7 100	15 300	15 300
Australia(d)	NA	NA	1 877 900	2 070 000
Botswana*	0	0	22 100	22 100
Brazil	184 300	209 700	209 700	209 700
Canada(d)	341 200	366 900	543 200	784 900
Central African Republic*	0	0	42 700	42 700
Chile(d)	0	0	0	700
China (People's Republic of)	58 200	133 800	177 700	177 700
Congo, Dem. Rep.*(a, c)	0	0	0	1 900
Czech Republic(d)	0	0	1 800	83 700
Finland(c)	0	0	1 500	1 500
Gabon(a, c, d)	0	0	6 400	6 400
Germany(c, d)	0	0	0	4 000
Greece(a, c, d)	0	0	0	1 300
Greenland(f)	0	0	0	102 800
India(e)	NA	NA	NA	197 200
Indonesia(b)	0	2 000	7 100	7 100
Iran, Islamic Republic of(b)	0	0	1 400	1 400
Italy(a, c, d)	0	6 400	6 400	6 400
Japan(c, d, f)	0	0	7 800	7 800
Jordan	0	0	6 900	6 900
Kazakhstan	256 000	342 300	471 200	494 800
Malawi*(d)	0	0	5 500	13 000
Mali	0	0	6 700	6 700
Mauritania*	0	0	800	1 200
Mexico	0	0	2 400	2 400
Mongolia(d)	0	64 200	64 200	64 200
Namibia*	0	0	419 100	460 600
Niger*	0	0	287 400	405 200
Paraguay*	0	0	0	3 400
Peru	0	20 000	20 000	20 000
Portugal(a, c, d)	0	6 000	8 000	8 000
Romania*(a, c, d)	0	0	4 000	4 000
Russia(b, d)	0	32 700	258 400	328 300
Slovak Republic(b)	0	10 900	10 900	10 900
Slovenia(c)	0	2 200	2 200	2 200
Somalia*(a, c, d)	0	0	0	6 700
South Africa(a, d)	0	239 800	338 100	369 100
Spain(d)	10 300	24 200	24 200	24 200
Sweden*(a, c)	0	0	6 500	6 500
Tanzania*(b)	0	47 900	49 600	49 600
Turkey(b)	0	9 000	9 000	9 000
Ukraine(d)	0	48 100	93 200	157 200
United States(f)	0	17 400	62 900	138 200
Uzbekistan*	46 700	46 700	72 000	72 000
Viet Nam	0	0	0	1 200
Zambia*	0	0	12 300	12 300
Zimbabwe(a, c)	0	0	0	1 800
Total(g)	896 700	1 637 300	5 156 500	6 450 200

* Secretariat estimate. (a) Not reported in 2017 responses; data from previous Red Book. (b) Assessment partially made within the last five years. (c) Assessment not made within the last five years. (d) 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). (e) Cost data not provided, therefore resources are reported in the <USD 260/kgU category. (f) Updated from previous report. (g) Totals related to cost ranges <USD 40/kgU and <USD 80/kgU are higher than reported in the tables because certain countries do not report low-cost resource estimates, mainly for reasons of confidentiality.

Table 1.4a. **Inferred resources (recoverable)**

(as of 1 January 2017, tonnes U, rounded to nearest 100 tonnes)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Argentina	2 400	4 000	19 000	20 000
Australia	NA	NA	548 500	654 200
Botswana*	0	0	59 800	59 800
Brazil[(d)]	0	73 500	120 900	120 900
Canada	7 600	35 200	104 700	253 500
Chad*[(a, c, d, e)]	0	0	0	2 400
Chile	0	0	0	900
China (People's Republic of)[(d)]	56 900	120 300	153 700	153 700
Congo, Dem. Rep.*[(a, c, d)]	0	0	0	1 300
Czech Republic	0	0	100	68 200
Egypt[(a, c, d)]	0	0	0	1 900
Gabon[(a, c)]	0	0	0	1 000
Germany[(c)]	0	0	0	4 000
Greece[(a, c)]	0	0	0	6 000
Greenland[(d, f)]	0	0	0	81 300
Hungary[(c, d)]	0	0	0	13 500
India[(d, e)]	NA	NA	NA	8 000
Indonesia[(b, d)]	0	0	2 200	2 200
Iran, Islamic Republic of[(b, d)]	0	0	5 100	5 100
Italy[(a, c)]	0	1 300	1 300	1 300
Jordan[(d)]	0	0	38 600	38 600
Kazakhstan[(d)]	253 200	335 100	427 000	469 700
Malawi*	0	0	1 800	4 600
Mali[(d)]	0	0	3 900	3 900
Mauritania*	0	0	15 700	22 800
Mexico[(d)]	0	0	1 900	3 200
Mongolia	0	63 800	63 800	63 800
Namibia*	0	0	106 800	172 900
Niger*	0	0	42 600	89 200
Paraguay*	0	0	0	700
Peru[(d)]	0	19 400	19 400	19 400
Portugal[(a, c)]	0	1 000	1 000	1 000
Romania*[(a, c)]	0	0	3 600	3 600
Russia[(b)]	0	15 300	271 000	396 900
Slovak Republic[(b, d)]	0	3 900	6 700	6 700
Slovenia[(c, d)]	0	3 800	7 500	7 500
Somalia*[(a, c, d)]	0	0	0	2 600
South Africa[(a)]	0	61 700	84 800	189 700
Spain	0	11 400	11 400	11 400
Sweden*[(a, c, d)]	0	0	4 700	4 700
Tanzania*[(b)]	0	8 500	18 500	18 500
Turkey[(b, d)]	0	500	500	500
Ukraine	0	16 900	32 900	81 300
Uzbekistan*	24 300	24 300	81 500	81 500
Viet Nam[(d)]	0	0	0	3 000
Zambia*	0	0	16 100	16 100
Total[(g)]	344 400	799 900	2 277 000	3 173 000

* Secretariat estimate. (a) Not reported in 2017 responses; data from previous Red Book. (b) Assessment partially made within the last five years. (c) Assessment not made within the last five years. (d) 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). (e) Cost data not provided, therefore resources are reported in the <USD 260/kgU category. (f) Updated to report recoverable resources. (g) Totals related to cost ranges <USD 40/kgU and <USD 80/kgU are higher than reported in the tables because certain countries do not report low-cost resource estimates, mainly for reasons of confidentiality.

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

(as of 1 January 2017, tonnes U, rounded to nearest 100 tonnes)

Country	Cost ranges			
	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Argentina[d]	3 400	5 600	26 400	27 800
Australia[d]	NA	NA	790 600	937 200
Botswana*	0	0	96 500	96 500
Brazil	0	104 900	172 600	172 600
Canada[d]	10 100	46 900	137 500	334 900
Chad*[a, e]	0	0	0	3 200
Chile[d]	0	0	0	1 200
China (People's Republic of)	69 600	150 400	193 200	193 200
Congo, Dem. Rep.*[a, c]	0	0	0	1 700
Czech Republic [d]	0	0	100	113 400
Egypt[a, c]	0	0	0	2 500
Gabon[a, c, d]	0	0	0	1 300
Germany[c, d]	0	0	0	5 300
Greece[a, c, d]	0	0	0	8 000
Greenland[f]	0	0	0	125 100
Hungary[c]	0	0	0	17 900
India[e]	NA	NA	NA	10 500
Indonesia[b]	0	0	3 000	3 000
Iran, Islamic Republic of[b]	0	0	6 700	6 700
Italy[a, c, d]	0	1 700	1 700	1 700
Jordan	0	0	55 200	55 200
Kazakhstan	284 500	376 800	485 000	536 500
Malawi*[d]	0	0	2 800	6 000
Mali	0	0	5 200	5 200
Mauritania*	0	0	18 100	27 500
Mexico	0	0	2 600	4 300
Mongolia[d]	0	80 000	80 000	80 000
Namibia*	0	0	133 400	216 100
Niger*	0	0	53 800	114 200
Paraguay*	0	0	0	900
Peru	0	27 700	27 700	27 700
Portugal[a, c, d]	0	1 300	1 300	1 300
Romania*[a, c, d]	0	0	4 800	4 800
Russia [b, d]	0	20 400	331 800	512 300
Slovak Republic[b]	0	4 900	8 400	8 400
Slovenia[c]	0	5 000	10 000	10 000
Somalia*[a, c, d]	0	0	0	3 500
South Africa[a, d]	0	82 200	112 200	261 500
Spain[d]	0	11 900	11 900	11 900
Sweden*[a, c]	0	0	6 300	6 300
Tanzania*[b]	0	10 600	23 200	23 200
Turkey[b]	0	700	700	700
Ukraine[d]	0	19 300	37 300	91 900
Uzbekistan*	30 400	30 400	107 800	107 800
Viet Nam	0	0	0	4 000
Zambia*	0	0	17 800	17 800
Total[g]	398 000	980 700	2 965 600	4 202 700

* Secretariat estimate. (a) Not reported in 2017 responses; data from previous Red Book. (b) Assessment partially made within the last five years. (c) Assessment not made within the last five years. (d) 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). (e) Cost data not provided, therefore resources are reported in the <USD 260/kgU category. (f) Updated from previous report. (g) Totals related to cost ranges <USD 40/kgU and <USD 80/kgU are higher than reported in the tables because certain countries do not report low-cost resource estimates, mainly for reasons of confidentiality.

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

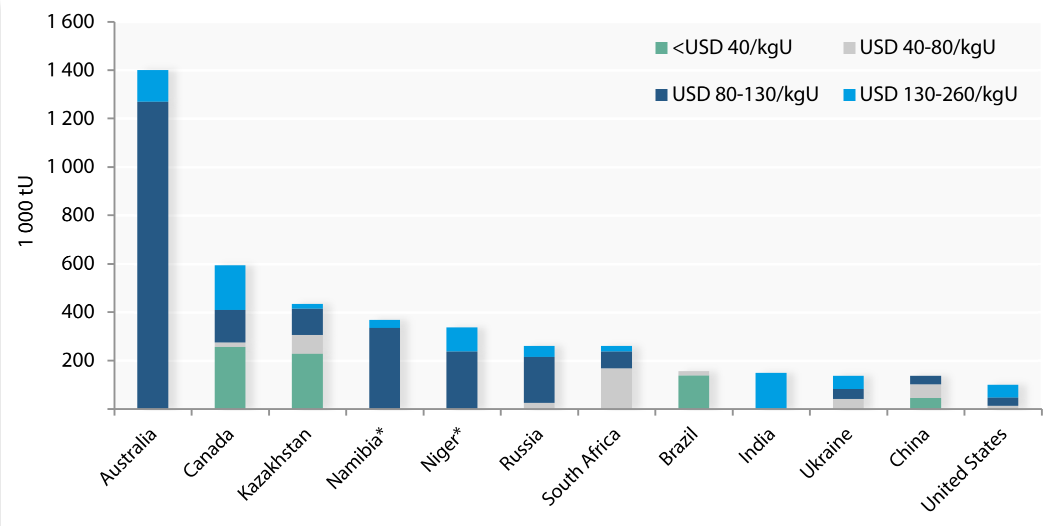
(recoverable resources in 1 000 tonnes U)

Country	Resource category	2015	2017	Changes	Reasons
Argentina	RAR				Private industry resource holdings evaluated and incorporated into national resource totals for first time.
	<USD 130/kgU	8.6	11.0	2.4	
	<USD 260/kgU	8.6	11.0	2.4	
	Inferred				
	<USD 130/kgU	9.9	19.0	9.1	
	<USD 260/kgU	11.0	20.0	9.0	
Australia	RAR				Additional resources defined at known deposits and reclassification of known resources due to changes in access.
	<USD 130/kgU	1 135.2	1 269.8	134.6	
	<USD 260/kgU	1 150.0	1 400.6	250.6	
	Inferred				
	<USD 130/kgU	528.9	548.5	19.6	
	<USD 260/kgU	630.8	654.2	23.4	
Canada	RAR				Decrease in identified resources in the USD <40/kgU and USD <80/KgU cost categories due to mining depletion. Increase of the total resources in the higher cost categories due to new resources identified as the result of exploration activities (i.e. Arrow, Phoenix, Griffon and Triple R deposits).
	<USD 40/kgU	226.1	225.9	-0.2	
	<USD 80/kgU	240.1	275.2	35.1	
	<USD 130/kgU	374.2	409.7	35.5	
	<USD 260/kgU	486.5	592.9	106.4	
	Inferred				
	<USD 40/kgU	25.1	7.6	-17.5	
	<USD 80/kgU	81.8	35.2	-46.6	
	<USD 130/kgU	134.8	104.7	-30.1	
	<USD 260/kgU	217.2	253.5	36.3	
China (People's Republic of)	RAR				Increases partly as a result of exploration of sandstones in the north and, to a lesser extent, exploration of volcanic and granite-type deposits in southern China. However, ISL (acid) recovery factor change accounts for the majority of the increases, since China reports in situ resources.
	<USD 40/kgU	38.9	44.3	5.4	
	<USD 80/kgU	95.0	102.2	7.2	
	<USD 130/kgU	128.3	136.7	8.4	
	<USD 260/kgU	128.3	136.7	8.4	
	Inferred				
	<USD 40/kgU	60.0	56.9	-3.1	
	<USD 80/kgU	111.2	120.3	9.1	
	<USD 130/kgU	144.2	153.7	9.5	
	<USD 260/kgU	144.2	153.7	9.5	
India	RAR				Additional exploration defines additional resources at existing deposits and converts inferred to reasonably assured resources.
	<USD 260/kgU	121.0	149.0	28.0	
	Inferred				
	<USD 260/kgU	17.7	8.0	-9.7	
Iran, Islamic Republic of	Inferred				Ongoing exploration within previously surveyed areas defines additional resources.
	<USD 130/kgU	2.7	5.1	2.4	
	<USD 260/kgU	2.7	5.1	2.4	
Jordan	RAR				Re-evaluation of known resources defines first reasonably assured resources and reduces overall resources.
	<USD130/kgU	0.0	4.8	4.8	
	<USD 260/kgU	0.0	4.8	4.8	
	Inferred				
	<USD 130/kgU	47.7	38.6	-9.1	
	<USD 260/kgU	47.7	38.6	-9.1	
Kazakhstan	RAR				Overall increases in identified resources a result of exploration activities. Decrease in inferred category as resources transferred to reasonably assured resources. Significant changes in cost categories owing to devaluation of the national currency.
	<USD 40/kgU	38.5	227.9	189.4	
	<USD 80/kgU	229.3	304.4	75.1	
	<USD 130/kgU	275.8	415.2	139.4	
	<USD 260/kgU	363.2	434.8	71.6	
	Inferred				
	<USD 40/kgU	59.0	253.2	194.2	
	<USD 80/kgU	437.9	335.1	-102.8	
	<USD 130/kgU	469.5	427.0	-42.5	
	<USD 260/kgU	578.4	469.7	-108.7	
Mali	RAR				Decline in identified resources as a result of re-evaluation of existing deposits.
	<USD 130/kgU	8.5	5.0	-3.5	
	<USD 260/kgU	8.5	5.0	-3.5	
	Inferred				
	<USD 130/kgU	4.5	3.9	-0.6	
	<USD 260/kgU	4.5	3.9	-0.6	

Table 1.5. **Major identified resource changes by country** *(cont'd)*
(recoverable resources in 1 000 tonnes U)

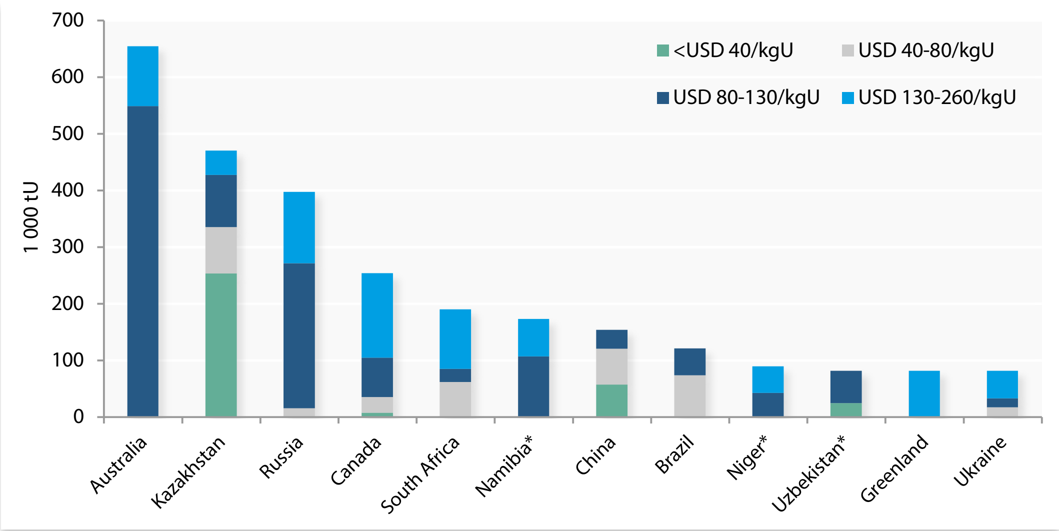
Country	Resource category	2015	2017	Changes	Reasons
Mexico	RAR				Re-evaluation of existing deposits following international standards results in decline of lower cost resources and increase in higher cost inferred resources.
	<USD 80/kgU	1.2	0.0	-1.2	
	<USD 130/kgU	1.8	1.8	0.0	
	<USD 260/kgU	1.8	1.8	0.0	
	Inferred				
	<USD 40/kgU	0.6	0.0	-0.6	
	<USD 80/kgU	0.6	0.0	-0.6	
	<USD 130/kgU	0.9	1.9	1.0	
	<USD 260/kgU	1.6	3.2	1.6	
Mongolia	RAR				Ongoing exploration activities in southern basins focusing on sandstone deposits amenable to ISL mining results in increased RAR.
	<USD 80/kgU	108.1	119.4	11.3	
	<USD 130/kgU	108.1	119.4	11.3	
	<USD 260/kgU	108.1	119.4	11.3	
	Inferred				
	<USD 80/kgU	33.4	31.8	-1.6	
	<USD 130/kgU	33.4	31.8	-1.6	
	<USD 260/kgU	33.4	31.8	-1.6	
Namibia	RAR				Ongoing exploration identifies additional resources in south Rössing (Z20 deposit) and more comprehensive historic data for all uranium projects.
	<USD 130/kgU	189.6	335.3	145.7	
	<USD 260/kgU	298.4	368.5	70.1	
	Inferred				
	<USD 130/kgU	77.5	106.8	29.3	
	<USD 260/kgU	164.6	172.9	8.3	
Niger	RAR				Ongoing exploration defines additional resources at developing deposits (e.g. Madaouela and Dasa).
	<USD 80/kgU	17.7	0.0	-17.7	
	<USD 130/kgU	235.3	237.4	2.1	
	<USD 260/kgU	316.0	336.4	20.4	
	Inferred				
	<USD 130/kgU	56.2	42.6	-13.6	
	<USD 260/kgU	95.3	89.2	-6.1	
Russia	RAR				Ongoing comprehensive exploration and technical economic evaluation of resources results in resource reductions due to increased costs and depletion by mining.
	<USD 80/kgU	27.3	24.5	-2.8	
	<USD 130/kgU	228.4	214.5	-13.9	
	<USD 260/kgU	273.8	260.0	-13.8	
	Inferred				
	<USD 80/kgU	20.4	15.3	-5.1	
	<USD 130/kgU	279.4	271.0	-8.4	
	<USD 260/kgU	421.4	396.9	-24.5	
Spain	RAR				Ongoing exploration focusing on a number of historically known uranium projects in Salamanca province, leads to increased resources as the country works towards open-pit mining of four deposits.
	<USD 40/kgU	0.0	9.8	9.8	
	<USD 80/kgU	0.0	23.0	23.0	
	<USD 130/kgU	0.0	23.0	23.0	
	<USD 260/kgU	12.9	23.0	10.1	
	Inferred				
	<USD 80/kgU	0.0	11.4	11.4	
	<USD 130/kgU	0.0	11.4	11.4	
	<USD 260/kgU	21.0	11.4	-9.6	
Uzbekistan	RAR				Ongoing exploration of sandstone deposits in the Central Kyzylkum area and black shale deposits in the Boztau area identifies additional resources to support ongoing mining.
	<USD 40/kgU	36.9	37.4	0.5	
	<USD 80/kgU	36.9	37.4	0.5	
	<USD 130/kgU	54.6	57.6	3.0	
	<USD 260/kgU	54.6	57.6	3.0	
	Inferred				
	<USD 40/kgU	21.3	24.3	3.0	
	<USD 80/kgU	21.3	24.3	3.0	
	<USD 130/kgU	75.5	81.5	6.0	
	<USD 260/kgU	75.5	81.5	6.0	
Zambia	RAR				Overall increase resulting from recovery factor increase (80 to 90.5%) as development of existing deposits continues.
	<USD 130/kgU	9.9	11.1	1.2	
	<USD 260/kgU	9.9	11.1	1.2	
	Inferred				
	<USD 130/kgU	14.7	16.1	1.4	
	<USD 260/kgU	14.7	16.1	1.4	

Figure 1.2. **Distribution of reasonably assured resources among countries with a significant share of resources**



* Secretariat estimate.

Figure 1.3. **Distribution of inferred resources among countries with a significant share of resources**



* Secretariat estimate.

Distribution of resources by production method

For this report, countries once again were asked to report identified resources by cost categories and by the expected production method, i.e. open-pit or underground mining, in situ leaching (ISL, sometimes referred to as in situ recovery, or ISR), heap leaching or in-place leaching, co-product/by-product or unspecified.

In the lowest cost category, <USD 40/kgU, underground mining is the predominant production method for RAR (see Table 1.6), mainly from Canada and to a lesser extent from Brazil. Resources in the ISL categories from China and Kazakhstan make a significant contribution along with co-product/by-product production, mainly from Brazil, making up most of the rest. The total is likely underestimated because of the difficulty in assigning mining costs accurately in the co-product/by-product category, particularly in Australia. In the <USD 80/kgU category, resources produced by underground mining and ISL methods make the largest contributions. The <USD 130/kgU category is dominated by resources in the co-product category; this is predominately a result of the world-class Olympic Dam deposit in Australia. The underground and co-product/by-product categories dominate in the <USD 260/kgU category (see Table 1.6), which is followed by open-pit mining that has shown a gradual decrease in the last couple of editions. Canada holds the largest resource total for underground mining while Namibia and Niger make the largest contributions to open-pit production. Olympic Dam is responsible for most of the by-product category, with Brazil, Greenland and South Africa making significant contributions. ISL makes an important contribution in all cost categories with Kazakhstan being the major player.

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

(recoverable resources as of 1 January 2017, tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Open-pit mining	18 089	96 787	908 839	1 078 486
Underground mining	320 784	449 777	1 002 018	1 464 394
In situ leaching acid	283 173	428 108	524 479	586 705
In situ leaching alkaline	20 300	27 720	30 100	70 704
Co-product/by-product	71 050	256 704	1 308 131	1 537 926
Unspecified	-	20 822	91 336	76 664
Total	713 396	1 279 918	3 864 903	4 814 879

The pattern of production method for IR is slightly different from that of RAR (see Table 1.7). In the lowest cost categories (<USD 40/kgU and <USD 80/kgU) ISL is dominant. In the <USD 130/kgU category, ISL continues to dominate but is followed closely by underground mining, co-product/by-product and open-pit categories. In the highest cost category (<USD 260/kgU), underground mining dominates with co-product/by-product, ISL and open-pit mining making significant contributions. The United States does not report IR, leading to under-representation in the ISL alkaline category for the inferred resources.

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

(recoverable resources as of 1 January 2017, tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Open-pit mining	2 430	46 665	431 091	567 678
Underground mining	16 785	110 100	567 310	925 081
In situ leaching acid	320 427	498 265	630 252	727 534
In situ leaching alkaline	4 760	8 470	9 240	9 240
Co-product/by-product	0	94 580	526 475	728 360
Unspecified	0	41 652	112 833	215 228
Total	344 402	799 732	2 277 201	3 173 121

Distribution of resources by processing method

In 2017, countries were once again requested to report identified resources by cost categories and by the expected processing method, i.e. 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 has changed very little since the last reporting period. In all cost categories for RAR (see Table 1.8), conventional processing from underground mining is the major contributor, with Australia dominating because of Olympic Dam. In the higher cost categories, conventional processing from open pit and ISL make increasing contributions, but even when combined do not surpass the underground resources. In the IR category (see Table 1.9), ISL dominates in the two lower cost categories, but in the two higher cost categories it is replaced by underground conventional methods with totals more than twice that of ISL in the highest cost category. The amount that is reported as unspecified is important because the exploration of many deposits is insufficiently advanced for any mine planning to have been carried out. Note that the United States does not report IR by processing method, leading to under-representation in the ISL alkaline category in Table 1.9.

Table 1.8. **Reasonably assured resources by processing method**
(recoverable resources as of 1 January 2017, tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional from OP	16 631	72 673	644 494	826 357
Conventional from UG	320 784	617 651	2 202 571	2 717 081
In situ leaching acid	283 173	428 108	524 479	586 705
In situ leaching alkaline	20 300	27 720	30 100	30 100
In-place leaching*	-	-	516	3 669
Heap leaching** from OP	1 458	24 114	261 911	312 923
Heap leaching** from UG	-	-	18 232	20 334
Unspecified	71 050	109 652	182 600	317 710
Total	713 396	1 279 918	3 864 903	4 814 879

* 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 resources by processing method**
(recoverable resources as of 1 January 2017, tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional from OP	2 430	28 952	295 374	395 182
Conventional from UG	16 785	171 756	1 004 728	1 424 419
In situ leaching acid	320 427	498 265	630 252	727 534
In situ leaching alkaline	4 760	8 470	9 240	9 240
In-place leaching*	-	-	2 068	15 933
Heap leaching** from OP	-	19 417	117 331	154 022
Heap leaching** from UG	-	-	6 675	14 431
Unspecified	-	72 872	211 533	432 360
Total	344 402	799 732	2 277 201	3 173 121

* 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 2017, countries also reported identified resources by cost categories and by geological types of deposits using a new deposit classification scheme that was introduced in the 2014 edition (Appendix 3).

Sandstone reasonably assured resources (in China, Kazakhstan, Niger, Russia and Uzbekistan) dominate all cost categories except in the <USD 130/kgU category. Polymetallic iron-oxide breccia complex deposits in Australia become the most important in the <USD 130/kgU category, followed closely by sandstone-related resources with Proterozoic unconformity-related, metasomatite, intrusive and paleo-quartz-pebble conglomerate resources still making important contributions. Other types of deposits take larger shares of the total only in the two highest cost categories with some significant shares of resources attributed to metasomatite, intrusive and paleo-quartz-pebble conglomerate types in the <USD 260/kgU category (see Table 1.10).

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

(recoverable resources as of 1 January 2017, tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Proterozoic Unconformity	255 930	275 190	522 280	688 771
Sandstone	303 473	516 830	954 282	1 188 711
Polymetallic Fe-oxide breccia complex	-	-	988 980	1 086 947
Paleo-quartz-pebble conglomerate[(a)]	-	167 874	230 321	255 147
Granite-related	27 580	63 060	69 663	92 288
Metamorphite	-	2 622	7 151	48 236
Intrusive	-	-	255 957	404 789
Volcanic-related	-	53 530	135 230	138 270
Metasomatite	66 663	104 737	327 926	441 008
Surficial deposits	-	-	167 138	174 305
Carbonate	-	400	400	74 855
Collapse breccia	405	405	405	405
Phosphate	53 270	53 270	117 088	124 065
Lignite-coal	-	-	-	-
Black shale	-	-	25 607	25 608
Unspecifed	6 075	42 000	62 475	71 474
Total	713 396	1 279 918	3 864 903	4 814 879

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

Similar observations can be made in the IR category (see Table 1.11). In all cost categories sandstone-hosted resources are dominant. In the <USD 260/kgU and <USD 130/kgU category, metasomatite and polymetallic iron-oxide breccia complex resources are the next most important deposit types. In the lowest cost categories (<USD 40/kgU and <USD 80/kgU), the second most important type of deposit after sandstone, is the Proterozoic unconformity-type.

Table 1.11. **Inferred resources by deposit type**
(recoverable resources as of 1 January 2017, tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Proterozoic Unconformity	7 560	35 200	146 978	258 575
Sandstone	327 137	532 604	833 010	1 039 020
Polymetallic Fe-oxide breccia complex	-	-	371 800	426 100
Paleo-quartz-pebble conglomerate[(a)]	-	72 306	85 011	134 722
Granite-related	-	12 350	63 146	78 680
Metamorphite	-	619	3 068	8 344
Intrusive	-	-	89 541	250 974
Volcanic-related	480	30 468	71 405	85 627
Metasomatite	-	23 686	362 818	531 110
Surficial deposits	-	-	89 079	109 128
Carbonate	-	-	-	-
Collapse breccia	-	18 744	18 744	18 744
Phosphate	-	30 705	33 480	39 601
Lignite-coal	-	-	8 571	79 346
Black shale	-	-	32 900	32 900
Unspecified	9 225	43 050	67 650	80 250
Total	344 402	799 732	2 277 201	3 173 121

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

Proximity of resources to production centres

A total of 9 countries provided estimates on the availability of resources for near-term production 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 (see Table 1.12). Resources proximal to existing and committed production centres in six of the countries listed a total of 1 296 035 tU at <USD 80/kgU (about 88% of the total resources reported in this cost category). This is 4% lower than the 2015 value of 1 345 999 tU. This modest change can be attributed primarily to a decrease of resources in this cost category for Kazakhstan and Russia. Resources proximal to existing and committed production centres in the nine countries listed a total of 3 341 873 tU at <USD 130/kgU (about 69% of the total resources reported in this cost category). This is 12% higher than the 2 974 059 tU reported for 2015 and mainly results from an update in this cost category for Australia.

Additional conventional resources

The NEA/IAEA provided estimates on additional identified resources (see Table 1.13). These were included for the first time in the 2011 Red Book. Some countries do not include resource determinations by junior exploration companies in national totals until additional information is provided to the pertinent agencies or until a mining licence application is filed (e.g. Peru). Other countries do not always have sufficient human resources to provide detailed information and evaluation as requested in the questionnaire. The table represents an NEA/IAEA estimate based on technical reports of resources that have been classified either as JORC, NI 43-101 or South African Mineral Resource Committee (SAMREC) compliant.

These additional resources amount to a total of 73 230 tU classified as RAR and IR in several countries, representing a small increase of 2 500 tU since the last reporting period, as some new resources for Mauritania that are not included in the national totals are included here, although this addition is offset by the movement of resources that were included from Paraguay in the last edition, to the national totals. The most significant "additional resources" occured in Cameroon (22 130 tU) and Peru (12 400 tU).

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

Country	RAR + inferred recoverable at <USD 80/kgU in existing or committed production centres			RAR + inferred recoverable at <USD 130/kgU in existing or committed centres		
	Total resources (tU)	%	Proximate resources (tU)	Total resources (tU)	%	Proximate resources (tU)
Australia	NA		NA	1 818 300	79	1 436 457
Brazil	229 400	66	151 404	276 800	66	182 688
Canada	310 400	97	301 088	514 400	60	308 640
Iran, Islamic Rep of	0	-	-	6 125	100	6 125
Kazakhstan	639 500	94	601 130	842 200	71	597 962
Namibia	0		-	267 000	93	249 498
Niger	17 700	100	17 700	291 500	87	253 747
Russia	39 800	86	34 228	485 585	24	116 540
South Africa	229 500	83	190 485	322 400	59	190 216
Total	1 466 300	88	1 296 035	4 824 310	69	3 341 873

N/A = not available.

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

Table 1.13. **Additional identified resources**(a)
(rounded to nearest 100 tU)

Country	Deposit/project	RAR and inferred resources
Bulgaria	ISL mineable deposits	7 900
Cameroon	Poli (Kitongo)	11 130
	Lolodorf	11 000
Colombia	Berlin	8 200
Egypt	Gabal Gutter	2 000
	Abu Zenima	100
Guinea	Firawa	7 500
Guyana	Kurupung	6 200
Mauritania(b)	Tiris	6 800
Peru	Kihitian	11 200
	Triunfador	1 200
Total		73 230

(a) Amount not reported in RAR and IR national totals.

(b) Additional resource as September 2017, not the resource for the entire deposit.

Source: NEA/IAEA estimate based on publicly available data.

Undiscovered resources

Undiscovered resources (*prognosticated* and *speculative*) 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 prognosticated and speculative resources 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 1.14).

Worldwide, reporting of PR and SR is incomplete; a total of 21 countries (including 2 NEA/IAEA estimates) reported undiscovered resources for this edition, compared to the 33 reporting RAR (including 9 NEA/IAEA estimates). Only seven countries of those reporting provided updated undiscovered resource figures for this edition, and two of these updates were NEA/IAEA estimates. Twenty countries report both prognosticated and speculative resources. Germany, Italy, Jordan, Mauritania, Poland, Senegal, Venezuela and Zimbabwe reported only speculative resources. Only prognosticated resources are reported for Bolivia, Bulgaria, Greece, Hungary, Indonesia, Portugal, the Slovak Republic, Slovenia and Uzbekistan. Some of the countries that do not report undiscovered resources, such as Australia are considered to have significant resource potential in sparsely explored areas. The United States completed part of their re-evaluation of undiscovered resources in 2015. Using a geology-based assessment methodology, the US Geological Survey (USGS) estimated that a mean 85 000 tU of recoverable U_3O_8 remain as potential undiscovered resources in southern Texas. In 2016, the USGS began estimating the undiscovered resources of surficial calcrete-type uranium deposits in the Southern High Plains region of Texas and New Mexico. Additionally, a deposit model is in development for the Coles Hill Deposit in Virginia as part of an evaluation of undiscovered resources in the southeast United States. However, this recent work is yet to be classified into either speculative or prognosticated resource categories and so was not reported in Table 1.14.

Total PR in the highest cost category (<USD 260/kgU) amounted to 1.698 million tU, which is only a 1.4% increase compared to 2015. In the lower cost categories (i.e. <USD 130/kgU and <USD 80/kgU) the amount decreased by 1.6% and increased by 35%, respectively, compared to the last reporting period. Increases were reported for India, Indonesia and Russia, and decreases for the Czech Republic and Kazakhstan with most other countries reporting no change since the last reporting period.

Total SR in the <USD 260/kgU cost category increased by 1.5% compared to 2015, with this increase attributed to updates from Argentina, India and Iran. This was partially offset by a decrease reported by Russia. In the unassigned category, there was an overall decrease of 22%, with decreases reported only for Russia due to reclassification of these resources into the <USD 260/kgU category, and these decreases are partially offset by the increases reported for India, and the addition of Senegal, reporting for the first time. The total SR in the <USD 130/kgU cost category increased by 38% from the last report, with additions made only from Russia. Other countries reported no change in this cost category.

High-cost (<USD 260/kgU) PR and total SR amount to a combined total of 7 530 600 tU, a minor increase of 1.5% from the 7 422 700 tU reported for 2015.

Table 1.14. **Reported undiscovered resources**

(in 1 000 tU as of 1 January 2017)

Country	Prognosticated resources			Speculative resources			Total SR
	Cost ranges			Cost ranges			
	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	<USD 130/kgU	<USD 260/kgU	Cost range unassigned	
Argentina	NA	13.8	13.8	NA	79.5	NA	79.5
Brazil[(a)]	300.0	300.0	300.0	NA	NA	500.0	500.0
Bolivia[(a)]	0.0	0.0	0.0	0.0	0.0	1.7	1.7
Bulgaria[(b)]	NA	NA	25.0	NA	NA	NA	NA
Canada[(a)]	50.0	150.0	150.0	700.0	700.0	0.0	700.0
Chile[(a)]	0.0	0.0	2.3	0.0	0.0	2.4	2.4
China (People's Rep. of)[(b)]	3.6	3.6	3.6	4.1	4.1	NA	4.1
Colombia[(b)]	NA	11.0	11.0	217.0	217.0	NA	217.0
Czech Republic	0.0	0.2	223.0	0.0	0.0	17.0	17.0
Germany[(a)]	NA	NA	NA	NA	NA	74.0	74.0
Greece[(b)]	6.0	6.0	6.0	NA	NA	NA	NA
Hungary[(a)]	0.0	0.0	13.4	0.0	0.0	0.0	0.0
India	NA	NA	114.5	NA	NA	50.9	50.9
Indonesia	0.0	0.0	30.2	0.0	0.0	0.0	0.0
Iran, Islamic Republic of[(c)]	0.0	12.4	12.4	0.0	0.0	33.2	33.2
Italy[(b)]	0.0	0.0	0.0	10.0	10.0	NA	10.0
Jordan[(a)]	0.0	0.0	0.0	0.0	50.0	NA	50.0
Kazakhstan	194.1	229.1	230.6	266.9	300.0	NA	300.0
Mauritania*	0.0	0.0	0.0	NA	NA	19.6	19.6
Mexico[(b)]	NA	3.0	3.0	NA	NA	10.0	10.0
Mongolia[(a)]	21.0	21.0	21.0	1 390.0	1 390.0	NA	1 390.0
Namibia*	0.0	0.0	57.0	0.0	0.0	110.7	110.7
Niger[(b)]	0.0	13.6	13.6	0.0	51.3	0.0	51.3
Peru[(a)]	6.6	20.0	20.0	19.7	19.7	0.0	19.7
Poland[(b)]	0.0	0.0	0.0	0.0	0.0	20.0	20.0
Portugal[(b)]	1.0	1.5	1.5	NA	NA	NA	NA
Romania[(b)]	NA	3.0	3.0	3.0	3.0	NA	3.0
Russia	115.1	115.1	143.9	390.1	591.1	NA	591.1
Senegal	0.0	0.0	0.0	0.0	0.0	1.5	1.5
Slovak Republic[(b)]	0.0	3.7	10.9	0.0	0.0	0.0	0.0
Slovenia[(b)]	0.0	1.1	1.1	0.0	0.0	0.0	0.0
South Africa[(b)]	0.0	74.0	159.0	243.0	411.0	280.0	691.0
Ukraine[(a)]	0.0	8.4	22.5	0.0	120.0	255.0	375.0
United States	NA	NA	NA	NA	NA	NA	NA
Uzbekistan[(b)]	24.8	24.8	24.8	0.0	0.0	0.0	0.0
Venezuela[(b)]	NA	NA	NA	0.0	0.0	163.0	163.0
Viet Nam[(a)]	NA	NA	81.2	NA	NA	321.6	321.6
Zimbabwe[(b)]	0.0	0.0	0.0	25.0	25.0	NA	25.0
Total	722.2	1 015.3	1 698.3	3 268.8	3 971.7	1 860.6	5 832.3

NA = Data not available. * Secretariat estimate; no changes since last edition. (a) Reported in 2017 responses, but values have not been updated within the last five years. (b) Not reported in 2017 response; data from previous Red Book. (c) Reported in 2017 responses, but only partially assessed within the last five years.

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. 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).

A comprehensive compilation of unconventional uranium resources and other potential nuclear fuel materials is challenging as many countries do not provide updated information. Unconventional uranium resources were reported occasionally by countries in Red Books beginning in 1965, and until 2003 estimates have been provided by 18 countries. Table 1.15 summarises unconventional resource estimates reported in Red Books between 1965 and 2003 (NEA, 2006) and incorporates unconventional resource assessments included in the national reports of this 2018 edition to illustrate the evolution of these resource estimates.

Table 1.15. **Unconventional uranium resources (1 000 tU) reported in 1965-2003 Red Books, with updated data* from 2011-2017 in parentheses**

Country	Phosphate rocks	Non-ferrous ores	Monazite	Carbonatite	Black schist/ shales, lignite	Other
Brazil	28-70	2		13		
Chile	0.6-2.8 (0.4[a])	4.5-5.2 (0.8[a])				
Colombia	20-60					
Egypt**	35-100					
Finland	1[a]			2.5 (2.5[a])	3.0-9.0 (35[a])	
Greece	0.5					
India	1.7-2.5	6.6-22.9			4	
Indonesia			(27)			
Iraq	(19-42.8[a])					
Iran, Islamic Rep. of						(53)
Jordan	100-123.4 (100)					
Kazakhstan	58***					
Mexico	100-151 (240[a])	1				
Morocco	6 526					
Peru	20 (41.6[a])	0.14-1.41				
South Africa	(180[a])				70.7[b]	
Sweden	(42.3[a])				300 (1 012[a])	
Syrian Arab Republic	60-80					
Thailand	0.5-1.5					(31.8)
United States	14-33 (576.5[b])	1.8			(19 014[b])	
Venezuela	42					
Viet Nam					0.5	

* Updated data from publicly available sources and information provided by countries in the Red Book questionnaire.

** Includes an unknown quantity of uranium contained in monazite.

*** Production of estimated 6 000 tU between 1959 and 1992 has been deducted from reported total.

(a) Not reported in 2017 questionnaire responses; data from 2011, 2014 and 2016 Red Books.

(b) Secretariat estimate.

Data for 23 countries are included for this edition with 6 countries, Brazil, Indonesia, Iran, Jordan, Russia and Thailand reporting updates. Additionally, NEA/IAEA Secretariat estimates were made for this reporting period for the United States and Uzbekistan. Based on this information a total of 26.9 to 28.5 million tU was assigned to the unconventional resource base.

The IAEA maintains a database, World Distribution of Uranium Deposits – UDEPO (www-nfcis.iaea.org), which provides additional information about the potential unconventional resource base. As of 1 September 2018 (IAEA UDEPO, 2018), UDEPO reports 35 million tU as original historical resources from 38 countries for deposits classified as lignite-coal, black shale, phosphate and carbonate deposits, which are typically considered unconventional resources. A note of caution is warranted: deposit types do not necessarily correspond to the definition of unconventional resources; for example, the phosphate deposits of Brazil and carbonate deposits of India are considered conventional. Despite this, because of their deposit type they are often included as a part of unconventional resource totals. For several editions of the Red Book they have also been included in the totals for Table 1.15, but for this edition this has been corrected and the amounts reported for Kazakhstan and Brazil are only the historical values (i.e. reported between 1965 to 2003; NEA, 2006). The amounts previously reported from Russia and Uzbekistan have been removed as they are already included in the national totals as conventional resources.

Over 70% of the total unconventional resources reported in UDEPO includes the black shales, phosphate and lignite-coal deposits in the United States. For this report the NEA/IAEA has provided an estimate for unconventional resources for the United States based on the values reported in UDEPO. Morocco has the highest reported phosphate resources in the world with over 6.5 million tU, and this comprises 19% of the total unconventional resources reported in UDEPO. Sweden also has significant unconventional resources, at just over 3% of the world total these resources are mainly associated with black shales (>1 million tU) and to a lesser extent phosphate deposits. Iraq has the fourth largest quantity of unconventional resources listed with 694 800 tU associated with phosphate deposits. The remainder (i.e. 34) of the countries with unconventional resources in the UDEPO database contribute to less than 8% of the world total unconventional resources. Note that UDEPO includes most of the data from Table 1.15 and the higher total for unconventional resources in UDEPO is due to more complete information for some countries and the fact that some of the reported total includes already mined resources. It is clear that additional data is still required to fully understand the unconventional resources picture. Nonetheless, the potential to expand the unconventional uranium resource base is readily apparent but will likely not be fully realised until market conditions strengthen considerably.

The potential to expand the unconventional uranium resource base is strongly tied to the ability to bring these resources into production. This will depend on i) market conditions, notably for the commercial recovery of phosphate reserves, since these determine the underlying economics of by-product uranium recovery; ii) changing business models and perceptions in the mineral industry consequent to recent market downturns resulting in expansion of portfolios to include multiple value-added products and especially materials for renewables technologies (e.g. electric storage batteries); iii) changing policies, notably to require uranium and other critical resources such as rare earth elements to be extracted for strategic and sustainability reasons rather than entirely on a commercial basis; and iv) a drive towards better environmental management and waste minimisation. Examples of possible policy drivers include the need to enhance the security of uranium supply to the national nuclear fuel cycle or to reap the environmental benefits of extracting uranium from phosphoric acid rather than through conventional mining, along with minimising the already very low amounts of uranium contained in fertiliser products.

Uranium as a co-product/by-product

A pre-feasibility report was released in 2011 for the Kvanefjeld rare earth element project of the Ilimausaq intrusion. In 2013, Greenland's parliament voted in favour of lifting the country's long-standing ban on the extraction of radioactive materials, including uranium. The move could enable the Kvanefjeld project to proceed, which is currently the subject of a definitive feasibility study to evaluate a mining operation to produce uranium, rare earth elements and zinc. If the deposit were to be mined, about 425 tU/yr could be recovered as a by-product while thorium would be precipitated with other impurities such as iron, aluminium and silica and stored in a residue storage facility with the possibility of recovering the Th in the future. Although uranium is a by-product, the resources are reported as conventional in the national report (i.e. similar to Australia, which reports by-product uranium production from Olympic Dam), with total recoverable identified resources of 148 200 tU.

Nolans Bore, Northern Territory, Australia is a rare earths-phosphate-uranium deposit, discovered in 1995. There is a conceptual plan to mine, concentrate and chemically process rare earths at the Nolans site, then transport a rare earths-rich intermediate product to an offshore refinery for final processing into high-value rare earth products. About 4 050 tU of RAR have been estimated. A feasibility study is in progress with a comprehensive technical and commercial work stream. In January 2018 it was announced that the project had received state-level approval from the Environmental Protection Authority (EPA). However, an environmental approval from the Australian government and a final approval from the state government still need to be obtained. The project is projected to start in 2020 and could produce 14 000 t of rare earth oxides and possibly uranium, thorium and phosphoric acid (110 000 t/a) as by-products.

Pitinga deposit in Amazonas, Brazil, is one of the largest tin deposits in the world. Thick rhyolitic ashflow and tuffs are intruded by a 1 800 Ma granite. After a period of deposition of locally derived sandstone and shales, a series of rapakivi, porphyritic and sub-alkaline biotite granites were emplaced, and contain ore minerals such as zircon, pyrochlore, columbite, tantalite, xenotime and cassiterite. Beside tin, minor tantalum is currently also produced. However, the columbite mineral also contains 3.16% U_3O_8 and 4.90% ThO_2. This along with Nb, Ta, Zr and rare earth elements (REEs) is not currently being recovered. A pre-feasibility study is in progress to study the possibility of by-product recovery of Ta, Nb, Y, REE, U and Th, with production forecasted to start around 2020.

Alum (black) shale in Sweden has been investigated since 2011 for potential recovery of molybdenum, vanadium, nickel, zinc, petroleum products and uranium. The major deposits are Häggån (307 692 tU), MMS Vicken (447 308 tU) and Narke (257 000 tU). A scoping study, which examined a range of heap leach options including bioheap leaching, was completed in 2012 with positive results reported. Expected production is about 3 000 tU/yr, but no definite start dates have been announced. Most recently, with the rise in the price of vanadium, the principal focus for the Häggån Project has been altered to focus on vanadium and owner Aura Energy Ltd. has commenced a revised scoping study focusing on the potential for a major vanadium project. The scoping study is expected to be completed during 2018.

Unconventional resources of uranium in the Terrafame mine (Talvivaara Sotkamo) black schist-hosted Ni-Zn-Cu-Co deposit is approximately 16 000 tU RAR, and about 24 000 tU total identified resources, as reported in the update in 2016 by Terrafame Oy. Although mining and production of other metals in the mine started in 2008, uranium present at 0.0017% in the ore started appearing as a contaminant in the downstream products. A licence for uranium extraction was granted in 2012, for annual production of 350 tU. However, waste water leaks in 2012 and 2013 stopped the operations completely, and the operator filed for bankruptcy protection in 2014. In August 2015, state-owned company Terrafame Oy acquired the operations and assets of Talvivaara Sotkamo Oy from its bankruptcy estate, and as of 1 November 2017, was carrying on the mining operations in Sotkamo. In October 2017, Terrafame Oy applied to the Finnish government for a licence to recover uranium as a by-product at Terrafame's mine. The mine site currently includes an almost fully completed uranium solvent extraction plant and Terrafame expects to start uranium production at Sotkamo (hopefully by 2020) after completion of licensing processes.

Elliot Lake district, Ontario, Canada, has a previous history of uranium and REE production. Between 1955 and 1996, the paleo-quartz-pebble conglomerate deposit produced about 115 394 tU, as well as a small quantity of rare earth oxides. Several years ago exploration in the area resulted in a proposal (Eco Ridge project), which would produce rare earth oxides and uranium as co-products. An NI 43-101 resource estimate, which was updated in 2013, reported 23 147 tU and 93 180 t of rare earth oxides. A 2013 economic review indicated that approximately 1 173 tU/yr could be produced over 14 years of mine life. There is no update for this reporting period for this project.

South Africa has reported a significant resource base in paleo-quartz-pebble conglomerates and derived tailings and coal-hosted deposits, 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. A pre-feasibility study has been completed in Springbok Flats and a bankable feasibility study is in progress. In the 2016 edition of the Red Book, 70 775 tU for lignite and coal deposits were reported as inferred conventional resources. This is a good example of a reclassification of resources from "unconventional" to "conventional" resources. 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 is reported as conventional and in association with the paleo-quartz-pebble conglomerate deposit type.

If uranium prices reach long-term levels greater than USD 260/kgU (USD 100/lb U_3O_8), and/or if improvements are made in reducing mining and processing costs, by-product recovery of uranium from unconventional resources could once again become commercially viable, even without the policy changes noted above.

Uranium from phosphates

In the market scenario, phosphate deposits will only be processed commercially when it is economically viable to do so. Hence, the phosphate market acts as the determining factor of how much uranium can even theoretically be extracted from phosphate resources.

In the policy-driven scenario, the value of other recoverable elements will be added by various means – such as long-term government contracts – to the overall economic evaluation. Governments could also place a premium on securing the supply of nuclear fuel, especially where this can come from national resources, thereby eliminating dependency on third parties. In some countries, uranium extraction from phosphates could perhaps be mandated.

A hybrid situation (market and policy-driven scenario) may, however, be the most sustainable scenario over the long term. The need to combine fuel security for the utility company with commercial viability to the phosphate company and to align these requirements with the equally significant role of phosphates in providing food security could drive new business models. One benchmark in Brazil has already been set for this scenario, the Santa Quitéria greenfield joint venture between the government company, Industrias Núcleares do Brasil S.A (INB), and Galvani phosphates, with the prime customer being Eletrobras, the leading producer of nuclear power. This project will produce both yellow cake and diammonium phosphate in a single integrated process, thus spreading business risk across both phosphates and uranium. The alternative model is when the government steps in as the customer, as in the case of India, on the premise that the wider challenge of sustaining energy production as the fundamental driver of economic development justifies an offset of risk from the commercial producer to the tax payer. Under the hybrid option, both phosphate and uranium are managed as utility products and not as market-dependent commodities.

Phos Energy Ltd and Cameco Corporation have developed the "PhosEnergy" process to extract uranium from the processing stream at operating phosphate mines. A demonstration plant was tested at a phosphate fertiliser production site in Florida in 2015 with good results, and a pre-feasibility study was completed for a relatively small facility (<150 tU/yr), and returned operating costs in the lower quartile of USD 50/kgU. The construction of a commercial model awaits favourable economic conditions.

Uranium from seawater

Seawater has long been regarded as a possible source of uranium because of the large amount of contained uranium (over 4 billion tU) and its almost inexhaustible nature. However, because seawater contains such a low concentration 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. In Japan 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 special issue devoted to several papers on recovery of uranium from seawater was published recently in the journal of Industrial and Engineering Chemical Research (ACS, 2016). One of the more recently studied methods considered for extracting uranium from seawater includes infusing fibres made of polyethylene, a common plastic, with amidoxime, a substance that attracts uranium dioxide and binds it to the fibre (Kuo et al., 2016; Abney et al., 2017). Researchers at Pacific Northwest National Laboratory and LCW Supercritical Technologies announced recently they were able to produce five grams of yellowcake using this method (PNNL, 2018). Over the past five years, the studies have indicated that the cost of uranium extraction from the sea has dropped by a factor of three to four (CNA, 2016; PNNL, 2016). These costs have been evaluated based on laboratory experience and an important parameter to consider in efficient recovery of uranium from seawater is the temperature (Kuo et al., 2018). Costs are still significantly above current market prices and furthermore the technologies to extract uranium from seawater are yet to be proved cost-effective outside the laboratory setting.

Uranium exploration

Non-domestic

Only four countries (China, France, Japan and Russia) reported non-domestic exploration and development expenditures since 2008 (see Table 1.16). 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 domestic and foreign sources within each country. During this reporting period, non-domestic exploration expenditures steadily declined from USD 800.9 million in 2014 to USD 582.2 million in 2015 and USD 419.9 million in 2016 and even further to USD 230.4 million in 2017 (preliminary data). During the last reporting period there was a sharp increase, principally as a result of China's investment in the Husab mine in Namibia. As development has progressed and the initial phase was completed, expenditures have declined to pre-2013 levels. China reported the development portion of total expenditures as 98% and 97% in 2015 and 2016, respectively. France, Japan and Russia reported only exploration expenditures. France reported a decrease from 2015 to 2016 with a small increase expected for 2017 with relatively steady overall expenditures for this reporting period. Total expenditures in Japan increased from 2015 to 2016 with a decrease of over 50% in 2017. Russia reported a sharp decrease from USD 17.1 million in 2015 to USD 6.1 million in 2016 and the decline is expected to continue into 2017 with estimates of USD 3.1 million for 2017.

Several countries do not report non-domestic expenditures or have not reported these expenditures recently, and thus the data are incomplete. Canada reported expenditures of USD 139 million in 2007, and it is likely that Canada continues to be a leading investor in foreign exploration and development, but no information was reported for this edition. Australia is also known to make non-domestic investments, but figures have not been reported since 2006.

Table 1.16. **Non-domestic uranium exploration and mine development expenditures**

(USD thousands in year of expenditures)

Country	Pre-2010	2010	2011	2012	2013	2014	2015	2016	2017 (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 (People's Rep. of)	573 020	94 950	94 740	81 690	599 100	762 980[1]	526 310[1]	378 010[1]	191 600[1]
France	1 244 328	61 652	68 670	68 320	71 710	27 600	34 866	30 736	33 460
Germany	403 158	0	0	0	0	0	0	0	0
Japan	428 490	3 020[2]	3 030[2]	5 371[2]	3 512[2]	5 465[2]	3 922[2]	5 089[2]	2 245[2]
Korea	NA	NA	NA	NA	NA	NA	NA	NA	NA
Russia	NA	26 300	31 100	30 100	18 200	4 900	17 100	6 100	3 100
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	3 120 482	185 922	197 540	185 481	692 522	800 945	582 198	419 935	230 405

Note: 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.

NA = Data not available. 1. Industry expenditures only. 2. Government expenditures only.

Domestic

Twenty-three countries reported domestic exploration and development expenditures in this edition. The totals reported are on a country-by-country basis and represent the total expenditures from domestic and foreign sources within each country. There is a notable decline in total expenditures compared to the last report (Table 1.17). Since 2011, the expenditures have decreased, except for 2014 where an increase is noted, mainly in relation to expenditures reported by Namibia (i.e. >USD 1 billion), which reflects development of the Husab mine. From 2014 to 2015, total expenditures dropped from over USD 2 billion in 2014 to USD 877 876 million and continued to decline to USD 663 678 million in 2016. From 2014 to 2016, expenditures decreased in most countries, mainly because of the declining uranium price, which slowed down many exploration and mine development projects. Significant decreases were reported for Australia, Canada, the Czech Republic, China, Namibia, Russia and the United States. In contrast, India and Argentina reported increases from 2014 to 2016, and while India indicated that expenditures continued to rise in 2017, Argentina reported a decline. Kazahkstan, the world's largest uranium producer, reported an increase in expenditures from USD 34.7 million to USD 60.9 million from 2014 to 2015, followed by a sharp decline to USD 23.9 million in 2016. Finland reported exploration expenditures for 2014; however, from 2015 onwards, there is no data for Finland as it wasn't possible to separate out the uranium exploration expenditures from the total for gold exploration for which uranium could be a potential co- or by-product. Spain, Turkey and Viet Nam reported an increase in expenditures from 2014 to 2015, followed by a decline for 2016.

Table 1.17. **Industry and government uranium exploration and mine development expenditures – domestic (in countries listed)**

(USD thousands in year of expenditures)

Country	Pre-2010	2010	2011	2012	2013	2014	2015	2016	2017 (preliminary)
Algeria	NA	0	0	0	0	0	0	0	0
Argentina	68 676	12 222	14 296	10 647	9 812	4 244	5 880	3 968	2 448
Australia	1 118 023	166 084	198 742	98 695	48 787	37 124	33 665	29 194	19 798
Bangladesh	453	NA	NA	NA	NA	NA	NA	NA	NA
Belgium	2 487	0	0	0	0	0	0	0	0
Bolivia	9 343	NA	NA	NA	NA	NA	NA	NA	NA
Botswana*	4 929	5 421	1 218	1 061	NA	NA	NA	NA	NA
Brazil	186 577	223	126	1 198	1 608	0	224	1 348	613
Cameroon	1 282	0	NA	NA	NA	NA	NA	NA	NA
Canada	3 373 835	750 484	948 223	847 721	845 124	525 677	397 249	296 779	282 127
Central African Rep.	21 800	NA	NA	NA	NA	NA	NA	NA	NA
Chile	8 346	1 272	NA	NA	NA	NA	NA	NA	NA
China (People's Rep. of)	213 000	89 000	118 000	131 000	189 000	197 000	152 000	128 000	122 000
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
Czech Republic[a]	314 804	5	12	203	176	1 327	633	514	27
Ecuador	1 945	NA	NA	NA	NA	NA	NA	NA	NA
Egypt	117 271	NA	NA	NA	NA	NA	NA	NA	NA
Ethiopia	22	NA	NA	NA	NA	NA	NA	NA	NA
Finland	21 261	2 367	19 657	58 894	22 295	1 753	0	0	NA
France	907 240	0	0	0	0	0	0	0	0
Gabon	102 443	NA	NA	NA	NA	NA	NA	NA	NA
Germany[c]	2 002 789	0	0	0	0	0	0	0	0
Ghana	90	NA	NA	NA	NA	NA	NA	NA	NA
Greece	17 547	NA	NA	NA	NA	NA	NA	NA	NA
Greenland (Denmark)	4 140	NA	NA	NA	70	2 195	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	447 362	55 778	56 227	49 771	38 510	43 983	49 858	52 156	57 385
Indonesia	16 491	327	455	275	490	100	464	194	180
Iran, Islamic Rep. of	57 092	32 165	53 156	82 070	43 197	50 179	6 276	17 320	25 904
Ireland	6 200	NA	NA	NA	NA	NA	NA	NA	NA
Italy	75 060	NA	0	0	0	0	0	0	0
Jamaica	30	NA	NA	NA	NA	NA	NA	NA	NA
Japan	16 697	0	0	0	0	0	0	0	0
Jordan	11 645	11 434	6 766	1 839	3 175	3 820	3 697	2 886	3 531
Kazakhstan	229 853	57 584	70 955	94 303	76 420	34 676	60 934	23 935	18 535
Korea	17 866	NA	NA	NA	NA	NA	NA	NA	NA
Lesotho	21	NA	NA	NA	NA	NA	NA	NA	NA
Madagascar	5 239	NA	NA	NA	NA	NA	NA	NA	NA

See notes on page 41.

Table 1.17. **Industry and government uranium exploration and mine development expenditures – domestic (in countries listed)** *(cont'd)*

(USD thousands in year of expenditures)

Country	Pre-2010	2010	2011	2012	2013	2014	2015	2016	2017 (preliminary)
Malawi	NA	NA	NA	NA	NA	NA	NA	NA	NA
Malaysia	10 478	NA	NA	NA	NA	NA	NA	NA	NA
Mali	56 693	NA	NA	NA	NA	1 516	774	387	1 033
Mexico(b)	30 456	150	NA	856	1 215	1 383	1 452	1 237	1 200
Mongolia	87 306	18 284	30 051	26 040	15 856	15 436	7 816	6 600	9 407
Morocco	2 752	NA	NA	NA	NA	NA	NA	NA	NA
Namibia	130 959	32 984	84 627	76 533	19 079	1 041 434	9 962	8 253	4 747
Niger	906 181	20 424	5 032	117 290	NA	NA	NA	NA	NA
Nigeria	6 950	NA	NA	NA	NA	NA	NA	NA	NA
Norway	3 180	0	0	0	0	0	0	0	0
Paraguay	26 360	NA	NA	NA	NA	690	0	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	NA	0	1 388	1 452	724	229	0	NA	NA
Portugal	17 637	0	NA	NA	NA	NA	NA	NA	NA
Romania	10 060	NA	NA	NA	NA	NA	NA	NA	NA
Russia	648 095	117 647	99 786	64 731	46 746	39 917	17 581	10 804	5 840
Rwanda	1 505	0	0	0	0	0	0	NA	NA
Slovak Republic	NA	3 576	5 579	2 484	1 956	408	NA	NA	NA
Slovenia(d)	1 581	0	0	0	0	0	0	0	0
Somalia	10 000	NA	NA	NA	NA	NA	NA	NA	NA
South Africa(e)	209 006	18 761	35 072	32 788	1 890	1 655	5 164	NA	NA
Spain	152 675	10 223	14 786	12 106	13 000	5 400	9 106	5 702	4 191
Sri Lanka	43	NA	NA	NA	NA	NA	NA	NA	NA
Sudan	200	0	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	0	0	0
Syrian Arab Republic	1 151	NA	NA	NA	NA	NA	NA	NA	NA
Tanzania	NA	23 783	25 557	28 871	NA	NA	NA	NA	NA
Thailand	11 299	NA	0	0	0	NA	NA	NA	NA
Turkey	22 257	91	2 230	2 815	3 048	4 875	6 842	223	1 416
Ukraine	48 352	3 207	1 992	2 633	1 324	1 337	689	484	529
United Kingdom	3 815	0	0	0	0	0	0	0	0
United States(f)	3 461 913	144 000	150 400	166 000	140 500	102 100	105 000	71 900	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	NA	NA	NA	NA
Viet Nam	3 729	3 137	5 383	1 697	1 427	1 875	2 610	1 794	1 537
Zambia(g)	25	NA	2 438	3 518	3 751	NA	NA	NA	NA
Zimbabwe	6 902	NA	NA	NA	NA	NA	NA	NA	NA
Total	19 307 185	1 580 633	1 952 154	1 917 491	1 529 180	2 120 333	877 876	663 678	562 448

Note: Domestic exploration and development expenditures represent the total expenditure from both domestic and foreign sources in each country for the year.

NA = Data not available. * Secretariat estimate. (a) Includes USD 312 560 expended in Czechoslovakia (pre-1996). (b) Government exploration expenditures only. (c) Includes USD 1 905 920, spent in German Democratic Republic between 1946 and 1990. (d) Includes expenditures in other parts of the former Yugoslavia. (e) Includes expenditures for both uranium and gold in the Witwatersrand Basin until 2012. (f) Includes reclamation and restoration expenditures from 2004 to 2012. Reclamation expenditures amounted to USD 49.1 million, 62.4 million, 41.7 million, 46.3 million in 2008, 2009, 2010, 2011, 2012, respectively. (g) Non-government industry expenditures between 2011 and 2013

Expenditures continued to decrease in 2017 by 15% to USD 562 448 000. Furthermore, declining expenditures are expected in the majority of the major uranium-producing countries including Australia, Canada, Kazakhstan and Namibia. There are no expenditure data available for Niger, but presumably the trend in declining expenditures mimic those of the other major aforementioned producing countries. For 2014 to 2016, of the countries that reported exploration and development expenditures separately, China, Kazakhstan and Russia, reported more exploration than development expenditures (90-92%, 74-95%, 78-93%, of total exploration and development expenditures, respectively). Canada reported mainly higher percentages of development expenditures (55-68%). In Namibia, development expenditures were 55-58% of the total, which is in contrast to the last reporting period when exploration expenditures were reportedly higher. The United States reported an increasing proportion of expenditures as related to development with the proportion ranging from 90-96% from 2014 to 2016. In Iran and Ukraine, expenditures have been more evenly balanced between exploration and development. Turkey reported a higher proportion of exploration expenditures in 2014 and 2016, but in 2015 about 82% of total expenditures were reported as development expenditures, primarily due to work on the Temrezli uranium deposit. The Czech Republic and Denmark/Greenland reported both exploration and development expenditures only for 2014. For the Czech Republic this reflects the closing of the Dolní Rozínka mine and only a small amount of exploration activity continued in relation to identification of further resources for the Rozná deposit.

Sixteen countries reported drilling activities. In terms of exploration drilling from 2014 to 2015, India, Kazakhstan, Namibia and Spain reported an increase followed by a decline in 2016. Canada also reported an increase from 2014 to 2015 and no data were made available for 2015 and 2016. Brazil reported no drilling activity for 2014, but a huge increase was reported for the period 2015 to 2016 as exploration drilling focused on the Lago Real Province. Iran reported an increase over the entire period, from 2014 to 2017. Ukraine's activities remained relatively consistent, although the length drilled dropped somewhat from 2014 to 2015, increasing again in 2016, and it dropped slightly in 2017, based on preliminary data. Argentina, China, Russia and Turkey all reported a decline in drilling efforts from 2014 to 2016, and while China and Russia continued this decline from 2016 to 2017, Argentina and Turkey are more optimistic, with reports for increased efforts. India and Namibia reported increased exploration drilling efforts for 2017 and, on the contrary, Brazil and Spain reported decreased drilling efforts for 2017. Finland and Viet Nam only reported exploration drilling for 2014 and 2015, respectively. Hungary reported exploration drilling in 2016 and 2017, but no information was provided on total expenditures. Globally, the overall trend since 2015 is a decline in exploration drilling.

Eight countries reported development drilling: Canada, China, Iran, Kazakhstan, Namibia, Turkey, Ukraine and the United States. Iran and Kazakhstan reported an increase in development drilling from 2014 to 2017. Namibia and Turkey reported an increase only from 2014 to 2015 and in Namibia a sharp decline in expenditures is reported for 2015 to 2017. Ukraine reported almost the same levels for drilling for 2014 and 2015, with a moderate decrease in 2016, but drilling activity is increased again to 2014 levels in 2017 (preliminary data). Canada reported a decrease from 2014 to 2015 and unfortunately, no data was available for 2016 and 2017, but given market conditions it is likely that drilling activity continued to decrease. China reported a decline in development drilling over the reporting period from 2014 to 2017.

The United States did not specify type of drilling (i.e. exploration or development) in their latest report, but they have reported that total drilling efforts have decreased from 2014 to 2016. It can be surmised that most of the drilling during this reporting period is related to development, as 90-95% of the total exploration and development expenditures for the United States are reported as development. For comparison and reference, in 2013, when the type of drilling was specified, exploration drilling accounted for about 24% of the total drilling.

Countries that reported only government expenditures include Argentina, Brazil, India, Iran, Jordan, Mexico, Ukraine and Viet Nam. Those reporting non-governmental (industry) expenditures include Australia, Canada, Finland, Kazakhstan, Mali, Namibia, Spain and the United States. Note that this is what is reported; there can be industry expenditures in countries reporting only government expenditures and vice versa. In some cases, it is a matter of the availability of data (e.g. industry expenditures in Argentina) or the amount has already been included as part of the industry total (i.e. state shares in projects, e.g. Kazakhstan). China and Russia reported both industry and government expenditures. In China, the government exploration expenditures ranged from 70% to 89% of the total from 2014 to 2017, with the percentage increasing over the reporting period.

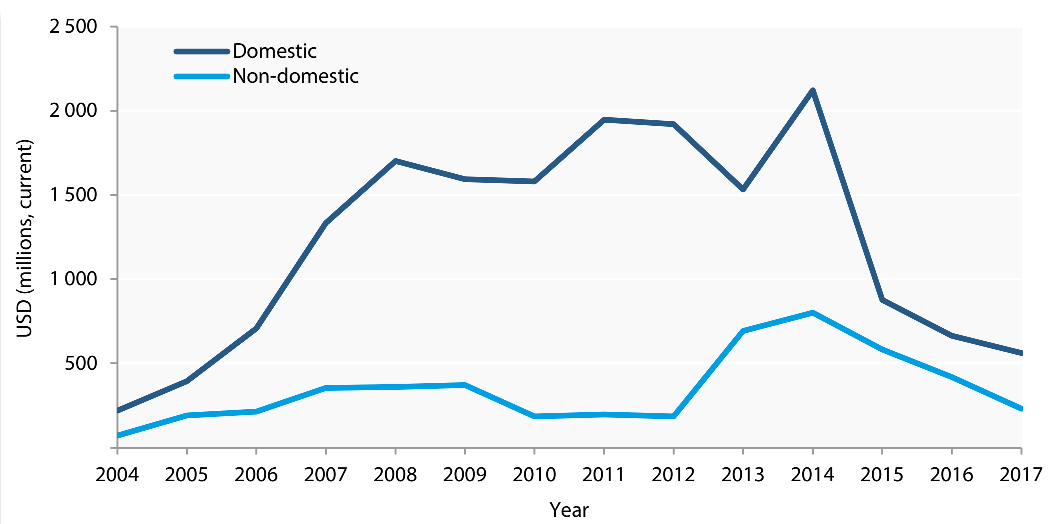
The Czech Republic and Denmark/Greenland reported expenditures from both industry and government in 2014, but for 2015 and 2016 they reported only industry expenditures and for Denmark/Greenland this includes all industry expenditures for the exploration of all commodities, not just uranium. Turkey has reported government and industry expenditures for 2014 and 2015 and only government expenditures for 2016.

For the 15 countries reporting in this edition, total drilling in 2014 amounted to 2 730 317 m (1 817 671 m exploration; 516 711 m development), 3 154 644 m (2 258 207 m exploration; 628 823 m development) in 2015 and 1 867 511 m (1 384 556 m exploration; 252 221 m development) in 2016. Note that the separate totals for exploration and development do not add up to the total metres drilled as the United States does not report this information separately. A large decrease in drilling effort is noted in comparison to the last reporting period. It should be noted that Canada did not report data for 2015 and 2016 and both Canada and the United States did not provide data for 2017.

Iran and Jordan are the only countries that report trenching data. From 2014 to 2016, Iran reported an increase in trenching with the amount to increase substantially to a total of 9 680 m in 2017. Jordan reported a sharp decrease from 10 008 m in 2014 to 4 964 m in 2015 and the amount was slightly higher in 2017 with 5 600 m estimated as total trenching.

Domestic and non-domestic uranium exploration and development expenditures since 2004 are depicted in Figure 1.4.

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



* 2017 values are estimates.

Current activities and recent developments

North America

In Canada, overall uranium exploration and development expenditures in 2015 amounted to USD 397 million (CAD 491 million), a 25% decrease from 2014. Expenditures have been steadily declining since 2011 when the total was USD 948 million. Provisional data suggests a continued decrease in expenditures to approximately USD 297 million and USD 282 million in 2016 and 2017, respectively. Uranium development expenditures alone were CAD 321 million in 2015, down 16% from 2014 development expenditures of CAD 384 million. Preliminary data for total expenditures of CAD 387 million and CAD 382 million for 2016 and 2017, respectively, indicate that development expenditures will increase slightly and that the decline in total exploration and development expenditures from 2016 to 2017 will mainly be a result of decreases in exploration expenditures.

Despite overall declining expenditures, globally Canada has maintained higher than average expenditures and in 2016 this accounted for 45% of the world total, for countries reporting this data. This sustained commitment to exploration activity has led to new uranium discoveries in the Athabasca Basin. Recently discovered large high-grade uranium deposits include Phoenix/Gryphon (Denison Mines Inc.), Triple R (Fission Uranium Corp.), Arrow (Next-Gen Energy Corp.) and Fox Lake (Cameco Corp.).

In the United States, total exploration and development expenditures have declined from USD 140.5 million in 2013 to USD 102.1 million and USD 102.1 million in 2014. There was a slight increase in 2015 to USD 105 million, which was followed by a sharp decline to USD 71 900 in 2016. This overall decrease in expenditures is primarily the result of the current depressed uranium market and concomitant global oversupply of uranium.

Central and South America

Note that expenditures are compared in Argentine pesos (ARS) for Argentina due to the extreme currency fluctuations in recent years, making it difficult to make reasonable comparisons in USD. Argentina reported domestic exploration expenditures in 2014 of ARS 34.5 million, a 34% decrease over 2013 expenditures of ARS 52.7 million. This increased to ARS 53.3 million in 2015 and to ARS 60.2 million in 2016, but decreased to ARS 43.9 million in 2017. However, it is worth noting that exploration and development expenditures and drilling totals, as reported by the government, are likely to not reflect all activity within the private sector as there is no requirement for private industry to report these expenditures.

The most significant uranium ore deposit in the assessment/exploration stage in Argentina is Cerro Solo, located in Chubut Province. Also under study within the Chubut Province is the Cuadrada Hill Uranium District. Exploration is relatively active, and there are several other areas where exploration is taking place including shallow low-grade, calcrete-type deposits within the Santa Cruz province; uranium mineralisation associated with either limestone deposits or granites, Province of La Rioja; the Mina Franca deposit, classified as granite-related type, Province of Catamarca; five exploration areas near Catriel town, Province of Río Negro; Don Otto sandstone-type deposit, Province of Salta; and reconnaissance-type studies in Gobernador Ayala, Province of La Pampa.

Of six private companies who have had projects in recent years, only Meseta Exploraciones S.A. (MEXSA), Sophia Energy S.A. and UrAmerica Ltd were working continuously during the past few years. The first two companies mentioned undertook uranium exploration in the south of the Chubut Province and in the north sector of Santa Cruz province, where exploration was focused on shallow low-grade uranium anomalies defined as a calcrete-type deposit. UrAmerica Ltd has undertaken an exploration programme supported by the drilling of 250 holes, for a total of approximately 24 000 m, on neighbouring areas of the Cerro Solo ore deposit in the Chubut Province.

The IAEA has provided support to many uranium production cycle activities in Argentina over the last several years. One of the recent IAEA Technical Cooperation projects was implemented from 2014 to 2015, "Improving and Strengthening Human Resources in the Areas of Environment, Mining, Nuclear Reactors, Nuclear Fuel, Human Health and Agriculture".

In Brazil, expenditures increased from USD 224 000 in 2015 to USD 1.3 million in 2016. This increase will primarily result from drilling of about 16 800 m in the Lagoa Real province. Expenditures decreased to USD 613 000 in 2017 (preliminary data).

Chile did not report exploration and development expenditures for this edition. Alliance Chile Pty Ltd has two projects in northern Chile's iron-oxide copper-gold belt with potential for copper, gold, silver and uranium. In 2015, Alliance Resources completed an airborne magnetic and radiometric survey over the eastern limb on the Monardes Basin in Chile and identified two sub-parallel uranium anomalous units with a combined strike length of 9 km. In 2016, Alliance Resources reported that ten reverse circulation drill holes totalling between 1 500 m and 2 000 m were drilled within the eastern anomalous unit at Monardes with some anomalous Cu and U values recorded. Follow-up on the sampling and analytical results indicated that Cu values were anomalous but U values were not significant.

The government of Paraguay reported domestic exploration and expenditures only for 2014 and this amounted to USD 690 000. In 2015, Uranium Energy Corporation (UEC) was granted regulatory approval to advance its Yuty in situ leach project from the exploration phase to the exploitation phase. However, in September 2015 the company requested a two-year suspension of the project due to low uranium prices. Due to depressed uranium market prices, the only other company that has been recently working on uranium projects in Paraguay is Transandes Paraguay S.A.

Peru does not report exploration and development expenditures, and the industry is not required to report expenditures to the government. Currently, there are a few active exploration companies in Peru including Plateau Energy (formerly Plateau Uranium Inc.) and Fission 3.0 Corp. Both companies have been advancing their uranium and lithium prospects through drilling on their Macusani district projects.

European Union

In the Czech Republic, exploration and development expenditures decreased from USD 1 327 000 in 2014 to USD 633 000 in 2015 and further decreased to USD 514 000 in 2016. In this reporting period, the most significant exploration activities were the identification of uranium resources in the deep parts of the Rozná deposit in 2016. In 2017, a total expenditure of only USD 27 000 was reported as preliminary data, reflecting decreased activities due to closing of the mine and depressed market prices.

Greenland reported government exploration expenditures of USD 2.2 million only for 2014. Total industry expenditures were reported for 2014 to 2016. However, the industry expenditure data is not available exclusively for uranium as it is not possible to separate out the different exploration expenditures by commodity. Since 2007, Greenland Minerals and Energy Ltd (GMEL) has conducted REE (U-Zn) exploration activities in the Kvanefjeld area, South Greenland, including drilling of 57 710 m of core. The Kvanefjeld Feasibility Study, as well as the environmental and social impact assessments (EIA and SIA), were carried out in 2014-2015 and were submitted together with the exploitation licence application in December 2015. The application is currently being evaluated by the Greenland government.

There is currently no actual uranium exploration in Finland. However, uranium is included as a so-called mining mineral in some exploration permits and exploration permit applications. Finland only reported expenditures in 2014 of USD 1.7 million and since that time no expenditures have been reported even though, as previously stated, uranium may be part of some of the exploration permits (e.g. gold projects).

The government of Hungary did not report any exploration or development expenditures. However, they do report exploration drilling in 2016 of 1 867 m and 1 050 m in 2017 in association with the Mecsek deposit.

In 2009, the government of Poland decided to consider introducing nuclear energy, and, as a result, the possibility of mining domestic uranium resources has been studied and exploration expenditures were reported for the first time in 2010. However, in recent years these expenditures have declined and no expenditures were reported for this edition as there was no country report.

The Slovak Republic did not provide any data during this reporting period. However, early in 2018 it was announced that the Economy Ministry has withdrawn from a memorandum of understanding in the energy sector with the Canadian company European Uranium Resources regarding energy, particularly uranium mining, dating from late 2012. This action implies that the planned uranium mining project near Košice has lost state support.

Spain reported an increase in domestic expenditures from USD 5.4 million in 2014 to USD 9.1 million in 2015, but this amount decreased back to 2014 levels, to USD 5.7 million in 2016, and to USD 4.2 million in 2017.

Work continues by Berkeley Energia Ltd, which has been actively exploring for uranium for several years, focusing on a number of historically known uranium projects located within their tenements. Due to these sustained efforts there is a reported increase in resources as the company works towards open-pit mining of four deposits.

The government of Sweden did not report exploration and development expenditures, but a few exploration programmes have been ongoing in the country since 2007. Most activity during 2013 and 2014 has been related to the potential of alum (black) shale, where uranium can be recovered as a by-product along with other co-products such as molybdenum, vanadium, nickel, zinc and petroleum products. Exploration expense figures for the course of these two years are, however, not available. During 2015-2017, Aura Energy Ltd. reported continued progress on the Häggån Project including commencement of a programme of community engagement and continuation of drilling to further define the mineralisation. Most recently, the company decided to focus on valuation of the Häggån Project for vanadium.

Although no domestic uranium activities have been carried out in France since 1999, Orano (formerly Areva) and its subsidiaries have been active abroad. During 2014-2016, Orano and its subsidiaries worked outside France focusing on targets aimed at the discovery of exploitable resources in Canada, Kazakhstan, Mongolia, Namibia and Niger. Total non-domestic exploration expenditures reported by the government have remained relatively steady over this reporting period with an increase from USD 27.6 million in 2014 to USD 34.8 million in 2015 and a decrease to USD 30.7 million in 2016. Expenditures remained at similar levels at around USD 33.4 million in 2017 (preliminary data). No development expenditures were reported.

Europe (non-EU)

Russia reported a steady decline in domestic exploration and development expenditures from USD 39.9 million in 2014 to USD 17.6 million in 2015, and a further decline to 10.8 million in 2016 and USD 5.8 million in 2017 shown as preliminary data.

There are two types of uranium exploration activities in Russia, one aimed at new deposit discovery and the second directed at exploration of earlier discovered deposits with a view to developing resource estimates and deposit delineation.

During this reporting period, the Republic of Buryatia, the Trans-Baikal and the Irkutsk regions were the main areas for prospecting, followed by the Republic of Kalmykia. For exploration around existing deposits "Atomredmetzoloto" (ARMZ), which is incorporated within the Russian State Corporation Rosatom continued exploration and resource estimation of uranium deposits, which are being prepared for development. ARMZ's uranium exploration budget was RUB 75 million in 2015 and decreased to RUB 52 million in 2016.

During 2015-2016, Dalur mining company continued exploration and pilot mining at Khokhlovskoe deposit in the Kurgan region.

The Priargunsky Mining-Chemical Production Association (PMCPA) focused exploration activities on additional resources identification on the flanks and at deep levels of operating deposits and on new high-grade deposits discovery within the Streltsovsk uranium district.

Overseas expenditures, made through the State Corporation Rosatom subsidiaries Uranium One Group and its Canadian branch Uranium One Inc., included expenditures for geologic exploration and research studies in Kazakhstan and Tanzania. Non-domestic exploration expenditures increased from USD 4.9 million reported for 2014 to USD 17.1 million in 2015, but expenditures declined again in 2016 to USD 6.1 million and dropped even further to USD 3.1 million in 2017. There were no overseas development expenditures reported from 2015 to 2017.

Exploration and development expenditures in Turkey increased from USD 4.8 million in 2014 to USD 6.8 million in 2015, which was followed by a sharp decline to USD 223 000 in 2016, and recovered somewhat to around USD 1.6 million in 2017. Public sector activities were focused on granitic, acidic igneous and sedimentary rocks in several areas. Private sector activities included work by Adur, a wholly owned subsidiary of Uranium Resources Inc., which conducted exploration and resource evaluation drilling at the Temrezli and Sefaatli uranium sites. In 2015 and 2016, an additional 592 tU were identified and added into the Manisa-Köprüba original estimates.

Exploration and development expenditures in Ukraine show a steady decline from 2014 expenditures of USD 1.3 million to USD 689 000 in 2015 and USD 484 000 in 2016. Preliminary data indicate an increase in 2017 to USD 529 000. During 2014, 2015 and 2016, SE Kirovgeology completed geological survey mapping at the scale 1:10 000 and 1:25 000 on all regions mentioned in the previous report. Starting in 2017, all exploration will be carried out around existing uranium mines.

Africa

In 2014, an IAEA Technical Cooperation project for the African region, "Supporting Sustainable Development of Uranium Resources", was initiated and the project continued through 2017. The main objective of the project was to increase and improve the current capacity in the member states for optimising production, implementation of good practices and overall effective management of the region's natural uranium endowment. Following up on this is a new IAEA Technical Cooperation project entitled, "Enhancing Regional Capabilities for a Sustainable Uranium Mining Industry (AFRA)", which began in 2018 and will continue into 2021.

In Algeria, no uranium prospecting or mine development work was carried out between January 2007 and January 2017.

Although the government of Botswana has not reported exploration expenditures, some activities have occurred in the country over the past several years. Exploration has focused on uranium occurrences in the Karoo Group, targeting similar deposits as those mined by Paladin Energy in Malawi (i.e. the sandstone-type Kayelekera deposit). Surficial calcrete-type mineralisation is a secondary target.

The Letlhakane uranium deposit has been the focus of detailed evaluation and technical work by A-Cap Resources Ltd. since 2006. A-Cap submitted a mining licence application on 18 August 2015, which was subsequently granted by the Botswana Department of Mines on 12 September 2016, and is valid for 22 years.

The Bakouma deposit in the Central African Republic was discovered in the 1960s. Areva suspended investment in the development of the Bakouma mine in 2011 because of current market conditions, even though inferred resources at Bakouma had been raised from 32 224 tU to 36 475 tU. There have been no reported activities involving uranium exploration since 2011.

The last time the Democratic Republic of Congo (DRC) reported exploration activities to the Red Book was in 1988 (at that time DRC was known as Zaire). Recently the IAEA is providing support for identification and evaluation of uranium and other radioactive resources in the DRC through the Technical Cooperation programme entitled, "Strengthening National Capacities for the Assessment of Uranium Resources and Other Radioactive Minerals and for the Regulation of Associated Mining Activities". The programme began in 2018 and will continue through 2019.

Egypt last reported exploration expenditures in 2008. It has had ongoing support for over a decade in developing uranium exploration and production capacities through several IAEA Technical Cooperation projects. The most recent projects include: "Supporting Technological Separation and Purification of Naturally Occurring Radionuclides and Rare Earth Elements from Minerals" and "Supporting a Feasibility Study for Uranium and Rare-Earth Element Recovery from Unconventional Resources", which began in 2016 and 2018, respectively.

Mauritania, does not report exploration and development expenditures. Recent activities by Aura Energy have advanced the Tiris (Reguibat) project and in May 2018 they announced an increase in inferred resources by 6% to 52 million lbs U_3O_8 (20 000 tU) as well as an increase in reasonably assured resources to 17 million lbs U_3O_8 (6 540 tU). Definitive feasibility studies are under way.

Support in the uranium production cycle has been provided through IAEA Technical Cooperation 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 environment management, 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.

Namibia reported expenditures of over USD 1 billion for 2014, principally related to development of the Husab mine and following that, expenditures dropped to USD 9.96 million in 2015 and continued to drop in 2016 to USD 8.3 million and again to USD 4.8 million in 2017. Current market conditions have contributed to a decline in the overall progression of projects, with some projects on hold until uranium prices increase. Despite poor market conditions, some projects have been making some progress, notably Deep Yellow Ltd. has announced further results on their Tumas 3 project and Bannerman Resources continues to work on their Etango deposit with a new resource estimate for this report.

Uranium exploration and development expenditures in Niger have been variable over the past few years as a result of security risks and market conditions. In the previous reporting period, expenditures were estimated by the NEA/IAEA. However, these were based on limited publicly available data, and because of difficulties in verification of these data, they are not reported for this edition.

Excavation of the first pit at the Imouraren project started in the middle of 2012. However, in May 2014, with current uranium prices not sufficient to allow profitable mining of the deposit, the government and Areva (today Orano) agreed to set up a joint strategic committee that will determine when mining should start.

GoviEx has developed an NI 43-101 Integrated Development Plan for five deposits (Marianne, Marilyn, Miriam, MSNE and Maryvonne). In November 2017, NI 43-101 compliant resources of the Madaouela Uranium Project were 42 615 tU measured and indicated resources and 10 654 tU inferred resources. In January 2016, GoviEx obtained two new exploration licences, Eralral and Agaliouk, in close proximity to the five other licences, Madaouela (I, II, III IV) and Anou Melle.

In 2017, Global Atomic Corporation (GAC) released a new NI 43-101 compliant report listing the indicated resources as 23 079 tU and inferred resources as 18 502 tU at the Dasa project. GAC also signed a Memorandum of Understanding with Orano (formerly Areva) on ore sales and co-operation. A 37 000 m drilling programme to further extend the reserves on Dasa project started in late January 2018.

The Karoo Group of the Morondava Basin in Madagascar has a similar geological setting to sandstone-hosted uranium deposits in the Karoo Group in other African countries including Botswana, Malawi, South Africa, Tanzania and Zambia. These similarities have prompted some interest in exploration for deposits of this type that may be of potential economic interest. A two-year IAEA Technical Cooperation project, "Establishing National Capabilities to Manage Uraniferous Mineral and Radioactive Ores in Line with Economic Development", began in 2016.

Since 2015, uranium exploration activities have been suspended in Malawi due to a moratorium imposed by the government of Malawi on applications and grants for all mining and exploration tenements, while it introduces a new cadastral system and a new minerals act. As a result, Paladin has suspended exploration activities in Malawi until there is more clarity on the provisions of the new mining code, and its exclusive prospecting licence (EPL) applications have been granted.

Industry exploration expenditures in Mali declined from USD 1.5 million in 2014 to USD 774 000 in 2015 and USD 387 000 in 2016. However, preliminary data for expenditures indicate an increase to over USD 1 million in 2017.

Uranium potential exists in three main regions. The best area covers 150 km^2 of the Falea-North Guinea Basin where the estimated potential is thought to be 5 000 tU. The 19 930 km^2 Kidal Project in north-eastern Mali is part of a large crystalline geological province known as L'Adrar Des Iforas. The sedimentary basin of the Gao region hosts the Samit deposit that contains an estimated potential of 200 tU.

As of 2015, seven uranium exploration permits had been granted to five exploration companies. However, because of the rebellion in the north-eastern part of the country, exploration activities are being undertaken only in the western part of the country.

South Africa did not report exploration and development expenditures for this edition. However, in general, exploration has decreased in recent years due to current market prices, which are influencing expenditures and investment in the uranium sector.

Exploration efforts have been focused on the uranium prospective Karoo Group sediments of southern Tanzania and to a lesser extent paleochannel associated calcrete and sandstone-hosted uranium targets within the Bahi catchment of central Tanzania. Exploration and development expenditures were not reported for this edition.

Major 2015-2016 activities at the Nyota deposit (Mkuju River Project) were focused on the additional investigations and resources amenability for ISL mining. In 2015, Mantra Resources obtained official approval and started a more advanced hydrogeology and two spot ISL test works. In late December 2016, Mantra Resources applied to the Ministry of Energy and Minerals of Tanzania for suspension of mining operations due to the unfavourable uranium market. In September 2017, the ministry had approved the amendment to the programme of mining operations.

Other companies have not reported uranium-related exploration activities since 2014.

Uganda does not report data to the Red Book, but this may change sometime in the future as the IAEA has recently supported Uganda's efforts to identify and evaluate their uranium resources through a Technical Cooperation programme entitled, "Strengthening the National Capacity for Uranium Exploration and Evaluation". The programme began in 2014 and ended in 2017. 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, exploration activities are focused on identifying sandstone-type deposits in the Karoo Group. Exploration expenditures were not reported for this edition.

In June 2016, GoviEx Uranium acquired Denison's Mutanga Project, and in October 2017 completed the acquisition of Africa Energy's Chirundu Project consolidating these adjacent projects.

Middle East, Central and Southern Asia

In India, government exploration expenditures increased slightly from USD 44 million reported in 2014 to USD 49.8 million in 2015, and USD 52.1 million in 2016 and USD 57.3 million in 2017. India is one of only two countries (the other is Argentina) that reported a sustained increase in exploration expenditures for this reporting period.

In recent years, exploration activities have been concentrated on the Proterozoic Cuddapah Basin, Andhra Pradesh; Mesoproterozoic Singhbhum Shear Zone, Jharkhand; Mesoproterozoic North Delhi Fold Belt, Rajasthan and Haryana; Cretaceous sedimentary basin, Meghalaya; Neoproterozoic Bhima Basin, Karnataka; and Dharmapuri Shear Zone in the Southern Granulite Terrain, Tamil Nadu. Other potential geological domains include the Kotri-Dongaragarh belt, Chhattisgarh; Lesser Himalayas, Uttarakhand; Chhotanagpur Gneiss Complex, Kaladgi Basin, Karnataka and Siwana Ring Complex, Rajasthan.

Iran reported a large decrease in exploration and development expenditures from USD 50.1 million in 2014 to USD 6.3 million in 2015. Expenditures then increased modestly to USD 17.3 million in 2016 and to USD 25.9 million in 2017.

At present, prospecting and general exploration is being undertaken in different parts of the country for granite-related, intrusive and sedimentary-type deposits, for example in the north-eastern, central and Kerman provinces.

Exploration expenditures by government and industry in Jordan decreased slightly from USD 3.8 million in 2014 to USD 3.7 million in 2015, and a further decrease was reported again in 2016 to USD 2.8 million. Expenditures increased to USD 3.5 million in 2017 according to the preliminary data. During 2015-2016, an exploration programme was carried out in the Central Jordan Area and included trenching, channel sampling, chemical analyses and JORC compliant resource estimation. In April 2016, the second JORC compliant report was prepared. Plans for 2017 included a trenching programme in the selected mining areas to upgrade the resource category leading prior to pre-feasibility studies.

Uranium production cycle activities in Jordan have been supported with several IAEA Technical Cooperation projects over the last few years including from 2014 to 2015 within the project entitled, "Supporting Extraction of Uranium from Local Ores", which was followed up with another project, “Extracting Uranium from Local Ores”, which started in 2016 and finished in 2017. The current project is, “Enhancing Capabilities in Extracting Uranium from Local Ores on a Pilot Scale Level”, which began in 2018 and is expected to continue into 2019.

In Kazakhstan, expenditures increased from USD 34.7 million in 2014 to USD 60.9 million in 2015; this was followed by a significant decrease in 2016 to USD 23.9 million and a further decrease to USD 18.5 million for 2017 (preliminary data). These figures are overall lower than the last reporting period when it was already noted that the expenditures reported were the lowest in the last several years since Kazakhstan started ramping up its exploration and development activities around the period 2007-2008. The decrease can be partially attributed to a decline in development activities.

During 2015 and 2016, exploration was undertaken at Uvanas, Moinkum, Inkai, and Budenovskoye in the Shu-Sarysu Uranium Province and in the Northern Kharasan and Zarechnoye deposits in the Syrdaria Uranium Province.

South-eastern Asia

Exploration expenditures in Indonesia were variable during this reporting period. In 2014, USD 100 000 was spent, and in 2015 it increased to USD 464 000, with expenditures then decreasing further to USD 194 000 in 2016 and to USD 180 000 in 2017.

In 2016, a regional geophysical survey, which included ground geomagnetic and gravity measurements, was conducted in the Mamuju area. Systematic exploration was conducted in the eastern part of Hulu Mamuju sector, which included geological and radiometric mapping, soil geochemistry, radon gas measurements and trenching. In other parts of the Mamuju area, systematic radiometric mapping was conducted in Orobatu sector.

In 2017, exploration focused on the Mamuju and Kalan areas.

The Philippines does not report exploration and development expenditures; although an IAEA Technical Cooperation project entitled, “Enhancing National Capacity for Extraction of Uranium, Rare Earth Elements and Other Useful Commodities from Phosphoric Acid”, aimed to increase activities related to uranium production was conducted from 2014 to 2015. Philippine Phosphate Fertilizer Corporation (Philphos) has an approximately 1 million tonnes/year capacity in the production of phosphoric acid. This phosphoric acid contains considerable concentrations of uranium and possibly other useful commodities. The project conducted a laboratory-scale study on the possibility of extracting uranium, REE and other resources from the phosphoric acid. A follow-up to this project began in 2018 – the IAEA Technical Cooperation project, ”Enhancing Bench-scale Simulation for the Development of Continuous Extraction Technology of Uranium and Other Valuable Elements from Phosphates: Phase II” – and is expected to continue to 2020.

East Asia

Total non-domestic development expenditures reported by China decreased during this reporting period from USD 759.2 million in 2014 to USD 518.9 million in 2015, and USD 368.7 million in 2016 and USD 180.5 million in 2017. However, note these expenditures are much higher than what has been reported for expenditures from 2010 to 2013. This is primarily due to the acquisition and subsequent ramp up in development associated with the Husab mine in Namibia, which was acquired in 2012 by Uranium Resources Co., Ltd, a subsidiary of China General Nuclear Power Group (CGNPC).

Non-domestic exploration expenditures increased over the reporting period from USD 3.8 million in 2014 to USD 7.7 million in 2015 and USD 9.3 million in 2016. A further increase to USD 11.1 million is noted for 2017. The increase in expenditures over the reporting period suggests a sustained commitment from China to exploration overseas.

Other than Husab, overseas expenditures occurred in several other uranium projects mainly in Kazakhstan, Namibia and Niger. China National Nuclear Corporation (CNNC) signed an agreement in 2014 to buy a 25% equity stake from Paladin Energy in its flagship Langer Heinrich uranium mine, and had acquired a total of 1 300 tU under the shareholder's equity by the end of 2016.

China domestic uranium exploration was relatively stable and consistent between 2015 and 2016. However, the budget decreased in comparison to 2013 and 2014; nonetheless; progress continued in uranium exploration. Expenditures decreased from USD 197 million in 2014 to USD 152 million in 2015 and declined further to USD 122 million in 2016. The expenditures continued to decline to USD 122 million in 2017. The majority is exploration-related and government expenditures account for 64-76% of the total.

The exploration, including regional uranium potential assessment and further works on previously discovered mineralisation and deposits in northern China has principally been focused on the Yili, Turpan-Hami, Junggar and Tarim Basins of the Xinjiang Autonomous Region; the Erdos, Erlian, Songliao, Badanjili and Bayingebi Basins of Inner Mongolia; the Caidamu Basin in Qinghai Province and the Jiuquan Basin in Gansu Province.

The exploration work in southern China is mainly directed at identifying metallogenic belts relating to volcanic-type and granite-type deposits, mostly focused in the Xiangshan and Taoshan uranium ore fields in Jiangxi Province; the Xiazhuang and Zhuguang uranium ore fields in Guangdong Province; the Miaoershan uranium ore field in the Guangxi Autonomous Region; the Dawan uranium ore field in Hunan Province; and the Ruoergai area of Sichuan Province. Potential deposits in carbonaceous siliceous pelitic rocks were the secondary targets in the most recent exploration campaigns.

Over the past several years, the IAEA has supported China through the Technical Cooperation 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 and the current project, "Studying Identification Technology and Technical Economic Evaluation of Typical Sandstone-hosted Concealed Uranium Deposits", which began in 2018.

Non-domestic government exploration expenditures from Japan varied over this reporting period from USD 5.5 million in 2014, to 3.9 million in 2015 followed by an increase to USD 5.1 million for 2016, and a decline to USD 2.2 million in 2017 (preliminary data). Japan-Canada Uranium Co. Ltd (JCU), which took over Japan Nuclear Cycle Development Institute's Canadian mining interests, is continuing exploration activities in Canada while Japan Oil, Gas and Metals National Corporation (JOGMEC) continues exploration activities in Australia, Canada, Namibia, Uzbekistan and elsewhere. Japanese private companies hold shares in companies developing uranium mines and with those operating mines in Australia, Canada, Kazakhstan and Niger.

Reported domestic exploration and development expenditures in Mongolia decreased over the past few years, a trend that continues from the last reporting period. Expenditures decreased from USD 15.4 million in 2014 to USD 7.8 million and USD 6.6 million in 2015 and 2016. Development expenditures are only reported for 2014. In 2017, expenditure estimates indicate an increase to USD 9.4 million. Currently, there are ten national and foreign investment companies carrying out exploration activities across the country.

In 2015-2016, the majority of the uranium prospecting was performed in south Mongolian basins, with the objective of identifying sandstone-type uranium mineralisation for ISL mining.

An IAEA Technical Cooperation project, Regional Asia Pacific, was initiated in 2016 and will continue through 2019. The project is entitled, "Conducting the Comprehensive Management and Recovery of Radioactive and Associated Mineral Resources", and is aimed at supporting member states in the Asia-Pacific region in relation to sustainable mining and production of minerals that have been found to be associated with radioactive minerals. Uranium production is one key aspect of economic development in the region, where efforts are being made to balance consumption and production. Though the region (especially China) is expected to grow significantly in terms of nuclear power production, a large part of the current and future uranium requirements will be met by imports. Even though potential for increasing domestic uranium production exists, several factors have prevented this growth from materialising. This project aims to address these challenges and opportunities by strengthening capacities and establishing centres of excellence in member states.

Pacific

Domestic exploration expenditures in Australia followed the same trend as the last reporting period and decreased steadily from USD 37.1 million in 2014 to USD 33.7 million in 2015, and then further to USD 29.2 million in 2016 and to USD 19.8 million in 2017 (preliminary data). During this period, uranium exploration tended to be around known resources in Western Australia, the Northern Territory, South Australia and Queensland.

In Western Australia, Vimy Resources announced that development work for the Mulga Rock Uranium project commenced on 10 March 2017. The Western Australian government granted approval to mine at Yeelirrie in January 2017 and Cameco announced that potential risks can be mitigated and the company is well-positioned to progress the project if market conditions improve. In 2015, Cameco secured environmental approval for the Kintyre project subject to conditions covering radiation, ground and surface water, terrestrial fauna and mine closure. Toro's expanded Wiluna project encompassing the Lake Maitland and Millipede resources was approved by the Western Australian government in January 2017 and the company is working to also finalise Commonwealth environmental approval for the expanded proposal.

Following the Western Australian state election in March 2017, the incoming government restated its policy banning new uranium mines. However, the newly elected Premier and Mines Minister confirmed the policy position prior to the election that those uranium projects with 'all necessary approvals in place for operation' would be permitted to proceed, pending further advice from the state Department of Mines and Petroleum.

In South Australia, plans for a large expansion at Olympic Dam have been scaled back, although BHP Billiton (BHP) plans to gradually increase production capacity and commence new underground operations in the "Southern Mining Area" of the resource in 2018, under existing approvals. The sandstone-hosted Honeymoon deposit is currently in care and maintenance. Additional resources were identified at Jason's deposit, which is located in the northern end of the Yarramba paleochannel, which hosts the Honeymoon deposit. Boss Resources proposes to undertake test leach processing on the deposit.

In New South Wales for 26 years uranium exploration had been banned, until the then state government overturned the ban in 2012. A ban on uranium mining and the construction or operation of nuclear reactors to produce electricity remains in place. Six companies were invited by the government to apply for uranium exploration licences. One company submitted an application to explore for uranium north of the town of Broken Hill, but subsequently withdrew the application in April 2016.

Through 2015 and 2016, several Australian-listed mineral companies undertook exploration activities for uranium in Canada, Kyrgyzstan, Namibia, Malawi, Peru and Tanzania. However, non-domestic expenditures were not reported to the Red Book.

Uranium production

In 2014, uranium was produced in 21 different countries; the same number as in the last reporting period. In 2015 this number decreased to 20 countries as the Kayelekera mine in Malawi was placed on care and maintenance and in 2016 production ceased in Romania, bringing the total countries with producing mines to 19, with global uranium production reaching 62 071 tU in 2016 and 59 342 tU in 2017. Three countries, Germany, Hungary and France, continued producing uranium as the result of mine remediation activities. Kazakhstan's growth in production continued, but at a much slower pace, and it remains the world's largest producer reporting production of 23 806 tU in 2015 and 24 689 tU in 2016. Production in 2016 from Kazakhstan totals more than the combined production reported in 2016 from both Canada and Australia, the second and third largest producers of uranium, respectively. Table 1.18 summarises major changes in uranium production in a number of countries and Table 1.19 shows production in all producing countries from pre-2014 to 1 January 2018. Figure 1.5 shows 2016 production shares, and Figure 1.6 illustrates the evolution of production shares from 2010 to 2017.

Table 1.18. **Production in selected countries and reasons for major changes**

(tonnes U)

Country	Production 2014	Production 2016	Difference	Reason for changes in production
Australia	5 000	6 313	1 313	Production from stockpiled ore at Ranger doubled from 2014. Four Mile ISL project started production in 2014 and continued to ramp up to full production capacity.
Brazil	55	0	-55	Open-pit portion of Cachoeira deposit mined out in 2014; licensing of underground operation ongoing.
Canada	9 136	14 039	4 903	Production gain from the continued ramp up of Cigar Lake underground mine, which started production in 2014. Some of the gain was offset by suspension of production at Rabbit Lake in mid-2016 due to depressed uranium market.
China (People's Rep. of)	1 550	1 650	100	Steps taken to improve production efficiency and new ISL operations commissioned.
Kazakhstan	22 781	24 689	1 908	Production gain from the continued ramp up of some ISL mines (e.g. Budenovskoe site 1, 3, 4 and Kharasan site 1).
Namibia	3 246	3 593	347	Production increase at Rössing with higher ore grades and improved recovery rates, which was offset by Langer Heinrich production decline due to lower ore grades and recovery rates. Husab mine started officially production in December 2016.
Niger	4 223	3 477	-746	Decrease of production at Somaïr open pit and Cominak undergound mine as uranium prices remain depressed; Azelik mine was shut down in 2015 as a result of poor economics.
Ukraine	954	808	-146	Production decline at old operating mines as a result of shutdowns and technical issues and lack of investment at the new mine (Novokonstantinovskiy).
United States	1 889	979	-910	Production decline with low uranium prices and limited purchases by US nuclear power plants. In the second quarter of 2016, Cameco made the decision to curtail production and defer all wellfield development at its US operations.

Table 1.19. **Historical uranium production**

(tonnes U)

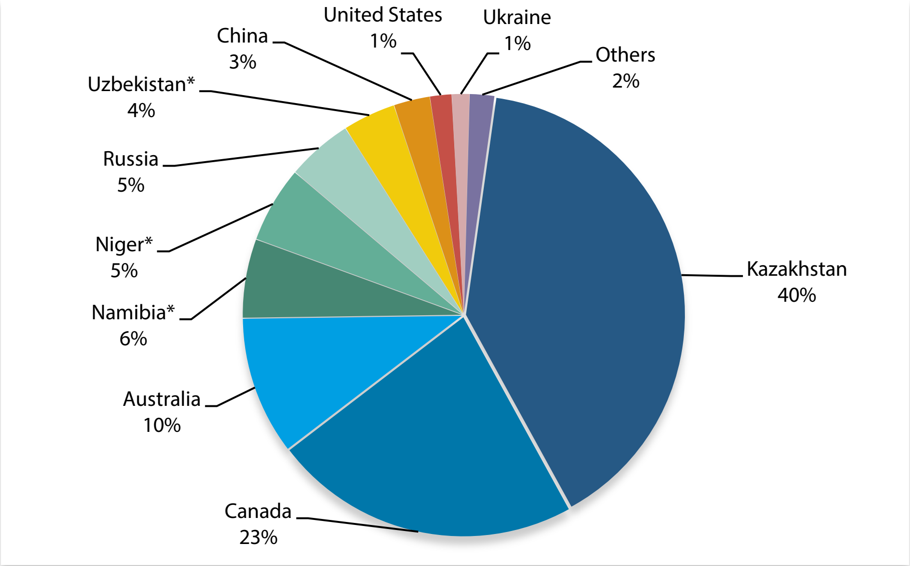
Country	Pre-2014	2014	2015	2016	Total to 2017	2017*
Argentina	2 582	0	0	0	2 582	0
Australia	189 671	5 000	5 636	6 313	206 620	5 800
Belgium	686	0	0	0	686	0
Brazil	4 117	55	44	0	4 216	60
Bulgaria	16 364	0	0	0	16 364	0
Canada[(a)]	474 821	9 136	13 325	14 039	511 321	13 130
China (People's Rep. of)	38 299*	1 550	1 600	1 650	43 099	1 700
Congo, Dem. Rep. of	25 600*	0	0	0	25 600*	0
Czech Republic[(b)]	111 611	154	152	138	112 055	70
Finland	30	0	0	0	30	0
France[(d)]	80 968	3[(c)]	2[(c)]	3[(c)]	80 976	2[(c)]
Gabon	25 403	0	0	0	25 403	0
Germany[(e)]	219 653	33[(c)]	0	45[(c)]	219 731	40[(c)]
Hungary	21 065	2[(c)]	4[(c)]	4[(c)]	21 075	5[(c)]
India*	11 013*	385*	385*	385*	12 258*	400
Iran, Islamic Rep of	55	11	10	8	84	20
Japan	84	0	0	0	84	0
Kazakhstan	221 926	22 781	23 806	24 689	293 202	23 400
Madagascar	785	0	0	0	785	0
Malawi	3 848	369*	0	0	4 217	0
Mexico	49	0	0	0	49	0
Mongolia	535	0	0	0	535	0
Namibia	117 173	3 246	2 992	3 593	127 004	4 000
Niger	127 960	4 223*	4 116*	3 477*	139 776	3 485
Pakistan*	1 394*	45*	45*	45*	1 529	45
Poland	650	0	0	0	650	0
Portugal	3 720	0	0	0	3 720	0
Romania	18 819*	80*	75*	0	19 049	0
Russia	155 853	2 991	3 055	3 005	164 904	2 900
Slovak Republic	211	0	0	0	211	0
Slovenia	382	0	0	0	382	0
South Africa	158 944	566	393*	490*	160 393	310
Spain	5 028	0	0	0	5 028	0
Sweden	200	0	0	0	200	0
Ukraine	128 850	954	824	808	131 436	615
United States[(f)]	371 909	1 889	1 427	979	376 204	960
USSR[(g)]	102 886	0	0	0	102 886	0
Uzbekistan	125 191*	2 700*	2 400*	2 400*	132 691*	2 400
Zambia	86	0	0	0	86	0
OECD	1 480 738	16 217	20 546	21 521	1 539 022	20 007
Total	2 768 421	56 173	60 291	62 071	2 946 956	59 342

Note: For pre-2010, other sources cite 6 156 tU for Spain, 91 tU for Sweden.

* NEA/IAEA estimate. (a) Includes production from refinery wastes; 14 tU in 2015 and 17 tU in 2016. (b) Includes 102 241 tU produced in the former Czechoslovakia and Czech and Slovak Federative Republic from 1946 through the end of 1992. (c) Production from mine rehabilitation efforts only. (d) Pre-2014 total updated after review of historic records. (e) Production includes 213 380 tU produced in the former German Democratic Republic from 1946 through the end of 1989. (f) Production in 2012 and 2013 updated after review of historic records. (g) Includes production in former Soviet Socialist Republics of Estonia, Kyrgyzstan, Tajikistan and partly of Uzbekistan and Kazakhstan, which shipped concentrates for processing to Kyrgystan and Tajikistan.

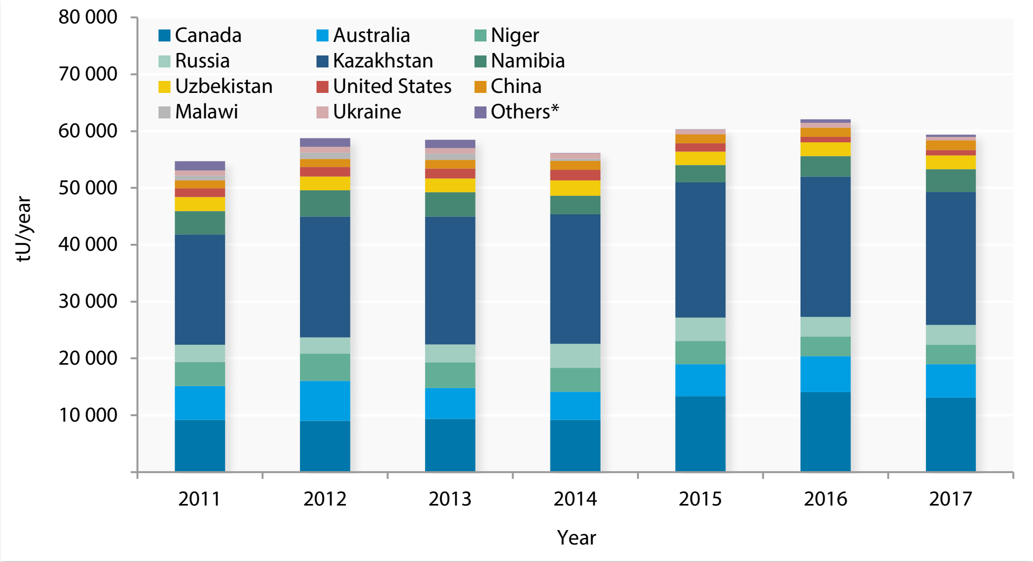
Niger and Namibia continue to alternate between being the 4th and 5th largest producers. Niger produced 4 116 tU in 2015, which is more than Namibia at 2 992 tU. However, in 2016, Namibia increased production to 3 593 tU while Niger reduced production to 3 477 tU. The top five producing countries (Kazakhstan, Canada, Australia, Niger and Namibia) retained their dominance, accounting for 84% of world production in 2016. Ten countries: Kazakhstan (39.7%), Canada (22.6%), Australia (10.1%), Namibia (5.7%), Niger (5.6%), Russia (4.8%), Uzbekistan (3.9%), China (2.7%), the United States (1.6%), and Ukraine (1.3%) accounted for about 98% of world production in 2016 (see Figure 1.5).

Figure 1.5. Uranium production in 2016: 62 071 tU



* NEA/IAEA estimate.

Figure 1.6. Recent world uranium production



* "Others" includes the remaining producers (see Table 1.21).

Overall, world uranium production increased 7.3% from 56 173 tU in 2014 to 60 291 tU in 2015 and increased again in 2016 to 62 071 tU. The increases are principally the result of increased production in Australia, Canada, and Kazakhstan with lesser contributions from China and Namibia (see Table 1.18). Within OECD countries, production increased from 16 217 tU in 2014 to 21 521 tU in 2016, primarily due to increased production in Australia and Canada. World production in 2017 decreased and amounted to just over 59 000 tU. Further decreases in world production are expected for 2018 because of the continued depressed uranium market. In Canada, mining at the McArthur River mine and milling at Key Lake was suspended at the end of January 2018 and recent announcements indicate the suspension is indefinite. The world's largest producer, Kazakhstan, also announced plans to reduce production by a total of 20% over the next three years. The Langer Heinrich mine in Namibia was placed on care and maintenance at the end of May 2018. Further reductions may come if depressed market conditions continue to put pressure on uranium producers.

Present status of uranium production

North American production amounted to 24% (15 018 tU) of world production in 2016, an increase of 3 993 tU since 2014. The increases are a result of the ramp up of production at the Cigar Lake mine in Canada, which began production in 2014. In contrast, production in the United States decreased over the period from 2014 to 2016.

Canada lost its standing as the world's largest producer in 2009 due to production increases in Kazakhstan, but it remains the dominant North American producer and the second-largest producer in the world. Production at the McArthur River mine, the world's largest high-grade uranium mine, was 7 292 tU and 6 893 tU in 2015 and 2016, respectively.

The Key Lake mill maintained its standing as the world's largest uranium production centre by producing 7 341 tU and 6 928 tU in 2015 and 2016, respectively. These totals represent a combination of high-grade McArthur River ore slurry and stockpiled, mineralised Key Lake special waste rock that is used to blend down high-grade McArthur River ore to produce a mill feed grade of about 5% U. In addition, uranium refinery wastes from Ontario were processed at Key Lake, producing 14 tU and 17 tU in 2015 and 2016, respectively.

The Rabbit Lake production centre, wholly owned and operated by Cameco, produced 1 621 tU and 428 tU in 2015 and 2016, respectively. Production at Rabbit Lake was suspended in mid-2016 due to low uranium prices and the facility was placed in care and maintenance. Exploratory drilling at the Eagle Point mine during the last several years has increased identified resources to 27 400 tU at an average grade of 0.58% U.

Cigar Lake, with identified resources of 121 300 tU at an average grade of 14.5% U, is the world's second-largest high-grade uranium deposit. The McClean Lake mill produced 4 345 tU and 6 666 tU from Cigar Lake ore in 2015 and 2016, respectively.

In the United States, uranium mines produced 979 tU in 2016, 31% less than in 2015 and 48% less than in 2014. Production in 2016 was from ten mines: two underground mines and eight ISR mines. The main difference since the last production period is the decrease in production due to declining uranium prices and in the second quarter of 2016, Cameco Corp announced the decision to curtail production and defer all wellfield development at its United States operations.

At the end of 2016, one uranium mill (White Mesa in Utah) was operating with a capacity of 1 538 tonnes of ore per day. Two mills (Shootaring Canyon in Utah and Sweetwater in Wyoming) are on standby status with a combined capacity of 2 884 tonnes of ore per day. Both the Sweetwater and Shootaring Canyon mills have been on standby status since the early 1980s and will require rehabilitation.

At the end of 2016, six US uranium ISL plants were operating with an approximate combined capacity of 4 700 tU per year (Crow Butte Operation in Nebraska and Lost Creek Project, Nichols Ranch ISL Project, Ross Central Processing Plant, Smith Ranch-Highland Operation and Willow Creek Project in Wyoming).

The ten-year contract between Centrus Energy Corporation and Techsnabexport (TENEX) to supply commercial-origin, Russian low-enriched uranium will replace some of the material previously provided by the Megatons-to-Megawatts programme, which ended in 2013. Deliveries under this contract began in 2013 and, in 2015, the contract term was extended through 2026.

In January 2018, the two main uranium producers in the United States (Energy Fuels Inc. and Ur-Energy) filed a petition with the US Department of Commerce requesting an investigation into the effects of uranium imports on US National security. As part of the inquiry and review it was requested that imports should be limited and that 25% of the US nuclear market be reserved for domestic uranium production. A recommendation was made in 2018 and an investigation by the US Department of Commerce was under way when this volume went to press.

Brazil was the only producing country in South America, with production continuing to decline from the last reporting period with only 55 tU produced in 2014 and 44 tU in 2015 and no production reported for 2016 at the country's only production centre, Lagoa Real, Caetité. The decrease in production over the reporting period was a result of the open-pit portion of the Cachoeira deposit being mined out by 2014. Expansion of this facility to the underground part is progressing but has been delayed somewhat to around 2019 with production planned for 2021. Expansion of the mill facility to 670 tU/yr involves replacement of the current heap leaching process by conventional agitated leaching. The Engenho deposit, located 2 km from the currently mined Cachoeira deposit, is under study and is expected to provide additional feed to the Caetité mill after 2018. The phosphate/uranium project of Santa Quitéria, an INB – Brazilian fertiliser producer partnership agreement, remains under development. In 2012, the project applied for a construction licence and the projected start of operation is now 2023. Work continues in Argentina to restart production at the Sierra Pintada mine of the San Rafael complex, but regulatory and environmental issues remain to be addressed. A strategic plan recently submitted by the National Atomic Energy Commission (CNEA) to national authorities includes development of a new production centre in the province of Chubut near the Cerro Solo deposit, with first production unknown at this time.

Primary uranium production in 2016 within the European Union (EU) was from only one country, the Czech Republic. A further three countries, France, Germany and Hungary, produced minor amounts of uranium from mine remediation activities only (a very small portion of Czech Republic production results from similar activities). Romania reported production only for 2014 and 2015 and by 2016 the mine had stopped production.

Total reported EU production in 2016 was 190 tU, a decrease of 30% from the 272 tU reported for 2014. The decline is primarily a result of decreases in production from the Czech Republic at its main production centre, Dolní Rozínka, as resources are depleted and being recovered from greater depths. In December 2016, Rozná underground mine was closed.

Output from non-EU countries in Europe in 2016 amounted to 3 813 tU, which is a decrease compared to 2014, although production increased in Russia by a very small amount, 14 tU; production in Ukraine decreased by 146 tU.

In 2016, uranium production in Russia amounted to 3 005 tU, of which 1 873 tU were produced using conventional underground mining method and 1 132 tU produced using in situ leach method. Since 2014 uranium production by underground method decreased by 5% and by ISL method increased by 11%.

Uranium production in Russia is carried out by three mining centres owned by ARMZ Uranium Holding Co.: the PMCPA, Dalur mine and Khiagda mine. The PMCPA remains the key uranium mining centre in Russia. In Ukraine, there are three production centres: Ingulskiy mine, Smolinskiy mine and the Novokonstantinovskiy mine, which are all underground mining operations in metasomatite deposits. A fourth underground mine, the Severinsky mine (metasomatite-type deposit), is planned for 2020s and an ISL facility, the Safonovski mine (sandstone-type deposit), is also planned by 2020.

The three producing countries in Africa, Namibia, Niger and South Africa, were joined by Malawi in 2009 when production commenced at the Kayelekera mine. However, the addition of Malawi was short-lived as the Kayalakera mine was shut down in 2014 and is now on care and maintenance. African production decreased from 8 238 tU in 2014 to 7 560 tU in 2016. Although the Husab mine in Namibia began production during this period, this was offset by the closure of the Kayelekera mine in Malawi and declining production in Niger. Overall reduced production during this reporting period is a result of poor uranium market conditions and further reductions in 2017 and 2018 will come as a result of reduced production in Niger and the recent closure of the Langer Heinrich mine in Namibia.

Possible production in Botswana, Tanzania and Zambia, and several projects under investigation in South Africa, could contribute to regional production increases in the future should market conditions and security conditions improve. However, it should be noted that this is seen only as a possibility in the long term, i.e. at least beyond 2030.

Increases in production in the Middle East, Central and South Asia continued into 2016 with a total of 29 177 tU produced. This was driven mainly by Kazakhstan, where production increased from 22 781 tU in 2014 to 23 806 tU in 2015, and 24 689 tU in 2016. It is now by far the largest uranium-producing country in the world, producing 40% of the world's total in 2016. Uranium was mined at the Kanzhugan, Moinkum, Akdala, Uvanas, Mynkuduk, Inkai, Budenovskoye, North and South Karamurun, Irkol, Zarechnoye, Semizbay, Northern Kharasan deposits. All uranium deposits were mined by in situ leaching acid technique. As of 1 January 2017, the total capacity of uranium production centres in Kazakhstan was 25 000 tU/yr. India and Pakistan do not report production figures, but their combined total is estimated to be about 430 tU in 2014, only a minor increase since the estimated 396 tU in 2014. Uzbekistan did not report production for this edition, and the NEA/IAEA estimates that production decreased somewhat to 2 400 tU in 2016. Iran continues to produce small amounts of uranium from its Gachin deposit and plans to commence production from its Saghand facility in the future. At present the development of mines No. 1 and 2 is being carried out in the Saghand ore field. Jordan continues to develop resources with the aim of producing uranium, but there are currently no firm plans for production.

China, the only producing country in East Asia, reported a small but steady increase in production from 1 550 tU in 2014 to 1 600 tU in 2015 and 1 650 tU in 2016 with six production centres in operation. Production is spread between granite-hosted, sandstone-hosted and volcanic-hosted deposits, with granite-related sources slightly higher than the others. Between 2015 and 2016, as a result of sustained depressed uranium prices, the Chinese companies engaged in the uranium industry adopted a series of measures for sustainability. This included closure or provisional suspension of several underground uranium mines with high production costs. In addition, ISL production centres in northern China were built or expanded, and environmentally friendly mines of considerable size were constructed in Xinjiang and Inner Mongolia. As a result, the proportion of production from underground uranium mines decreased significantly, while production from ISL uranium mines increased and dominated the total production.

Australia is the only producing country in the Pacific region. Production increased steadily from 5 000 tU in 2014 to 5 636 tU in 2015, and to 6 313 tU in 2016. Increases can be attributed to start-up of the Four Mile mine in 2014 with uranium processed at the Beverley plant and continued ramp up of production during this reporting period. Additional production increases came from doubling of processing of the stockpiled ore at Ranger.

Ownership

Table 1.20 shows the ownership of uranium production in 2016 in the 19 producing countries. Domestic mining companies controlled about 55% of 2016 production, which is only slightly lower than the 58.6% reported for 2014. Domestic government participation decreased from 43% in 2014 to 37% in 2016. Non-domestic mining companies controlled about the same amount of production as in the last report, that is, around 43%. However, for this reporting period, the percentage of control (i.e. government vs. private) in this category, for both Australia and the United States, is not known as this data was not reported.

Table 1.20. **Ownership of uranium production based on 2016 output**

Country	Domestic mining companies				Non-domestic mining companies				Total tU
	Government-owned		Privately owned		Government-owned		Privately owned		
	tU	%	tU	%	tU	%	tU	%	
Australia	0	0	2 298	36.4	NC	NC	4 015	63.6	6 313
Brazil	0	0	0	0	0	0	0	0	0
Canada	0	0	8 634	61.5	4 547	32.4	858	6.1	14 039
China (People's Rep. of)	1 650	100	0	0	0	0	0	0	1 650
Czech Republic	138	100	0	0	0	0	0	0	138
France	3	100	0	0	0	0	0	0	3
Germany	45	100	0	0	0	0	0	0	45
Hungary	4	100	0	0	0	0	0	0	4
India*	385	100	0	0	0	0	0	0	385
Iran, Islamic Rep. of	8	100	0	0	0	0	0	0	8
Kazakhstan	13 175	53	0	0	7 310	30	4 204	17	24 689
Namibia*	43	1.2	0	0	362	10.07	3 188	88.73	3 593
Niger*	1 196	34.4	0	0	0	0	2 281	65.6	3 477
Pakistan*	45	100	0	0	0	0	0	0	45
Russia	3 005	100	0	0	0	0	0	0	3 005
South Africa*	0	0	490	100	0	0	0	0	490
Ukraine	808	100	0	0	0	0	0	0	808
United States	0	0	NC	NC	0	0	NC	NC	979
Uzbekistan*	2 400	100	0	0	0	0	0	0	2 400
Total	22 905	37	11 422	18	12 219	20	14 546	23	62 071

* Secretariat estimate.

NC – Data not available for reasons of confidentiality.

Employment

Although the data are incomplete, Table 1.21 shows that employment levels at existing uranium production centres declined by 16% from 2014 to 2016 However, if future production expansions and restarting of mines currently on care in maintenance in countries such as Australia, Canada, India, Kazakhstan, Namibia, Niger, Malawi and Russia are successfully completed, employment will increase in the longer term. Table 1.22 provides employment directly related to uranium production (excluding head office, R&D, pre-development activities, etc.), in selected countries.

Table 1.21. **Employment in existing production centres of listed countries**
(person-years)

Country	2010	2011	2012	2013	2014	2015	2016	2017 (preliminary)
Argentina	133	128*	78	78	85	82	65	58
Australia[(a)]	4 813	4 888	5 574	5 620	5 805	4 481	3 630	4 488
Brazil	620	620	620	620	620	590	680	680
Canada[(b)]	2 399	2 060	2 109	2 148	2 874	2 676	2 246	2 000
China (People's Rep. of)	7 560	7 650	7 560	7 650	7 660	7 670	6 750	5 950
Czech Republic	2 164	2 118	2 126	2 110	2 072	2 040	1 955	1 455
Germany[(c)]	1 489	1 452	1 372	1 204	1 147	1 062	1 043	1 031
India	4 917	4 917	4 962	4 962	4 689	4 725	4 741	5 000
Iran, Islamic Rep of	325	340	350	500	500	350	340	290
Kazakhstan	8 828	8 550	9 760	7 682	7 728	8 042	8 222	8 213
Malawi	1 036	766	759	NA	NA	NA	NA	NA
Namibia*	2 554	1 886	2 786	NA	5 101	8 107[(d)]	4 331	4 881
Niger	2 915	2 915	2 915	NA	NA	NA	3 935	3 843
Romania*	2 000	2 000	2 000	2 000	2 000	NA	NA	NA
Russia	8 989	9 028	9 526	10 164	8 790	6 857	6 077	5 788
South Africa	4 825	4 320	237	1 742	4 141	3 815	NA	NA
Spain[(c)]	25	24	23	23	23	21	76	78
Ukraine	4 310	4 470	4 350	4 480	4 500	4 555	4 426	4 450
United States	948	1 089	1 017	957	626	509	462	NA
Uzbekistan	8 860	NA	NA	NA	NA	NA	NA	NA
Total	69 710	59 221	58 124	51 940	58 361	55 582	48 979	48 205

See notes below in Table 1.22.

Table 1.22. **Employment directly related to uranium production**

Country	2014		2015		2016	
	Production employment (person-years)	Production (tU)	Production employment (person-years)	Production (tU)	Production employment (person-years)	Production (tU)
Australia[(a)]	3 872	5 000	3 121	5 636	2 499	6 313
Brazil	340	55	310	44	310	0
Canada[(b)]	1 829	9 136	1 867	13 325	1 616	14 039
China (People's Rep. of)	6 960	1 550	6 970	1 600	5 880	1 650
Czech Republic	1 105	154	1 059	152	985	138
Iran, Islamic Rep of	135	11	110	10	112	8
Kazakhstan	6 915	22 781	7 179	23 806	7 394	24 689
Namibia*	5 101	3 246	8 107[(d)]	2 992	4 331	3 593
Niger*	NA	4 223	NA	4 116	1 800	3 477
Russia	6 126	2 991	5 395	3 055	4 956	3 005
South Africa	406	566	NA	393*	NA	490*
Ukraine	1 610	954	1 600	824	1 585	808
United States	540	1 889	451	1 427	424	979

* 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) Employment related to decommissioning and rehabilitation. (d) The high value for 2015 is due to the Husab mine construction period.

Production methods

Historically, uranium production has been produced mainly using open-pit and underground mining techniques processed by conventional uranium milling. 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 called 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 once 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 or "material sources" for 2013 through 2017 is shown in Table 1.23. The category "other methods" includes recovery of uranium through treatment of mine waters as part of reclamation and decommissioning, and more recently production from refinery wastes in Canada was included.

Table 1.23. **Percentage distribution of world production by production method**

Production method	2013	2014	2015	2016	2017 (preliminary)
Open-pit mining	17.6	13.9	12.6	12.9	13.7
Underground mining	28.6	27.3	32.2	30.8	31.9
ISL	44.5	51.0	48.7	49.7	48.1
In-place leaching	7.1	-	-	-	-
Co-product/by-product	1.5	7.2	6.0	6.1	5.8
Heap leaching	0.7	0.5	0.4	0.4	0.5
Other[(a)]	-	0.1	0.0	0.1	0.1
Total	100.0	100.0	100.0	100.0	100.0

(a) Includes production from refinery wastes in Canada; 14 tU in 2015 and 17 tU in 2016.

As can be seen in Table 1.23, ISL production has continued to dominate uranium production, largely because of the rapid growth of production in Kazakhstan along with other ISL projects in Australia, China, Russia and Uzbekistan. Note that not all countries report production by method, and for this reporting period, the United States, where most of production is by ISL, this information is not available. World uranium production by ISL amounted to 49.7% of the total production in 2016 and a similar percentage of about 48.1% was estimated for 2017. The co-product/by-product method could increase in importance in coming years, if the planned expansion of Olympic Dam proceeds.

Projected production capabilities

To assist in developing projections of future uranium availability, member countries were asked to provide projections of *production capability* through 2035. Table 1.24 shows the projections 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 through 2035 for all countries that either are currently producing uranium or have plans and the potential to do so in the future. Note that both the A-II and B-II scenarios are supported by currently identified local RAR and IR in the <USD 130/kgU category, with the exception of Pakistan.

Table 1.24. **World uranium production capability to 2035**

(in tonnes U/year, from RAR and inferred resources recoverable at costs up to USD 130/kgU)

Country	2016	2017*	2020***		2025***		2030***		2035***	
	Production	Production	A-II	B-II	A-II	B-II	A-II	B-II	A-II	B-II
Argentina*	0	0	0	0	0	0	0	200	0	200
Australia	6 313	5 800	6 000	7 000	6 000	7 000	6 000	8 000	6 000	10 000
Brazil	0	60	300	300	300	1 600	300*	1 600	300*	1 600
Botswana*	0	0	0	0	0	0	0	0	0	1 350
Canada[(a)]	14 039	13 130	12 330	18 700	12 330	18 850	12 330	18 850	12 330	18 850
China (People's Rep. of)*	1 650	1 700	1 700	1 700	1 700	1 700	1 700	1 700	1 700	1 800
Czech Republic	138	70	50	50	50	50	50	50	30	30
Finland**	0	0	0	250	0	250	0	250	0	250
Greenland**	0	0	0	0	0	425	0	425	0	425
India*	385	400	400	600	600	800	800	800	800	1 200
Iran, Islamic Republic of	8	20	50	80	70*	80*	70*	80*	70*	80*
Kazakhstan	24 689	23 400	27 000	28 000	27 000	28 000	22 000	24 000	14 000	16 000
Mauritania*	0	0	0	0	0	400	0	400	0	400
Mongolia*	0	0	0	0	0	0	150	150	150	800
Namibia*	3 593	4 000	5 500	5 500	7 200	7 200	7 200	7 200	7 200	9 800
Niger*	3 477	3 485	3 500	3 500	5 000	5 000	5 000	5 000	5 000	6 800
Pakistan*	45	45	45	45	45	45	45	45	45	45
Spain*	0	0	0	0	0	0	0	0	0	1 690
Russia	3 005	2 900	2 780	2 780	1 660	3 960	1 890	8 490	1 800	6 800
South Africa*	490	310	500	500	500	500	500	500	500	500
Tanzania*	0	0	0	0	0	0	0	2 000	0	3 000
Ukraine	808	615	2 480	2 480	2 000	2 000*	1 700	2 000*	1 700*	2 000*
United States*	979	960	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Uzbekistan*	2 400	2 400	2 700	2 700	3 000	3 000	3 000	3 000	3 000	3 000
Zambia*	0	0	0	0	0	0	0	0	0	1 570
Total	62 071[(b)]	59 342[(b)]	67 335	76 185	67 955	81 360	64 735	86 740	56 625	90 690

A-II = Production capability of existing and committed centres supported by RAR and inferred resources recoverable at <USD 130/kgU. B-II = Production capability of existing, committed, planned and prospective centres supported by RAR and inferred resources recoverable at <USD 130/kgU. * NEA/IAEA estimate. ** By-product production. *** Production capability projections. (a) The projections do not take into account the recent announcements concerning the production suspension at McArthur/Key Lake. (b) Total Includes also production from mine rehabilitation.

Several current or potential uranium-producing countries including Argentina, Botswana, China, India, Mauritania, Mongolia, Namibia, Niger, Pakistan, Spain, South Africa, Tanzania, the United States, Uzbekistan and Zambia did not report, or only partially reported, projected production capabilities to 2035. In some countries, the NEA/IAEA suggested updates to the submitted data in order to take into account recent and important changes since the cut-off date for submission of data. As a result, estimates of production capability for many countries were developed by the NEA/IAEA using data submitted for past Red Books, company reports and other public data.

The reported projected production capacities for existing and committed production centres in the A-II category for 2017 was 70 179 tU, while the NEA/IAEA Secretariat estimates that the actual production for 2017 was 59 342 tU, which is 85% of the projections. For comparison, the projected 2015 production capability was estimated initially as 67 240 tU. However, actual 2015 production amounted to 60 291 tU, or about 90% of stated production capability. In 2013, production amounted to 54 740 tU, or about 80% of stated production capability, 75% in 2011, 76% in 2007, 84% in 2005 and 75% in 2003, demonstrating that full capability is rarely, if ever, achieved. In 2017 production amounted to 84% of total B-II capability, 90% in 2015, 80% in 2013 and 73% in 2011, 2010 and 2007, 81% in 2005 and 74% in 2003.

Since 2003, expansion in production capability was being driven by generally higher uranium prices, and production had correspondingly increased during the same period, although not as rapidly as the projected production capability. Despite the sustained depressed uranium market over the last several years, production increased over this reporting period; mainly due to the start-up of the large Cigar Lake mine in Canada and continued expansion of production in Kazakhstan and to a lesser extent some of the overall increases came from Australia and the starting of Husab mine in Namibia. That production increased even during these poor market conditions can be attributed to the long planning times and investment required to bring new production into the market and the time it takes to respond to changing demand and market conditions. Thus, these new production centres are responding to the increased demand and concurrent rise in uranium market prices from over a decade ago. However, this is changing as producers are now adjusting to the sustained downturn in the uranium market. In 2018, some producers have already made announcements regarding shutdowns and scaling back in operations. Additionally, the growth in production capacity has decreased during this reporting period. In addition, it should be noted that turning stated production capability into production takes time, expertise and investment, and can be confounded by unexpected geopolitical events, legal issues and technical challenges.

There continues to be a delay in the expansion of the Olympic Dam project in Australia, first announced in August 2012, there is still no recent update, which makes the timing of the additional production from this project uncertain. In addition, several projects have been put on hold in Australia (Honeymoon), in Malawi (Kayelekera) and in Namibia (Trekkopje mine). In the near-term production capability will decline and in the short to medium term, expansion will come mainly from development of ISL projects in Kazakhstan and to a lesser extent in China, production from the Cigar Lake mine in Canada, and production from the Husab mine in Namibia.

The current report shows that projections of production capacity have decreased when compared to the projections made for the same year in the last Red Book 2016, as developments are being brought in line with the slowdown in nuclear generation capacity growth since the Fukushima Daiichi accident (see Table 1.24). Comparing future capabilities, projections to 2020 are 5-6% lower than what was reported in 2016 for A-II and B-II categories, respectively and in 2035 the difference is 13-15% lower for A-II and B-II categories, respectively. Comparing the values reported for 2017 to 2013, there are even larger differences, which can be expected because of the continuous updating of plans and responses to the market conditions and the amount of time it takes to respond to these changes. In the longer term, growth prospects for nuclear power will also be affected, but to what degree it is not certain as projections of this nature over the long term are subject to numerous factors. Due to adjustments to recent events, and the depressed uranium market, the revised figures on production capability to 2035 have decreased overall from the projections in the 2016 Red Book.

As currently projected, production capability of existing and committed production centres is expected to reach over 67 335 tU/yr in 2020, increasing only 1% to about 67 955 tU in 2025, then decreasing to 64 735 tU in 2030 and decreasing again to 56 625 tU in 2035. Total potential production capability (including planned and prospective production centres, category B-II) is only expected to rise to 81 360 tU/yr by 2025, followed by a slow increase to around 86 740 tU/yr and 90 690 tU/yr in 2030 and 2035, respectively. The current projections for B-II category indicate a steady growth in production capability with an increase of 19% from 2020 to 2035. For comparison, the predicted rate of growth over the same period was 31% in the 2016 edition of the Red Book.

Recent, committed mines and expansions

There was limited new production started during this reporting period. Production in Canada at the world's highest-grade uranium mine, Cigar Lake, commenced in 2014 with the first commercial production in 2015. In Kazakhstan, ISL pilot production at site No. 4 of the Budenovskoye deposit was completed in 2015 and has proceeded to commercial production. This was followed by the first production from the Husab mine in Namibia, which produced just about 200 tU in 2016. Production at the Lance (Ross) mine in the United States began in December 2015 with the first delivery of drummed product in June 2016. However, production was decreased in late 2016 in response to low uranium prices and the project is currently amending their licence to change to a low pH (acid) leach. Table 1.25 summarises these recent developments, adding some detail to the global capacity expansions outlined in Table 1.24. Committed production centres (C) are those that are either under construction or are firmly committed for construction, whereas expansions (Exp) are planned capacity increases at existing sites (E).

Table 1.25. **Recent, committed mines and expansions**

(in year of estimated first production and tonnes U per year estimated production capacity)

Country	Production centre	2016	2018	2019	2021	2022	2024
Australia	Olympic Dam[1]						
	Beverley/Four Mile[2]						
Brazil	Lagoa Real/Caetité (Engenho)		E (200)				
India	Tummalapalle		C (210)				
Iran, Islamic Rep. of	Ardakan			C (50)			
Kazakhstan	Inkai 3					Exp (2 000)	
	Zhalpak					C (500)	
	Moinkum 3				Exp (250)		
Namibia	Husab	E (5 700)					
Russia	Priargunsky Mine 6						C (2 300)
United States	Lance[3]	E (270)					

E = existing; C = committed; Exp = expansion.

1) BHP has proposed trials of heap leach technology, which should assist the company in assessing less capital-intensive mineral processing technology for ore mined underground.

2) Approval has been granted to extend the capacity of the Beverley plant to produce 1 500 t of uranium oxide concentrate (1 270 tU) per year when the company decides it is commercially viable to do so. Satellite ISR operations are proceeding at the Pepegoona and Pannikan (including Four Mile) deposits. Uranium resins from satellite ion-exchange plants are trucked to Beverley for further processing.

3) Amending licence and permit to change to low pH (acid) leaching.

There are some additions to the existing and committed production capacities until 2020, with production increases projected mainly in Namibia as the Husab mine ramps up production and reaches full capacity. Other additions to the existing and committed production capacities through 2035 are projected in Australia, Brazil, India, Kazakhstan, Russia, Ukraine and the United States.

Planned and prospective production capability is predicted to gradually ramp up through 2025 and may continue through 2035 with the main increases coming primarily from the planned expansion of the Olympic Dam deposit in Australia. Other increases, which may include new mines, are projected from Argentina, Botswana, Finland, India, Greenland, Mauritania, Mongolia, Namibia, Niger, South Africa, Spain, Russia, Tanzania, Ukraine, United States and Zambia. Production in countries such as Canada, China and Uzbekistan are projected to remain relatively constant, with only minor increases or decreases. Kazakhstan, on the other hand, has a long-term forecast for production to start decreasing after 2025.

Total production capacity could increase by more than 31 000 tU by 2035 (see Tables 1.24, 1.25 and 1.26). It is important to note, however, that many of these projected increases in production capacity will likely only go forward with strengthening market conditions. Increased mining costs and development of new exploitation technologies, combined with risks of producing in jurisdictions that have not previously hosted uranium mining, mean that strong market conditions will be needed to secure the required investment to develop these mines.

In addition, several prospective and planned production centres were noted in national reports and company reports for which a projected start-up date, and in some cases mine capacities, have not yet been determined (see Table 1.26). While there is greater uncertainty surrounding the development of these sites, these potential capacity additions underscore the availability of uranium deposits of commercial interest. Once again, it must be noted that strengthened market conditions will be necessary before mine developments will proceed. Additionally, since these sites span several stages of approvals, licensing and feasibility assessments, it can reasonably be expected that at least some will take several years to be brought into production.

Table 1.26. **Prospective and planned mines (estimated production capacity in tU/yr)***

Country	Production centre	Starting year
Australia	Kintyre (2 300 tU/yr)	
	Mulga Rock (1 150 tU/yr)	
	Wiluna P (850 tU/yr)	
	Yeelirrie (3 000 tU/yr)	
Botswana	Letlhakane (1 350 tU/yr)	
Brazil	Itataia (970 tU/yr)	2023
Canada	Kiggavik (3 000 tU/yr)	
	Michelin (2 200 tU/yr)	
	Midwest (2 300 tU/yr)	
	Millenium (2 750 tU/yr)	
India	Gogi (130 tU/yr)	2024
	Lambapur-Peddagattu (130 tU/yr)	2024
	KPM (Kylleng) (340 tU/yr)	2028
Finland	Terrafame mine (250 tU/yr)	2020
Greenland	Kvanefjeld (500 tU/yr)	
Kazakhstan	Budenovskoe 6, 7	2022
Mauritania	Reguibat/Tiris (400 tU/yr)	
Mongolia	Zuuvch Ovoo	
Namibia	Etango (3 000 tU/yr)	
	Norasa (2 000 tU/yr)	
Niger	Dasa (770 tU/yr)	
	Madaouela (1 040 tU/yr)	

Table 1.26. **Prospective and planned mines (estimated production capacity in tU/yr)*** *(cont'd)*

Country	Production centre	Starting year
Russia	Elkon (5 000 tU/yr)	2030
	Gornoe (300 tU/yr)	
Spain	Retortillo/Alameda (1 030 tU/yr)	
Sweden	Häggån (3 000 tU/yr)	
Tanzania	Mkuju River (3 000 tU/yr)	
Turkey	Temrezli (385 tU/yr)	
Ukraine	Safonovskiy (150 tU/yr)	2020
	Severinskiy (1 200 tU/yr)	
United States	Dewey-Burdock	
	Mount Taylor	
	Roca Honda	
Zambia	Lumwana (650 tU/yr)	
	Mutanga (575 tU/yr)	

* As noted in country reports or from public data, in several cases start-up dates and/or capacity are not known.

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Chapter 2. **Uranium demand**

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

Nuclear generating capacity and reactor-related uranium requirements

World

On 1 January 2017, a total of 449 commercial nuclear reactors were connected to the grid in 31 countries/territories and 64 reactors were under construction.

During 2015 and 2016, 20 reactors were connected to the grid and 9 reactors were permanently shut down. Table 2.1 and Figures 2.1 and 2.2 summarise the status of the world's nuclear power plants (NPPs) as of 1 January 2017. The global NPP fleet generated a total of about 2 451 TWh of electricity in 2015 and about 2 474 TWh in 2016 (see Table 2.2).

World annual uranium requirements amounted to 62 825 tU as of 1 January 2017.

OECD

As of 1 January 2017, the 318 reactors connected to the grid in 18 OECD countries constituted about 76% of the world's nuclear electricity generating capacity. A total of 16 reactors were under construction. During 2015 and 2016, three reactors were connected to the grid and nine reactors were permanently shut down in Germany, Japan, the United Kingdom and the United States. However, 16 reactors were considered firmly committed to construction, including the first units in Turkey. On the other hand, some reactors are planned to be retired from service, reducing OECD nuclear generating capacity. Included are closures in Germany as part of the plan to phase out nuclear power by the end of 2022, as well as potential reactor closures in Korea, Sweden, Switzerland and in the United States as a result of non-technical factors, such as economic challenges or policy decisions.

In Japan, 13 reactors have been approved by the Nuclear Regulation Authority, while only 3 reactors were online at the end of 2016. The reactor restarts have been heavily influenced by judicial rulings and local acceptance. Despite the Fukushima Daiichi accident, a number of OECD member countries, namely the Czech Republic, Finland, Hungary, the Slovak Republic and the United Kingdom, remain committed to maintaining or increasing nuclear generating capacity in their energy mix. In North America, some new build construction plans made progress while others were put on hold. In the United States, the nuclear power industry is preparing applications for subsequent licence renewals that would allow continued operation beyond 60 years (potentially for 80 years).

The OECD reactor-related uranium requirements were 45 340 tU as of 1 January 2017.

Table 2.1. **Nuclear data summary**
(as of 1 January 2017)

Country	Operating reactors	Generating capacity (GWe net)	2016 uranium requirements (tU)	Reactors under construction	Reactor grid connections in 2015 and 2016	Reactors shut down during 2015 and 2016	Reactors using MOX
Argentina	3	1.6	110	1	0	0	0
Armenia	1	0.4	65	0	0	0	0
Belarus	0	0.0	0	2	0	0	0
Belgium	7	6.0	1 305	0	0	0	0
Brazil	2	1.9	400	1	0	0	0
Bulgaria	2	1.9	300*	0	0	0	0
Canada	19	13.0	1 830	0	0	0	0
China (People's Rep. of)	36	31.4	6 700	21	13	0	0
Czech Republic	6	3.9	565	0	0	0	0
Finland	4	2.8	435	1	0	0	0
France	58	63.0	8 000	1	0	0	22
Germany	8	10.8	1 400	0	0	1	5[(b)]
Hungary	4	1.9	280	0	0	0	0
India	22	6.2	990*	5	1	0	1
Iran, Islamic Rep. of	1	0.9	160	0	0	0	0
Japan	42	39.8	2 315	3	0	6	3
Korea	25	23.1	3 400	5	2	0	0
Mexico	2	1.6	380	0	0	0	0
Netherlands	1	0.5	60	0	0	0	1
Pakistan	4	1.0	160*	3	1	0	0
Romania	2	1.3	230*	0	0	0	0
Russia	35	26.9	4 800	7	2	0	0
Slovak Republic	4	1.8	320	2	0	0	0
Slovenia	1	0.7	150	0	0	0	0
South Africa	2	1.8	290*	0	0	0	0
Spain[(c)]	8	7.5	1 165	0	0	0	0
Sweden	10	9.1	1 200	0	0	0	0
Switzerland	5	3.1	200	0	0	0	0
United Arab Emirates	0	0.0	0	4	0	0	0
Ukraine	15	13.1	2 480	2	0	0	0
United Kingdom	15	8.9	1 265	0	0	1	0
United States	99	99.8	21 070	4	1	1	0
OECD	318	297.3	45 340	16	3	9	31
World Total[(a)]	449	391	62 825	64	20	9	32

* NEA/IAEA estimate.

(a) The following data for Chinese Taipei are included in the world total: six NPPs in operation, 5.0 GWe net; 800 tU as 2016 uranium requirements; two reactors under construction; none started up or shut down during 2015 and 2016.

(b) Number of units that are expected to have MOX fuel elements in the core.

(c) Includes one reactor (Santa María de Garoña) disconnected from the grid but with operating licence renewal under review as of 1 January 2017. However, the operating licence renewal was denied by ministerial order in August 2017.

MOX not included in uranium requirements figures.

Source: i) Government-supplied responses to a questionnaire; ii) NEA *Nuclear Energy Data 2017* for OECD countries; and iii) IAEA *Energy, Electricity and Nuclear Power Estimates for the Period up to 2050* (IAEA, 2017) for non-OECD countries.

Table 2.2. **Electricity generated at nuclear power plants**
(TWh net)

Country	2013	2014	2015	2016
Argentina	5.7	5.3	6.5	7.7
Armenia	2.4	2.3	2.6	2.2
Belgium	41.0	32.0	25.0	41.0
Brazil	14.6	15.4	13.9	15.0
Bulgaria	13.3	15.0	14.7	15.1
Canada	97.0	100.9	96.0	95.4
China (People's Rep. of)	104.8	123.8	161.2	197.8
Czech Republic	29.0	28.6	25.3	22.7
Finland	22.6	22.2	22.4	22.3
France	403.7	415.9	416.8	384.0
Germany	92.1	91.8	86.8	80.1
Hungary	14.4	14.7	14.9	15.2
India	35.3	38.0	34.6	35.0
Iran, Islamic Rep. of	3.9	3.7	3.2	5.9
Japan	0.0	0.0	9.4	17.5
Korea	133.2	150.4	164.7	154.3
Mexico	11.4	9.3	11.6	10.3
Netherlands	2.7	3.5	3.9	3.7
Pakistan	4.4	4.6	4.3	5.4
Romania	10.7	10.8	10.7	10.4
Russia	172.2	180.5	182.4	183.3
Slovak Republic	14.7	14.5	14.1	14.7
Slovenia	5.0	6.0	5.6	5.4
South Africa	13.6	14.8	11.0	15.2
Spain	54.3	54.8	54.8	56.1
Sweden	63.6	62.2	54.3	60.5
Switzerland	24.8	26.4	22.0	20.0
Ukraine	83.2	88.6	82.4	76.1
United Kingdom	64.1	57.8	63.9	65.1
United States	789.0	797.0	797.2	805.7
OECD	1 862.6	1 888.0	1 888.7	1 874.0
World Total[a]	2 366.5	2 431.6	2 451.3	2 473.6

(a) The following data for Chinese Taipei are included in the world total: 39.8 TWh in 2013, 40.8 TWh in 2014, 35.1 TWh in 2015 and 30.5 TWh in 2016.

Source: i) government-supplied responses to a questionnaire; ii) NEA *Nuclear Energy Data 2017* for OECD-NEA countries; and iii) IAEA *Energy, Electricity and Nuclear Power Estimates for the Period up to 2050* (IAEA, 2017a) for non-OECD countries.

Figure 2.1. **World installed nuclear capacity: 391 GWe net**

(as of 1 January 2017)

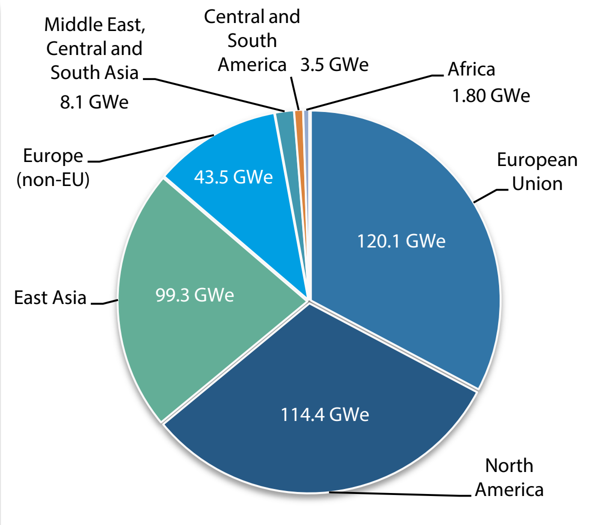
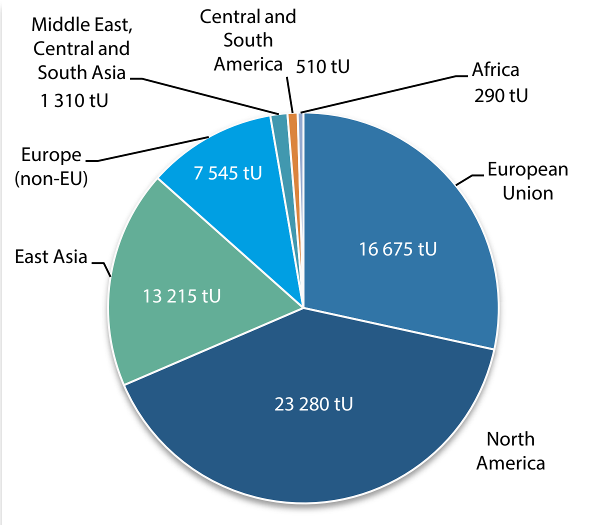


Figure 2.2. **World uranium requirements: 62 825 tU**

(as of 1 January 2017)



European Union

As of 1 January 2017, 128 nuclear reactors were operational in the European Union (EU) with a total installed generating capacity of 120.1 GWe (net), and 4 reactors were under construction. The operating NPPs produced about 27% of electricity in the EU in 2016.

Nuclear phase-out policies remain in place in Belgium and Germany. Nevertheless, other countries in the EU remain committed to nuclear power and plan to add nuclear generating capacity in the coming years.

In 2015, the European Commission (EC) released a series of proposals that call for strengthening energy security and developing an energy union. The Energy Union proposals call for increased harmonisation of energy markets, but do not yet include enforceable legislation. However, eventually the proposals could lead to EU-wide rules that limit the powers of national regulators and enable a greater degree of energy transmission among different nations. The European Commission is seeking greater diversification and independence from Russia for the EU's natural gas market and also wants to modernise the electricity market. In addition, the European Commission seeks greater energy efficiency. Proposals released in 2018 contain little mention of nuclear power but call for greater diversification of nuclear fuel supplies and also for a transition to a low-carbon society.

In Belgium, seven nuclear power plants provide about 50% of domestic electricity generation. In 2015, the Belgian government agreed to a ten-year extension of the operation of Doel 1 and 2 amid concerns about the security of energy supply. Under current Belgian law, nuclear power is to be phased out by 2025.

In Bulgaria, following the closure of four older reactors by the end of 2006, only two units (about 0.95 GWe net each) remain operational at the Kozloduy NPP. To compensate for the loss of nuclear generating capacity and to regain its position as a regional electricity exporter without increasing carbon emissions, the government has plans to build new reactors. A nuclear station at Belene was originally planned in the 1980s, but the project was stopped in the early 1990s due to environmental and financial concerns. The project was revived in 2008, but formally abandoned in 2012 because of uncertainties about its financial viability. In 2016, Bulgaria paid EUR 600 million compensation to Russia for components that had already been manufactured before the cancellation of Belene and has since been searching for ways to revive the project.

In the Czech Republic, a total of six reactors were operational on 1 January 2017, with an installed capacity of 3.9 GWe net. After the modernisation and power uprate programme for all reactors at the Dukovany NPP, an upgrade of the Temelin units began in 2013 and resulted in a capacity increase to 1 078 MWe gross for each block. In May 2015, the Czech government announced a national energy policy that favours an ambitious increase in nuclear power from its current 35% to about 50% by 2035 as a means to reduce carbon emissions. In 2016, the government set up a new committee to co-ordinate the development of nuclear power in the country. The committee will be responsible for the new construction, supply chain, wastes and legislation to move the nuclear sector forward.

In Finland, four units (two each at the Olkiluoto and Loviisa NPPs) with a total generating capacity of 2.8 GWe were operational on 1 January 2017, providing about 34% of domestic electricity generation. Teollisuuden Voima Oyj (TVO), a non-listed public limited company, owns and operates the two plant units, Olkiluoto 1 and 2, and is building a new unit, Olkiluoto 3 (OL3). The OL3 construction has suffered numerous delays and cost overruns. According to the latest schedule, OL3 should start producing electricity in 2019. In December 2013, Fennovoima signed a "turnkey" plant supply contract for an AES-2006-type water-water energetic reactor (VVER) with Rosatom Overseas. Fennovoima submitted the construction licence application at the end of June 2015. The preparatory works have started at the Pyhäjoki site.

In France, 58 operational reactors generated 72% of domestically produced electricity in 2016. Construction of a new European pressurised reactor (EPR) at the Flamanville NPP began in late 2007 and the unit is scheduled to begin commercial operation by 2019. In 2016, major construction steps were achieved, including the completion of the main civil engineering work. Cold tests were performed during 2017 and the fuel loading is expected by the end of 2018. The government passed legislation in 2015 for the transition to a low-carbon economy, restricting nuclear power to its current level of capacity, with a goal of ultimately reducing the percentage of nuclear power to 50% by 2025 through increased deployment of renewable capacity. However, more recently, the new government announced that it would abandon the 2025 target, noting that that this goal would be difficult to complete without resorting to new fossil fuel power plants, which would not respect the French government's commitments towards climate change mitigation.

In Germany, eight reactors were operational on 1 January 2017, producing about 13% of domestic electricity generation in 2016. Following the Fukushima Daiichi accident, the German government announced that it was accelerating the nuclear phase out by permanently shutting down the oldest reactors, plus the Krümmel NPP. The remaining reactors are to be permanently shut down no later than the end of 2022 in the following order: Philippsburg 2 by the end of 2019; Grohnde, Gundremmingen C and Brokdorf by the end of 2021, and the three most recently built facilities – Isar 2, Emsland and Neckarwestheim – by the end of 2022. With reduced nuclear generating capacity, renewable energy sources are being added at a rapid rate, but it has also been necessary to increase the use of coal-fired plants, which in turn increases greenhouse gas emissions.

In Hungary, four operational VVER reactors at the Paks NPP (1.9 GWe net) accounted for over 54% electricity generation at the end of 2016. In January 2014, Hungary signed an intergovernmental agreement with Russia. The agreement covers the design, construction and commissioning of two new nuclear units (1.2 GWe each), the supply of nuclear fuel and the return of the spent fuel to Russia. The financial contract was elaborated by the stakeholders and covers the state-loan and investment details. In 2015, the EU launched an investigation into the procurement agreement for Rosatom to supply two new units for the Paks nuclear power plant. In March 2017, the EC approved state aid arrangements on the basis of commitments that Hungary has made to limit the impact of state aid on energy market competition.

In Lithuania, following the election of a new coalition government in 2012, led by a party that had opposed the construction of the proposed Visaginas NPP on economic grounds, prospects for a new nuclear plant diminished. In 2016, the government released its national energy strategy and announced a delay of the nuclear project until more favourable market and economic conditions arise. With no nuclear generating capacity, Lithuania relies heavily on imports, in particular natural gas from Russia.

In the Netherlands, the single operational reactor (0.5 GWe net) supplied 4% of domestically generated electricity in 2016. In 2011, the government issued a list of conditions that must be met to build a new NPP, including that the reactor design and safety levels meet the highest standards (e.g. withstanding an airplane crash) and that the plant owner be responsible for dealing with waste and decommissioning, as well as posting financial guarantees to do so. Companies had originally expressed an interest in building a new unit at the existing Borssele site, but prospective investors announced that such plans had been put on hold for at least a few years owing to the size of the investment required, as well as current overcapacity in the electricity market.

In Poland, where coal-fired plants currently generate more than 90% of domestic electricity, the government continues to advance plans to construct about 6 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. However, the financial aspects of the proposed nuclear programme remain to be finalised.

In Romania, the two CANDU reactors at the Cernavoda NPP provided 16.5% of the electricity generated in the country in 2016. A tender for the construction of Cernavoda units 3 and 4 was launched and in 2015, China General Nuclear Power Corporation (CGNPC) was designated as the selected investor for the construction of these two units. A memorandum of understanding has been signed. Nuclearelectrica has also announced plans to refurbish unit 1 of Cernavoda NPP in order to extend the lifetime operation, and recently, received shareholder approval.

In the Slovak Republic, a total of four reactors with a combined capacity of 1.8 GWe net were operational as of 1 January 2017. In 2016, the reactors provided 55% of the total electricity generated in the country. Fuel with higher enrichment (4.87% ^{235}U) has been used in the Mochovce reactors since 2011 and in the Bohunice units since 2012. The completion of the construction of two additional units at the Mochovce NPP has been delayed as a result of design safety improvements and technology updates. The new units are now expected to be in operation in late 2018 (unit 3) and 2019 (unit 4), respectively. When in operation, the new units will add 0.9 GWe of electrical generating capacity to the grid.

In Slovenia, the single nuclear reactor in operation (Krško, 0.70 GWe) 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 18% of the electricity generated in Slovenia in 2016, although a proportion of this is exported to meet about 20% of Croatia's electricity requirements. The Slovenian government had been considering the construction of a second unit by 2025, but the plan was put on hold.

In Spain, nuclear energy provided 21.4% of total domestically generated electricity in 2016. The Spanish government supports a balanced electricity mix that takes into account all energy sources and available capacities. In addition, it notes that since nuclear energy contributes both to the diversification of energy supply and the reduction of greenhouse emissions, it cannot be disregarded when the reactors are in compliance with nuclear safety and radiological protection requirements. In July 2013, the definitive shutdown of the Santa María de Garoña NPP was declared by ministerial order. As this declaration was not motivated by safety reasons, in May 2014, the licence holder applied for a renewal of the operating licence until 2031. This renewal was subject to a favourable report by the Nuclear Safety Council. However, the operating licence renewal was denied by ministerial order in August 2017.

In Sweden, nine operational reactors (a total of 9.1 GWe net) generated about 40% of domestic electricity supply in 2016. In 2013, Vattenfall announced plans to invest USD 2.4 billion between 2013 and 2017 to modernise and upgrade its 5 most recently built units (Ringhals 3, 4 and Forsmark 1-3) in order to continue operations for up to 60 years. The results of the election in September 2014 brought to an end the possibility of constructing replacement reactors at existing sites, when a new coalition government set up an energy commission to drive the country towards total reliance on renewable energy sources. In response to the proposed increase in nuclear taxes from 2015, the operators of the NPPs stated that older plants may have to be shut down earlier than expected because of these increased taxes, along with costly post-Fukushima safety upgrades, which have reduced profitability. In February 2016, a decision was made to take Oskarshamn-1 unit out of service and the reactor was shut down in June 2017. Ringhals-1 and 2 units will be closed prematurely in 2019 and 2020. For the remaining reactors, plans remain to continue operation for at least 60 years. After the 2016 energy agreement, the nuclear tax was reduced in 2017 and removed as of 1 January 2018.

In the United Kingdom, 16 operational reactors with a combined capacity of 8.9 GWe net as of 1 January 2017 provided about 20% of total domestic electricity generation. In the upcoming decades, the current UK fleet will be shut down, with the first units expected to come offline in 2023 and the last currently expected to close by 2035. The government has taken a series of actions to encourage nuclear new build. Current plans to develop new nuclear power at six sites in the United Kingdom are set out below: i) Électricité de France (EDF) and CGNPC are currently constructing two EPRs at Hinkley Point C (3.2 GWe) and have plans for an additional two EPRs at Sizewell (3.2 GWe). The two companies also intend to deploy HPR1000 technology at Bradwell; ii) Horizon Nuclear Power has proposed to build two advanced boiling water reactors (ABWRs) at each of its sites in Wylfa and Oldbury (2.7 GWe each) and iii) NuGen has proposed to build up to 3.8 GWe of nuclear power generation at the Moorside site near Sellafield.

The reactor-related uranium requirements for the EU amounted to about 16 675 tU as of 1 January 2017.

North America

At the beginning of 2017, a total of 99 reactors were connected to the grid in the United States, 19 in Canada and 2 in Mexico. Abundant supplies of low-cost natural gas and competition from subsidised renewable energy sources currently limit prospects for growth in nuclear generating capacity in this region.

In Canada, nuclear energy provided about 15% of the country's electricity needs in 2016 (over 60% in Ontario) and should continue to play an important role in the future. The provincial government of Ontario intends to proceed with the refurbishment of ten reactors. Four of these reactors are at the Darlington Nuclear Generating Station and six at the Bruce Nuclear Generating Station. Refurbishments will add about 25-30 years to the operational life of each unit. Plans are progressing to support the development of small modular reactors (SMR). Canadian Nuclear Laboratories received 80 responses to a "request for expressions of interest" to build an SMR at the Chalk River site.

In Mexico, the two units at Laguna Verde NPP (a total of 1.6 GWe net) typically provide about 3-4% of the electricity generated in the country. Laguna Verde unit 1 received permission from the national regulator to operate at the extended power uprate level (120%). In 2015, an application for a licence renewal of Laguna Verde units was submitted to the Mexican regulatory authority, which could authorise its operation for an additional 30 years. In its drive to diversify its energy mix, Mexico plans to generate 35% of its electricity from clean energy sources by 2024.

In the United States, 99 reactors were operational as of 1 January 2017, contributing about 20% of the total electricity generated in the country. Watts Bar 2 unit, the first new nuclear power plant in the country in 20 years, entered commercial operation in 2016. During 2016, licence renewals for 84 of the 99 operating reactors had been granted and applications for 10 reactors to operate for a total of 60 years were under review. The nuclear power industry is preparing applications for licence renewals that would allow continued operation beyond 60 years, potentially for 80 years. NuScale Power submitted the first-ever Design Certification Application for an SMR to the Nuclear Regulatory Commission in June 2017. In 2017, it was announced that the construction project to build two Westinghouse AP1000 reactors at the V.C. Summer nuclear power plant in South Carolina was terminated. The reasons cited included rising costs, decreasing electricity demand, construction delays and the bankruptcy of Westinghouse, the lead contractor for the project and the designer of the reactors. However, after a lengthy evaluation and decision process, construction of two other AP1000 reactors continued at the V.C. Summer site.

Annual uranium requirements for North America were about 23 280 tU as of 1 January 2017.

East Asia

As of 1 January 2017, 109 reactors were operational in East Asia. In 2015 and 2016, 13 new reactors were connected to the grid in China and 2 new reactors in Korea. Six reactors in Japan were definitively shut down. 31 reactors were under construction in East Asia as of 1 January 2017. Prospects for nuclear growth are greater in East Asia than in any other region of the world, principally driven by rapid growth under way in China. However, political developments and public dissent in Japan and Korea could somewhat limit the overall expected growth in the region.

In China, 36 operational reactors provided about 3.5% of national electricity production in 2016 and a total of 21 reactors were under construction as of 1 January 2017. The government plans to add significant nuclear generating capacity in order 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. Projected nuclear growth remains strong in China with the release of the five-year plan to more than double its 2015 capacity to 58 GWe by 2020. However, taking into consideration the capacity of all reactors currently under construction, it is more likely that China will achieve this target by 2022. China is moving ahead with the planning and construction of new nuclear power plants and the development of its own Gen III technologies.

In Japan, new regulations for reactor restarts came into force in July 2013, leading a number of utilities to apply to restart reactors. With most NPPs 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. Reactor restarts and rejuvenation of the industry is proving to be challenging. Nevertheless, the finalisation in 2015 of a new long-term energy policy envisions nuclear power representing 20-22% of total energy supply in 2030. During 2016, three additional reactors returned to operation, bringing the total to five under the new regulatory regime. In 2016, Kansai became the first operator to be granted extended, 60-year operating licences for its Takahama and Mihama plants.

In Korea, 25 operational units produced about 30% of the total electricity generated in 2016. Construction of five reactors is under way. The first nationally designed advanced pressurised reactor APR-1400, unit 3 at the Shin Kori NPP, was connected to the grid in January 2016. The government decided to shut down Kori 1, the first commercial NPP to start operation in 1978, in June 2017. An energy transition policy was announced in October 2017, outlining a long-term phase out of nuclear power. The ongoing construction of Shin Kori units 5 and 6 was highlighted during the public debate on nuclear energy in 2017.

Although Mongolia does not currently have nuclear generating capacity, it has signalled its interest in the use of small and medium-sized reactors after signing an agreement with Russia on the exploration, extraction and processing of uranium resources.

The reactor-related uranium requirements for the East Asia region were 13 215 tU as of 1 January 2017.

Europe (non-EU)

As of 1 January 2017, 56 reactors were operational in 4 countries. This region is also undergoing strong growth with 11 reactors under construction. Several countries in this region continue to support nuclear power and overall growth in nuclear generating capacity is expected.

In Armenia, the single operational reactor (Armenia 2, 0.4 GWe) provided about 30% of the electricity generated in the country in 2016. It was reported that following an intergovernmental agreement, Rosatom will finance the extended operation of the reactor. According to the Armenian energy sector development plan, construction of one new unit is envisaged by 2026.

In Belarus, a USD 10 billion agreement was signed with Atomstroyexport in 2012 to build the country's first NPP, consisting of two VVER-1200 reactors, with expected completion dates by 2020-2025. It was reported that Russia would extend a loan to Belarus for construction costs.

In Russia, 35 operational reactors (26.1 GWe net) provided about 18% of the total electricity generated in the country in 2016. The first VVER-1200, Novovoronezh II unit 1 was connected to the grid in 2016, and the BN-800 sodium-cooled reactor at the Beloyarsk NPP began commercial operation. Unit 3 of Novovoronezh NPP was shut down in December 2016, becoming the oldest VVER-440 reactor to enter decommissioning after having started operations in 1971. In addition to an active domestic programme, the state-run energy company Rosatom is currently involved in new reactor projects in several countries (e.g. Bangladesh, Belarus, China, Hungary, India, Iran and Turkey).

In Switzerland, the five operating reactors typically produce about 35% of the electricity generated in the country. On 21 May 2017, a public referendum was organised on the new Energy Strategy 2050. Under the new law, no permits for the construction of new NPPs or any basic changes to existing NPPs will be allowed. The existing NPPs may remain in operation for as long as they are declared safe by the Federal Nuclear Safety Inspectorate (ENSI).

In Turkey, the government continues to advance its nuclear development programme as its fast growing economy faces rapidly escalating electricity demand. The Akkuyu Project Company applied for an electricity generation licence and a construction licence in early 2017, paving the way for construction activities at the first NPP in Turkey (Russian VVER-1200 reactor type). In April 2015, Turkey's Parliament voted to ratify an agreement with Japan's government, along with a commercial agreement for the construction of a four-reactor nuclear power plant at the Sinop site, which could become the nation's second nuclear power plant.

In Ukraine, 15 reactors with a combined installed capacity of 13.1 GWe net were operational on 1 January 2017, producing 50% of the electricity generated in the country in 2016. The national energy programme foresees that nuclear energy will continue to generate about 50% of total electricity production by 2035.

Reactor-related uranium requirements for the Europe (non-EU) region amount to about 7 545 tU as of 1 January 2017.

Middle East, Central and Southern Asia

As of 1 January 2017, 27 reactors were operational in this region and 14 were under construction. Growth in nuclear generating capacity in this region is expected in the coming years as governments continue to work towards implementing plans to meet rising electricity demand without increasing greenhouse gas emissions.

In Bangladesh, the government ratified an agreement with Rosatom 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. Construction is expected to begin in 2018, with a target date of 2025-2030 for first electricity generation. Site works started in 2013.

In India, 22 reactors (6.2 GWe net) were operational on 1 January 2017, providing about 2.6% of domestic electricity generation in 2016. Agreements in 2008 that granted India the ability to import uranium and nuclear technology have resulted in improved reactor performance through adequate uranium supply. However, concerns about nuclear liability legislation have slowed the development of agreements on imported technology. Construction of four pressurised heavy water reactors and one prototype fast breeder are in progress. The national plan is to increase installed nuclear capacity to about 10 GWe by 2022. The Russian-built second unit of Kudankulam nuclear power plant entered commercial operation in 2017.

In the Islamic Republic of Iran, commissioning of the Bushehr-1 reactor (about 0.9 GWe net) supplied by Atomstroyexport took place in 2011. The Iranian government plans to develop up to 8 GWe net of installed nuclear capacity by 2030 in order to reduce its reliance on fossil fuels, beginning with the installation of additional units at Bushehr. Construction works of Bushehr 2 started in 2017.

In Jordan, a plan to construct two reactors to generate electricity and desalinate water, along with development of the country's uranium resources, has been moving forward since 2004, driven by rising energy demand and the current need to import around 95% of its energy needs. However, the Fukushima Daiichi accident has created some local resistance. Currently, detailed studies are being carried out to evaluate the selected site for the new build, as well as other studies related to the construction and operation of an NPP.

As of 2017, Kazakhstan 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 a generating capacity of between 300 and 1 200 MWe. Discussions on the possibility of building an NPP in Kazakhstan are still pending.

In Pakistan, four reactors (1 GWe net) were operational on 1 January 2017, supplying about 5% of domestic electricity production in 2016. 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. Chasma 3 reactor (300 MWe) was completed in December 2016 and Chasma 4 unit was connected to the grid in June 2017.

In the United Arab Emirates, a consortium from Korea led by the Korea Electric Power Corporation (KEPCO) won a contract in 2009 to build four APR-1400 reactors (a total of 5.4 GWe net). Construction of the first and second units (Barakah 1, 2) officially began in 2012 and 2013, respectively. The first unit is awaiting an operating licence and all four units are scheduled to be in operation by 2020. Increasing energy demand, combined with policies to reduce greenhouse gas emissions and domestic consumption of natural gas in order to maintain the inflow of foreign capital through exports, were central considerations in the government's decision to develop the Barakah NPP.

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.

Other countries in the region, currently without NPPs, have been considering the development of such facilities, including Uzbekistan.

Reactor-related uranium requirements for the Middle East, Central and Southern Asia region were about 1 310 tU as of 1 January 2017.

Central and South America

As of 1 January 2017, a total of five reactors were operational in two countries and two reactors were under construction. The governments of 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 plans to install nuclear generating capacity following the Fukushima Daiichi accident.

In Argentina, three reactors were operational on 1 January 2017, accounting for 5.1% of domestic electricity production in 2016. In support of the national nuclear development plan, initiatives are under way to extend the life of Embalse and Atucha I reactors. In addition, the National Atomic Energy Commission (CNEA) is completing the development and construction of the CAREM-25 (25 MWe), a small locally designed power reactor, and is planning to build other larger units by 2032.

In Brazil, two reactors (Angra 1 and 2, 0.5 GWe net and 1.3 GWe net, respectively) were operational on 1 January 2017, providing about 3% of electricity generated in the country in 2016. Construction of the Angra-3 reactor (1.2 GWe net) was restarted in 2010. Work on this reactor originally began in 1984, but was suspended in 1986. The national long-term electricity supply plan includes a total of 4 GWe nuclear generating capacity installed by 2030 in order to help meet rising energy demand.

Other countries in the region, currently without NPPs, have been considering the development of such facilities, including Bolivia, Chile, Cuba, Uruguay and Venezuela. Venezuela has put its nuclear development plans on hold. Legislation in Uruguay promotes development of renewable energy sources, which means putting nuclear development plans on hold for the time being.

The uranium requirements for Central and South America amount to about 510 tU as of 1 January 2017.

Africa

Nuclear capacity remained constant in Africa with the region's only two operational reactors located in South Africa. Government plans to increase nuclear generating capacity are projected to drive growth in this region, but no construction activities have been initiated. Although several countries are considering adding NPPs to the generation mix to help meet rising electricity demand, development of the required infrastructure and human resources could delay these ambitions.

In South Africa, two operational units (a total of 1.8 GWe net) accounted for about 6.5% of the total electricity generated in the country in 2016. Coal-fired plants dominate current electricity generation, accounting for about 90% of generating capacity. In order to meet electricity demand, avoid additional power shortages and reduce carbon emissions, South Africa solicited bids from several reactor vendors during the past few years, but the process was put on hold owing to cost concerns.

Although no other countries in Africa have NPPs at this time, several have expressed interest in developing nuclear power for electricity generation and desalination in recent years, including Algeria, Egypt, Ghana, Kenya, Morocco, Namibia, Niger, Nigeria, Tunisia and Uganda.

Egypt reaffirmed plans to install nuclear generating capacity and is planning to host four VVER-1200 units at the El Dabaa site.

Annual reactor-related uranium requirements for Africa amounted to about 290 tU as of 1 January 2017.

South-eastern Asia

No reactors were operational in this region at the end of 2016, 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.

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

In Thailand, the revision of the National Energy Policy Council scaled back the planned contribution from nuclear energy from 10% to 5% and set back the schedule for the installation of the first unit from 2020 to 2028. The postponements were implemented in order to ensure safety and improve public understanding of nuclear energy. Currently, Thailand relies on natural gas to generate over 70% of its electricity. Domestic fossil fuel energy reserves are in decline and electricity demand is expected to double by 2024.

In Viet Nam, as a result of increasing electricity demand, along with a reliance on hydro with little prospect for expansion and a shortage of fossil fuels, the government has established a master plan with a goal of nuclear power supplying as much as 25% of domestic electricity production by 2050. In 2013, it was announced that construction of a centre for nuclear science technology would be undertaken, funded by loans from Russia to further accelerate training. In 2015, Rosatom and Vietnam Electricity signed a framework agreement for the construction of unit 1 at the proposed Ninh Thuan nuclear power plant. However, in November 2016, the Vietnamese Parliament voted to abandon its nuclear programme.

The governments of Indonesia, the Philippines and Singapore have considered the use of nuclear power to help meet rising electricity demand despite recurring large-scale natural hazards.

Pacific

This region has no commercial nuclear capacity at present. Current policy prohibits the development of commercial nuclear energy in Australia. However, a new interest in nuclear power was prompted by the South Australian premier in 2015 when it was announced that a Royal Commission would investigate South Australia's future role in the nuclear fuel cycle. The government of New Zealand also has a policy prohibiting the development of nuclear power.

Projected nuclear power capacity and related uranium requirements to 2035

Factors affecting capacity and uranium requirements

Reactor-related requirements for uranium over the short term are fundamentally determined by installed nuclear capacity, or more specifically by the number of kilowatt-hours of electricity generated in operating NPPs. Since the majority of the anticipated near-term capacity is already in operation or under construction, short-term requirements can be projected with greater certainty. However, both short-term and long-term requirements are much more challenging to project following the accident at the Fukushima Daiichi NPP.

Uranium demand is also directly influenced by changes in the performance of installed NPPs and fuel cycle facilities, even if the installed base capacity remains the same. Energy availability and capacity factors have increased to over 80% in the period 2000-2010 (IAEA, 2014). Increased availability tends to increase uranium requirements, but unexpected events in recent years have disrupted the trend of increasing availability factors. The world average availability factor declined to 78.7% in 2011 and further to 73.9% in the period 2012-2014 (IAEA, 2016) following the Fukushima Daiichi accident that led to the entire Japanese nuclear fleet being taken offline pending safety checks. In 2016, the global average capacity factor was 80.5%, in comparison to 81% in 2015 (IAEA, 2017b).

Other factors that affect uranium requirements include fuel cycle length, burn-up, improved fuel design, as well as strategies employed to optimise the relationship between the price of natural uranium (NatU) and enrichment services.[3] 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, in contracts and the ability of the enrichment facilities. Overcapacity in the enrichment market since the Fukushima Daiichi accident has provided incentive to operators to "underfeed" enrichment facilities by extracting more ^{235}U from the uranium feedstock. This reduces the amount of uranium required to produce contracted quantities of enriched uranium and, in turn, creates a stockpile of uranium. In recognition of these recent market trends, uranium requirements for the operational lifetime of projected new reactors in this publication have been reduced from 175 tU/GWe/yr, assuming a tails assay of 0.30% (2012 edition), to 160 tU/GWe/yr, assuming a tails assay of 0.25% over the lifetime of the reactor. In the absence of data provided by governments, this lower uranium requirement factor has been applied in this edition of the Red Book.

Enrichment providers have indicated that they are considering re-enrichment of depleted uranium tails in modern centrifuge facilities as an economic means of creating additional fissile material suitable for use in civil nuclear reactors. In addition, technological development of laser enrichment led to an agreement in 2013 between the US Department of Energy (DOE) and Global Laser Enrichment (GLE) to further develop the technology using a portion of the US inventory of high assay uranium tails. Successful deployment of laser enrichment to re-enrich depleted uranium tails could bring a significant source of secondary supply to the uranium market in the mid-term, although technological hurdles remain to be overcome before commercial deployment can be achieved. In the United States, development of the GE-Hitachi laser enrichment technology has slowed, reflecting depressed market conditions.

The combined impact of strategies to optimise reactor operation and fuel costs, as well as unanticipated reactor closures and the idling of reactors in Japan, are evident in the fluctuating uranium requirements data collected for this edition, since global requirements have decreased from 63 875 tU in 2011 to 57 980 tU in 2015 and then increased to 62 825 tU as of 1 January 2017. Uranium requirements (defined in this publication as anticipated acquisitions, not necessarily consumption) are, however, expected to increase in the coming years as the significant amount of capacity currently under construction comes online, particularly in Asia.

The strong performance and economic competitiveness of existing plants, chiefly because of low operating, maintenance and fuel costs, has made retention and improvement of existing plants desirable in many countries. This has resulted in a trend to keep existing plants operating as long as this can be achieved safely and upgrading existing

3. A reduction of the enrichment tails assay from 0.3 to 0.25% ^{235}U would, all other factors being equal, reduce uranium demand by about 9.5% and increase enrichment demand by about 11%. The tails assay selected by the enrichment provider is dependent on many factors, including the ratio between natural uranium and enrichment prices.

generating capacity where possible. This strategy has been undertaken in the United States, and other countries have or are planning to upgrade their generating capacities and/or extend the lifecycles of existing NPPs (e.g. Canada, the Czech Republic, Hungary, Mexico, the Netherlands, the Slovak Republic and Russia). Competition from subsidised renewable energy sources and low natural gas prices as a result of technological advances in shale gas recovery have nevertheless recently rendered some plants uneconomic in liberalised energy markets in the United States, thus leading to shut downs before the end of the originally planned operational lifetime (e.g. Kewaunee, Vermont Yankee or Fort Calhon 1). Regulatory responses to the Fukushima Daiichi accident have also increased operating costs that may affect the competitiveness of other reactors, in particular the smaller, single units operating in liberalised markets in the United States.

Installation of new nuclear capacity will increase uranium requirements, particularly since first load fuel requirements are roughly some 60% higher than reloads for plants in operation, providing that new build capacity outweighs retirements. A wide range of factors must be taken into consideration before any new significant building programmes are undertaken. These factors include projected electricity demand, security and cost of fuel supplies, the cost of financing these capital-intensive projects, the competitiveness of nuclear power compared to other generation technologies and environmental considerations, such as greenhouse gas emission reduction targets. Proposed waste management strategies and non-proliferation concerns stemming from the relationship between the civil and military nuclear fuel cycles also must be addressed. Following the Fukushima Daiichi accident, public acceptance of the safety of nuclear energy will require greater attention and this remains a pivotal issue in Japan.

Declining electricity demand in several developed countries, the low cost of natural gas in the United States, competition from subsidised renewable energy sources in Europe and the United States and the challenge of raising the significant investment required for capital-intensive projects with lengthy regulatory approval and construction times like NPPs, has made nuclear power development generally more challenging, particularly in liberalised energy markets.

However, despite these challenges and the reaction of a few countries to back away from nuclear power following the Fukushima Daiichi accident (i.e. the strengthening of nuclear phase-out programmes in Belgium and Germany and the decision to not proceed with nuclear power development in Italy for at least five years following a national referendum), many countries have decided that, on balance, objective analysis of these factors supports development of nuclear power. This is particularly so in countries with growing air pollution issues like China and India where coal-fired generation presently provides the majority of electricity. Significant nuclear build programmes are under way in China and are continuing in India. Although the impacts of the global financial crisis have slowed the implementation of ambitious new build plans in some countries (e.g. South Africa), several other nations remain committed to long-term growth in nuclear generating capacity. Smaller scale programmes to increase nuclear generating capacity are under way in the Czech Republic and Finland, for example, while Poland continues to work towards the construction of its first reactors. In the United States, despite the unexpected closure of some reactors and the Westinghouse bankruptcy, construction activities are under way at the two units of the Vogtle plant.

The 2017 World Energy Outlook (IEA, 2017a) notes that global energy demand is set to grow by 40% from 2017 to 2040 in the central scenario (New Policies Scenario), driven primarily by India. Overall, developing countries in Asia account for two-thirds of global energy growth, with the rest coming mainly from the Middle East, Africa and Latin America. It was noted that, compared with the past 25 years, the way that the world meets its growing energy needs changes dramatically in the New Policies Scenario, with the lead being taken by natural gas, by the rapid rise of renewables and by energy efficiency (IEA, 2017a). The outlook for nuclear power has decreased since the 2016 report, but China continues to lead a gradual rise in output, overtaking the United States by 2030 to become the largest producer of nuclear-based electricity. Despite some positive signs that a low-carbon transition is under way, energy-related CO_2 emissions are projected to increase slightly to 2040 in the New Policies Scenario.

The extent to which nuclear energy is seen as beneficial in meeting greenhouse gas reduction targets could have an effect on the role that nuclear energy plays in meeting future electricity demand.

Projections to 2035[4]

Forecasts of installed capacity and uranium requirements, although uncertain because of the above-mentioned factors, continue to point to long-term growth. Installed nuclear capacity is projected to increase from about 391 GWe net at the beginning of 2017 to between about 331 GWe (low case) and 568 GWe (high case) by the year 2035. The low case[5] represents a decrease of about 15% from 2016 nuclear generating capacity, while the high case represents an increase of about 45% (see Table 2.3 and Figure 2.3). By 2025, high case scenario projection sees an increase of 10%, indicating that significant expansion activities are already under way in several countries.

Table 2.3. **Installed nuclear generating capacity to 2035**

(GWe net)

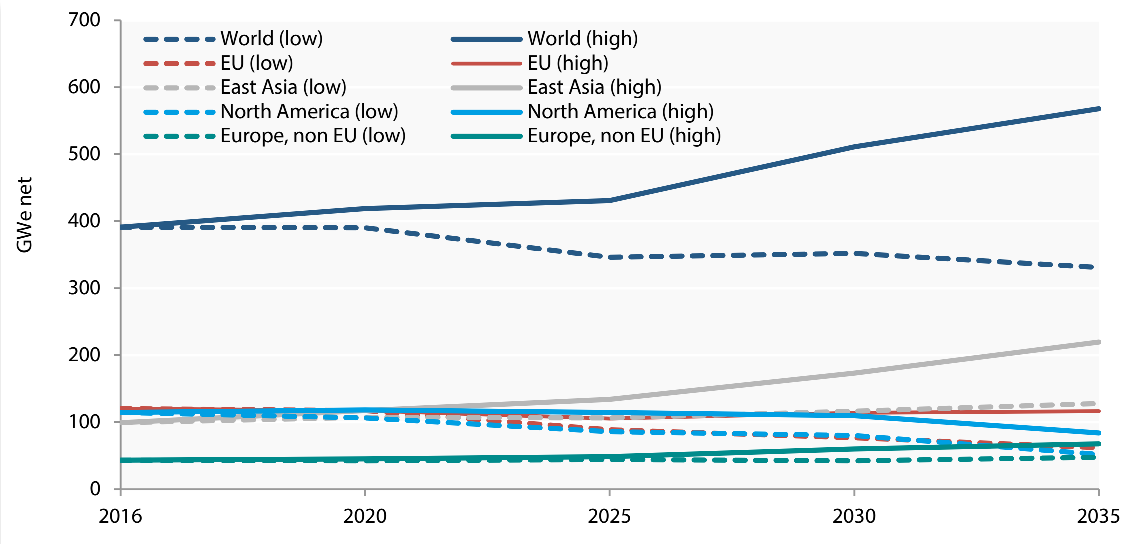
	2016	2020*	2020*	2025*	2025*	2030*	2030*	2035*	2035*
		Low	High	Low	High	Low	High	Low	High
European Union	120.1	117.2	117.3	88.8	105.4	76.5	113.9	62.1	116.3
North America	114.4	106.2	118.3	86.0	114.4	80.0	109.9	51.8	83.8
East Asia	99.3	107.1	117.3	106.5	134.2	116.2	173.4	128.0	219.6
Europe (non-EU)	43.5	42.4	45.4	44.1	48.7	42.3	60.1	47.5	67.8
Central and South America	3.5	3.6	3.6	3.2	3.3	6.4	7.4	5.8	11.6
Middle East, Central and South Asia	8.1	11.4	15.6	15.5	23.0	27.3	42.3	32.7	60.1
South-eastern Asia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Africa	1.8	1.8	1.8	1.8	1.8	3.0	4.2	3.4	7.3
Pacific	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
World Total	391	390	419	346	431	352	511	331	568

* 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, 2018b.

4. Projections of nuclear capacity and reactor-related uranium requirements are based on official responses from member countries to questionnaires circulated by the NEA/IAEA and projections established by an expert group (IAEA/NEA) and published in the IAEA *Energy, Electricity and Nuclear Power Estimates for the Period up to 2050* (IAEA, 2018b). Because of the uncertainty in nuclear programmes in the years 2017 onward, high and low values are provided.
5. The low case forecast 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. 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.

Figure 2.3. **Projected installed nuclear capacity to 2035**

(low and high projections)



However, these projections are subject to 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 low and high case, cheap natural gas and subsidies for renewables will continue to affect nuclear growth in some regions of the world. New safety requirements have in general strengthened the robustness of responses to extreme events, but the costs of implementing these measures could reduce the competitiveness of nuclear power in some liberalised markets.

The low case installed nuclear capacity projection to 2025 has decreased by 10% compared to the last edition of this publication in 2016. The low case scenario incorporates the current policy of the French government to reduce the nuclear generation share of electricity production, strengthened phase-out policies in Belgium and Germany and reduced expectations of capacity additions or delays in nuclear projects in several countries (e.g. India, Korea, Romania, Sweden, Turkey and the United States). In Japan, installed nuclear capacity is projected to decline from 39.8 GWe in 2016 to about 9.7 GWe by 2035 (low case) as reactors are permanently shut down owing to a range of factors including location near active faults, technology, age and local political resistance.

The high case projection to 2025 has declined by 15% compared to projections made in 2016, as policies concerning climate change mitigation are still unclear and financing is uncertain. Expectations of nuclear capacity additions in a number of countries (e.g. Argentina, Armenia, Brazil, China, the Czech Republic, Korea, Turkey, Ukraine, the United Kingdom and the United States) have been delayed or reduced. Construction launches have been low in China in recent years (2.3 GWe in 2016 and only 0.6 GWe in 2017). The high case global projection to 2035 has also decreased (about 17%) compared to the last edition of this publication in 2016. Several currently operating reactors, mainly in the OECD area, were on a path for early decommissioning as a result of economic challenges or policy decisions. The high case projection for Japan sees installed capacity staying about the same, as several reactors remain in service and ageing units are replaced by new reactors.

Nuclear capacity projections vary considerably from region to region. The East Asia region is projected to experience the largest increase and could result in the installation of between 30 GWe and 120 GWe of new capacity in the low and high cases, respectively, by the year 2035, representing increases of about 30% and 122% over 2016 capacity. While representing significant regional capacity increases, it is important to note that while the projections are based on recently revised nuclear development plans in Korea, China's new build programme beyond 2020 has yet to be clarified, in particular with respect to inland power plants. However, countries of this region, namely China and Korea have demonstrated the ability to build multiple reactors with predictable costs and schedules.

Nuclear capacity in non-EU member countries on the European continent is also projected to increase considerably, with between 47.5 and 67.8 GWe of capacity projected by 2035 (increases of about 9% and 56% over 2016 capacity, respectively). Other regions projected to experience significant nuclear capacity growth include the Middle East, and the Central and Southern Asia regions, with India's ambitious expansion plan. More modest growth is projected in Africa, the Central and South American, and the South-eastern Asia regions.

For North America, the projections see nuclear generating capacity decreasing by 2035 in the both low and high case, depending largely on future electricity demand, lifetime extension of existing reactors and government policies with respect to greenhouse gas emissions. The reality of financial losses in several reactors in the United States, have resulted in a larger number of premature shutdowns to be assumed. In Canada, despite the reactor refurbishment programme that will result in the long-term operation of the actual fleet, there is little support for new reactor construction in the period to 2035. In the EU, nuclear capacity in 2035 is projected to decrease by 48% in the low case scenario and decrease by 3% in the high case. The low case projection includes the implementation of phase-out or reduced nuclear generation policies, continued subsidisation of intermittent renewable energy sources and weak growth in electricity demand. In the high case, phase-out policies are maintained, but plans for the installation of additional nuclear generation capacity are assumed to be successfully realised in the Czech Republic, Finland, Hungary, Romania, Poland and the United Kingdom.

World reactor-related uranium requirements by the year 2035 are projected to increase to a total of between 53 010 tU/yr in the low case and 90 820 tU/yr in the high case. The projections for the low case decrease by about 15% and increase by 45% in the high case by 2035, compared with 2016 requirements (see Table 2.4 and Figure 2.4). As a result of reductions in installed nuclear capacity projections, projected uranium requirements to 2035 have declined by 21% in the low case and 13% in the high case compared to the last edition of this publication in 2016.

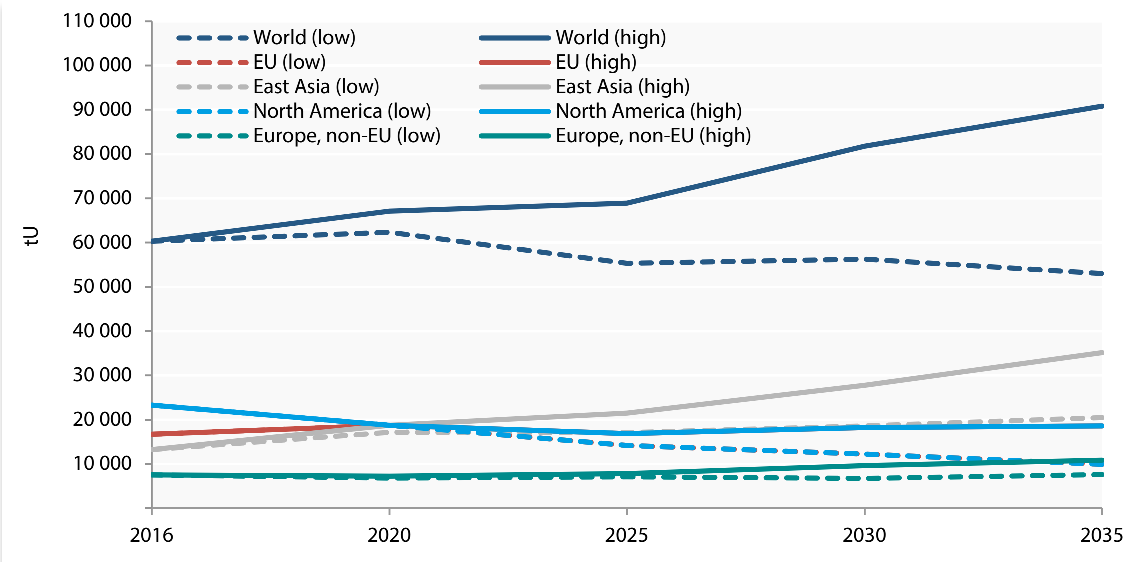
Table 2.4. **Annual reactor-related uranium requirements to 2035**

(tonnes U)

	2016	2020*	2020*	2025*	2025*	2030*	2030*	2035*	2035*
		Low	High	Low	High	Low	High	Low	High
European Union	16 675	18 750	18 770	14 210	16 860	12 240	18 220	9 940	18 610
North America	23 280	16 990	18 930	13 760	18 300	12 800	17 580	8 290	13 410
East Asia	13 215	17 140	18 770	17 040	21 470	18 590	27 740	20 480	35 140
Europe (non-EU)	7 545	6 780	7 260	7 060	7 790	6 770	9 620	7 600	10 850
Central and South America	510	580	580	510	530	1 020	1 180	930	1 860
Middle East, Central and South Asia	1 310	1 820	2 500	2 480	3 680	4 370	6 770	5 230	9 620
South-eastern Asia	0	0	0	0	0	0	0	0	160
Africa	290	290	290	290	290	480	670	540	1 170
Pacific	0	0	0	0	0	0	0	0	0
World Total	62 825	62 350	67 100	55 350	68 920	56 270	81 780	53 010	90 820

* NEA/IAEA estimate.

Figure 2.4. **Annual reactor uranium requirements to 2035**
(low and high projections)



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 significant growth in uranium needs.

Uranium supply and demand relationships

Uranium supply has been adequate to meet demand for decades, and there have been no supply shortages since the last edition of this report. However, a number of different sources of supply are required to meet demand. The largest is the primary production of uranium that, over the past few years, has satisfied as much as 50 to 100% of world requirements. The remainder has been provided or derived from secondary sources including stockpiles of natural and enriched uranium, blending down weapons-grade uranium, reprocessing of spent fuel, underfeeding and uranium produced by the re-enrichment of depleted tails.

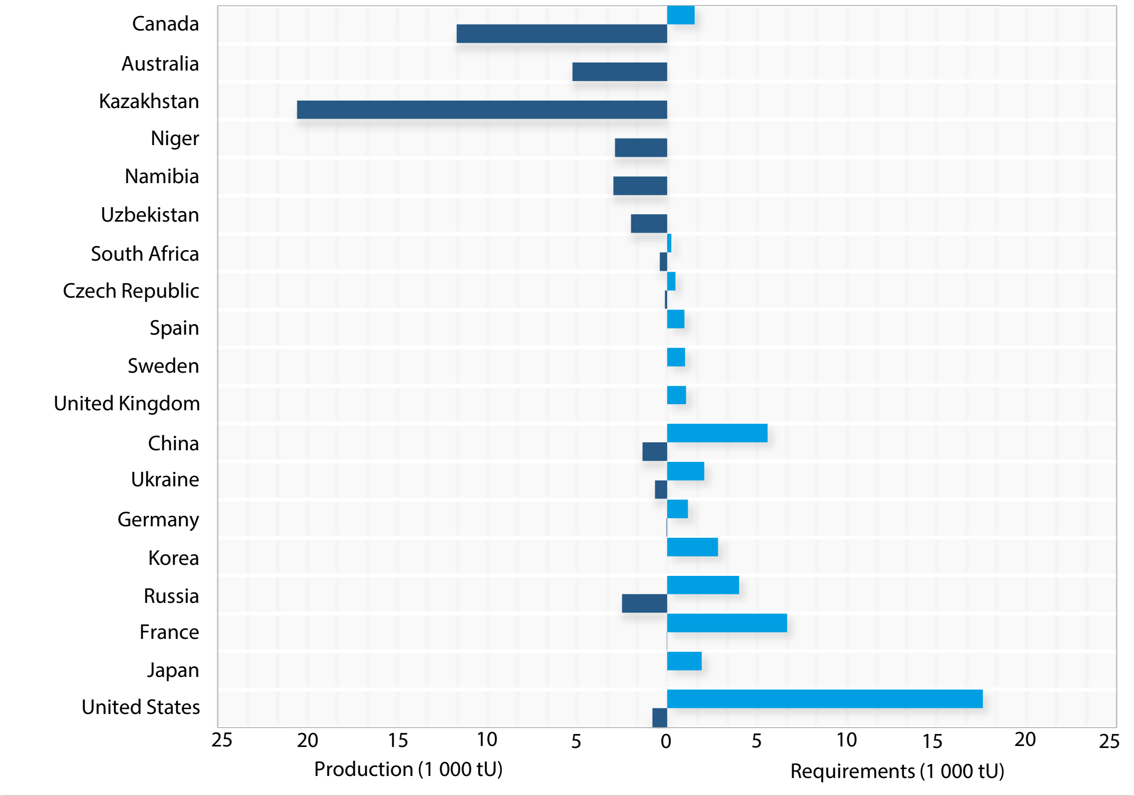
Primary sources of uranium supply

Uranium was produced in 19 countries in 2016 and 2017, with total global production amounting to 62 071 tU in 2016 and 59 342 tU in 2017. Of these 19 producing countries, three reported limited production through mine remediation efforts only (France, Germany and Hungary). Kazakhstan surpassed Canada in 2009 to become the world's largest producer and remained in this position through 2017, continuing its run of production increases over the past few years (24 689 tU in 2016), albeit levelling off and dropping slightly to 23 400 tU in 2017. The top 5 producing countries in 2016 (Kazakhstan, Canada, Australia, Namibia and Niger) accounted for 78% of world production and 11 countries – Kazakhstan, Canada, Australia, Namibia, Niger, Russia, Uzbekistan, China, the United States, Ukraine and South Africa – accounted for almost 99% of global mine production.

Of the 30 countries currently using uranium in commercial NPPs, only Canada and South Africa produced enough uranium in 2016 to meet domestic requirements (see Figure 2.5), thereby creating an uneven distribution between producing and consuming countries. All other countries with nuclear power must make use of imported uranium or secondary sources and, as a result, the international trade 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 unnecessary delays and impediments. Difficulties that some producing countries, in particular Australia, have encountered with respect to international shipping requirements and transfers to international ports have therefore always been a matter of some concern. However, efforts to objectively inform port authorities on the real risks involved, and better recognition of the long-standing record of successful shipments of these materials, have helped avoid unnecessary delays.

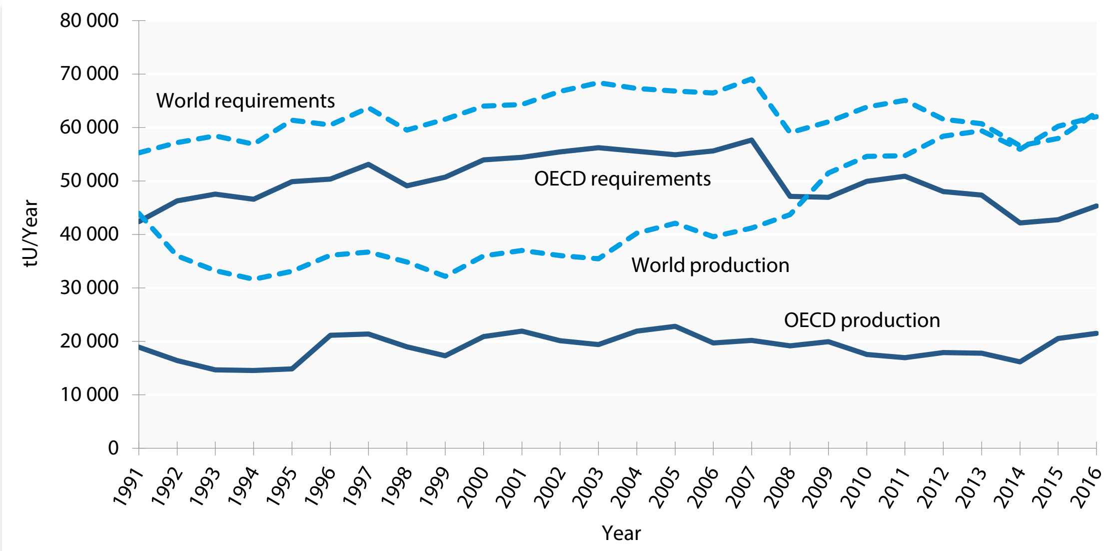
Figure 2.5. **Uranium production and reactor-related requirements for major producing and consuming countries**

(data as of 1 January 2017)



Because of the availability of secondary supplies, primary uranium production volumes have been significantly below world uranium requirements for some time. However, this has changed in recent years as production has increased and requirements have declined. In 2016, world uranium production (62 071 tU) provided 99.9% of world reactor requirements, whereas in 2017, global primary production provided about 95% of requirements. In OECD countries, the gap between production and requirements has changed little as both have declined in the past two years. In 2016, production of 21 521 tU provided 47% of requirements (45 340 tU; Figure 2.6). Remaining reactor requirements were met by imports and secondary sources.

Figure 2.6. **OECD and world uranium production and requirements**



Secondary sources of uranium supply

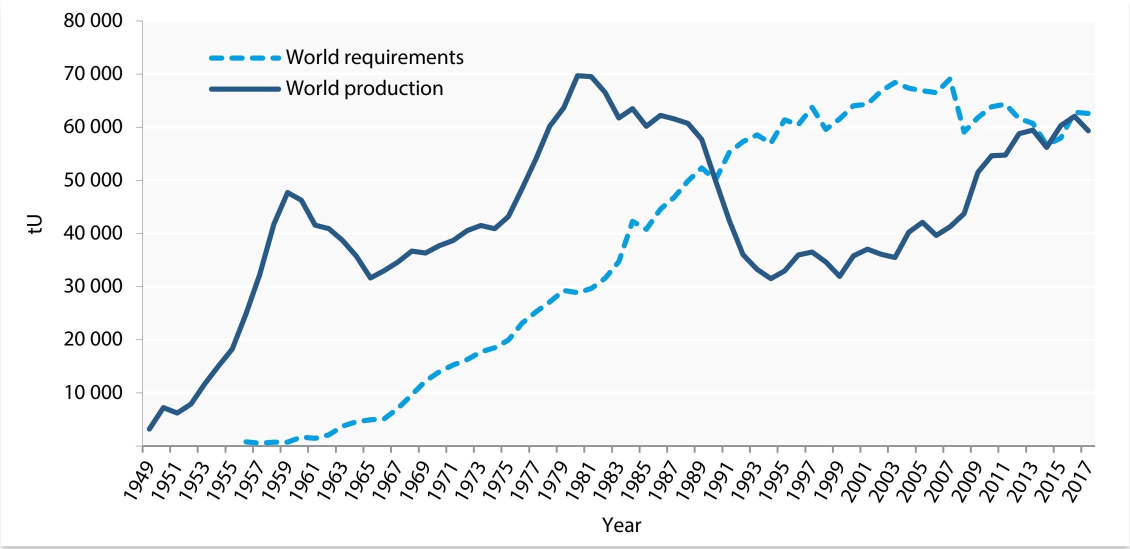
Uranium is unique among energy fuel resources in that historically, a significant portion of demand has been supplied by secondary sources rather than direct mine output. These secondary sources include: stocks and inventories of natural and enriched uranium, both civilian and military in origin; nuclear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

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 2.7). 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 over production 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. However, this gap has closed in the last two years as mine production is increasing and uranium requirements are declining, at least temporarily. The decline in requirements in 2008 was likely related to utilities specifying lower tails assays at enrichment facilities and a reduced number of reactors being refuelled. 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 accident. Uranium production since 2007 has generally increased and has closed the gap between production and reactor requirements.

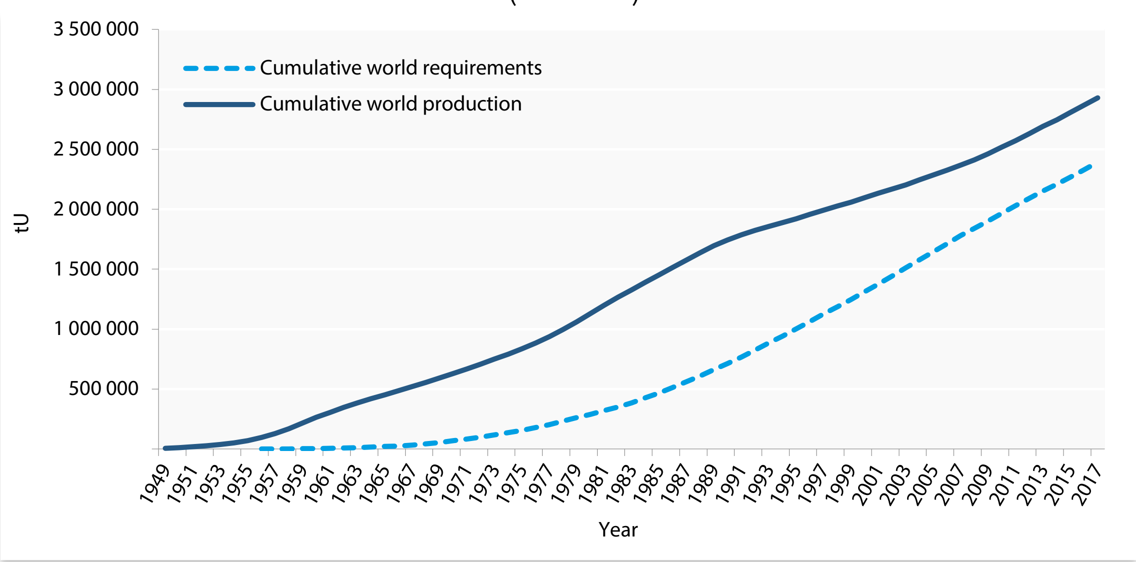
Following the political and economic transition in Eastern Europe and the former Soviet Union in the early 1990s, steps have been taken to move towards the development of an integrated global commercial market. More uranium is now available from the former Soviet Union, most notably from Kazakhstan, 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. These latter uncertainties combined with uncertainty about the desired levels of commercial inventories, continues to influence the uranium market.

Figure 2.7. **Annual uranium production and requirements**
(1949-2017)



Data from past editions of this publication, along with information provided by member states, give a rough indication of the possible maximum upper level of the potential inventories commercially available. Cumulative production through 2017 is estimated to have amounted to over 2 900 000 tU, whereas cumulative reactor requirements through 2017 amounted to about 2 390 000 tU. This leaves an estimated remaining stock of roughly 535 000 tU, which is a rough estimate of the upper limit of what could potentially become available to the commercial sector (see Figure 2.8). 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 2.8. **Cumulative uranium production and requirements**
(1949-2017)



Civilian inventories include strategic stocks, pipeline inventory and commercial stocks available to the market. In recent years, material held by financial investors has been a part of the inventory, although reports indicate that the major investment banks are in the process of exiting commodity markets because of declining demand and increased regulation. Utilities are believed to hold the majority of commercial stocks because many have policies that require them to carry the equivalent of one to two years of natural uranium requirements. Despite the importance of this secondary source of uranium, information about the size of these stocks is limited because few countries are able or willing, because of confidentiality concerns, to provide detailed information on stockpiles held by producers, consumers or governments (see Table 2.5).

Nonetheless, available data suggest that industry has been increasing inventories in recent years. In the United States, 2016 year-end total commercial uranium inventories (natural and enriched uranium equivalent held by producers and utilities) amounted to 49 615 tU, an increase of almost 6% compared to 2015 levels (US EIA, 2017). As of 1 January 2017, the total uranium inventories (including government, producer, utility, brokers and traders stocks) in the United States were 55 385 tU. Uranium inventories held by EU utilities at the end of 2016 totalled 51 513 tU, enough for an average of three years' fuel supply, a slight decrease of 1% since the end of 2015 and an increase of 9% since the end of 2009 (ESA, 2017). These data from the two largest regions of nuclear power generation suggest that global commercial inventories have been increasing.

Uranium requirements are growing rapidly in East Asia (in particular in China where 21 reactors were under construction at the end of 2016). By 2035, demand in this region is expected to surpass both that of North America and the EU. Questionnaire responses received during the compilation of this volume revealed little about national inventory policies in the East Asia region. However, based on import statistics, it is estimated that China had accumulated an inventory of over 138 800 tU by the end of 2017 (Chinese General Administration of Customs), in anticipation of increasing uranium requirements due to the significant number of reactors under construction and planned. In 2015, the government of India announced its intention to create a "uranium reserve" by importing uranium into the country.

The World Nuclear Association (WNA) reports that questionnaire responses from industry show a clear build-up of utility inventory, mainly in East Asia (WNA, 2017). At the end of 2016, global commercial inventories totalled 146 000 tU, an increase of 26 000 tU since 2010.

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 2 900 tU at the end of 2016 (US EIA, 2017). Financial investors also hold a certain amount of uranium inventory. The Uranium Participation Corporation (UPC), for example, held about 5 800 tU as U_3O_8 and UF_6 as of February 2017 (company website). Some banks have also purchased uranium stocks (e.g. Macquarie, Deutsche Bank). However, because of stricter regulations related to commodities activities, some banks have withdrawn from the uranium market.

In July 2013, the United States DOE outlined for Congress its plan to manage its excess uranium inventory in various forms that amounts to between 46 000 and 56 000 tNatU (tonnes of natural uranium equivalent; DOE, 2013). It identifies uranium inventories that have entered the commercial uranium market since the issuance of the last plan in 2008, as well as transactions that are ongoing or being considered through 2018. A DOE Secretarial Determination must be made every two years in advance of sales or transfers in order to provide assurance that the transactions will not have an adverse material impact on the domestic uranium mining, conversion or enrichment industries.

Table 2.5. **Uranium stocks in countries responding to the 2017 questionnaire**
(tonnes natural U-equivalent as of 1 January 2017)

Country	Natural uranium	Enriched uranium
Argentina[a]	N/A	N/A
Australia[b]	N/A	N/A
Belgium	N/A	N/A
Brazil	0	0
Bulgaria[c]	0	81
Canada[b]	N/A	0
China (People's Rep. of)	N/A	N/A
Czech Republic[d]	<100	0
Finland[e]	N/A	N/A
France[f]	N/A	N/A
Germany	N/A	N/A
Hungary[g]	4	0
India	N/A	N/A
Iran, Islamic Republic of	N/A	N/A
Japan	N/A	N/A
Kazakhstan	N/A	N/A
Korea[c, h]	2 000	6 000
Mexico	N/A	N/A
Netherlands	N/A	N/A
Niger	N/A	N/A
Portugal[c]	168	0
Russia	N/A	N/A
Slovak Republic[c]	0	228
South Africa	N/A	N/A
Spain[i]	N/A	608
Switzerland[j]	662	1 487
Turkey	2	0
Ukraine	N/A	N/A
United Kingdom	N/A	N/A
United States[k]	> 41 796	> 26 062
Total	> 44 732	> 34 466

(a) Commercial data are not available. A minimum of two years' inventory is required from the plant's operator.
(b) Government stocks are zero in all categories. Commercial data are not available.
(c) Data from the 2016 edition of the Red Book.
(d) CEZ maintains strategic and working inventories in various forms, including fuel assemblies, amounting to about two years of requirements. Data reported for uranium stocks in the table include only producer stocks.
(e) The nuclear power utilities maintain reserves of fuel assemblies sufficient for 7-12 months of use.
(f) A minimum strategic inventory, amounting to a few years of forward fuel requirements, is maintained by EDF.
(g) Inventory from mine water treatment only.
(h) A strategic inventory is maintained along with about one year of forward consumption in pipeline inventory.
(i) Regulations require a strategic inventory of at least 608 tU to be maintained jointly by nuclear utilities.
(j) Utilities also hold 68 t (U-equivalent) of reprocessed uranium.
(k) Natural uranium hexafluoride (UF_6) and enriched uranium in fuel assemblies held in storage prior to loading in the reactor is not included. Government stocks also include 30 000 t (U-equivalent) of depleted uranium. Data from producers (5 889 tU) is also not included.

In the calendar year 2015, the DOE Secretarial Determination authorised the transfer of up to 2 000 tU to DOE contractors for clean-up services at the Portsmouth Gaseous Diffusion Plant and up to 500 tNatU to the US National Nuclear Security Administration (NNSA) for blending down highly enriched uranium (HEU) to low-enriched uranium (LEU). Other transactions involved the transfer of up to 9 082 t of depleted uranium to Energy Northwest in 2012 and 2013, the majority of which would be enriched for use in the company's power reactor and the remainder sold to Tennessee Valley Authority (TVA) as part of a commercial transaction to support future power generation and tritium production from 2013 through 2030. In 2016, the DOE Secretary determined that exchange of LEU to HEU down-blending services serves national security purposes and that in this case the transfers no longer require a Secretarial Determination.

In 2017, the DOE issued a new Secretarial Determination that further reduces transfers of material to support Portsmouth Gaseous Diffusion Plant D&D activities to 1 200 tU as natural UF_6 for 2017.

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 the military 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 NatU 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). The United States Enrichment Corporation (USEC), the executive agent for this agreement, 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 completed at the end of 2013.

HEU from the United States

In December 2008, the DOE excess uranium inventory included 67.6 t of HEU that was declared unallocated (not presently allocated or approved for a specific purpose or programme). The disposition plan for this material noted that the HEU will be made available gradually over several decades at a rate controlled by weapons dismantlement initiatives and the rejection of material from naval reactors (DOE, 2008).

In 2013, the DOE reported that it held 11.4 t of surplus HEU remaining in the active disposition programme and approximately 18 t of unallocated surplus HEU (DOE, 2013). These amounts reflect the material blended down since 2008, the allocation of 5 t HEU to the blended low-enriched uranium (BLEU) programme and the reallocation of significant quantities of surplus HEU to activities not expected to impact uranium markets (i.e. research reactor and naval fuel requirements).

As of June 2015, the US DOE reported 15 t of unallocated HEU. Following the current campaign, the NNSA plans to conduct HEU down-blending offering for tritium (DBOT) programme in the fiscal years 2019-2025. However, the NNSA does not plan to transfer any LEU arising from the DBOT campaign until at least 2026.

Fuel banks

Efforts by governments and international agencies have also 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 a number of 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 an LEU bank to serve as a supply of last resort for nuclear power generation. The IAEA reserve, expected to be about half the size of the Russian LEU reserve, is to be a backup mechanism to the commercial market in the event that an eligible member state's supply of LEU is disrupted and cannot be restored by commercial means. The plan is to have sufficient LEU in the bank to meet the fuel fabrication needs for three 1 000 MWe light water reactor reloads. In May 2015, Kazakhstan signed a draft agreement with the IAEA to host the IAEA LEU bank at the Ulba Metalurgical Plant.

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

The constituents of spent fuel from NPPs 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 about 96% of the original fissionable material remains, along with the plutonium created during the fission process. The recycled plutonium can be reused in reactors licensed to use MOX. 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 has not altered world uranium demand since only a relatively small number of reactors are using this type of fuel. Moreover, the number of recycles possible using current reprocessing and reactor technology is limited by the build-up of plutonium isotopes that are not fissionable by the thermal neutron spectrum found in light water reactors and by the build-up of undesirable elements, especially curium.

As of January 2017, there were 32 reactors, or about 7% of the world's operating fleet, licensed to use MOX fuel, including reactors in France, Germany, India, Japan 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 processing plant (200 tHM/yr), planned to be operational in the mid-2020s.

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. Commercial operation of JMOX is expected to begin around 2019 (130 tHM/yr capacity).

Following the closure in 2003 of the Cadarache MOX fuel production plant in France and the MOX fuel plant in Belgium (Belgonucleaire) in 2006, the MELOX plant in Marcoule, France was licensed in 2007 to increase annual production from 145 tHM to 195 tHM of MOX fuel (corresponding to 1 560 tNatU). Annual MOX production in France varies below this licensed capacity, in accordance with contracted quantities. Most of the French MOX production is used to fuel French NPPs (a total of about 120 t/yr; 960 tNatU) and the remainder is delivered abroad under long-term contract arrangements.

The Euratom Supply Agency (ESA) reported that the use of MOX fuel in the EU decreased by 23% in 2016 to 9 012 kg Pu from 10 780 kg Pu in 2015. Use of plutonium in MOX fuel reduced natural uranium requirements in the EU by an estimated 807 tU in 2016 (ESA, 2017). In the 1996-2017 period, MOX fuel use in EU reactors has displaced a cumulative total of 23 806 tU through the use of 214.7 t of Pu (ESA, 2017). Since the great majority of world 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 Table 2.6).

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 is a relatively costly endeavour, in part because of the requirement for 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. Since 2007, China and France have reportedly been discussing the possibility of France supplying a commercial-scale recycling facility.

Table 2.6. **MOX production and use**

(tonnes of equivalent natural U)

Country	Pre-2014	2014	2015	2016	Total to 2016	2017 (preliminary)
MOX production						
Belgium[(a)]	523	0	0	0	523	0
France	19 712*	1 072	997	992	22 773	1 040
Japan	684	0	0	0	684	0
United Kingdom	N/A	N/A	N/A	N/A	N/A	N/A
MOX use						
Belgium	520	0	0	0	520	0
France	N/A	917	961	960	N/A	960
Germany	6 730	N/A	N/A	N/A	N/A	N/A
Japan	912	0	72	18	1 002	0
Switzerland	1 407	0	0	0	1 407	0

N/A = Not available or not disclosed.

* Includes Cadarache historical production and Marcoule production adjustment.

(a) Data from the 2016 edition of the Red Book.

Table 2.7. **Reprocessed uranium production and use**

(tonnes of equivalent natural U)

Country	Total to end of 2013	2014	2015	2016	Total to end of 2016	2017 (preliminary)
Production						
France[(a)]	17 900	1 180	1 170	1 080	21 330	1 120
Japan[(b)]	645	0	0	0	645	0
Russia	N/A	N/A	N/A	N/A	N/A	N/A
United Kingdom[(b)]	15 000	0	0	0	N/A	0
Use						
Belgium[(b)]	508	0	0	0	508	0
France[(a)]	5 300	0	0	0	5 300	0
Germany	N/A	N/A	N/A	N/A	N/A	N/A
Japan	217	0	0	0	217	0
Switzerland[(b)]	1 698	273	143	161	2 275	152
United Kingdom[(b)]	1 611	0	0	0	1 611	37

N/A = Data not available.

(a) Cumulative in storage.

(b) 2017 edition of *NEA Nuclear Energy Data*.

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 were in place. Both countries agreed to dispose of the surplus plutonium by fabricating MOX fuel suitable for irradiation in commercial nuclear reactors that would convert the surplus plutonium into a form that cannot be readily used to make a nuclear weapon.

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) at Savannah River in 2001 and construction was officially started in 2007. In late 2012, construction was reportedly 56% complete. 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. President Obama's fiscal year 2017 budget proposal, issued in February 2016, called for the termination of the MOX project. Russia – which had agreed to dispose of the material in fast reactors – suspended the agreement in October 2016.

The Russian MOX facility was reportedly abandoned in favour of burning excess plutonium in fast breeder reactors (WNA, 2017). 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 neutron reactor will use MOX fuel.

Uranium produced by re-enrichment of depleted uranium tails[6] *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.

At the end of 2016, the inventory of depleted uranium was estimated to amount to about 1 200 000 tU (WNA, 2017). Following the construction of new centrifuge enrichment facilities and declining demand since the Fukushima Daiichi 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.

Deliveries of re-enriched tails from Russia had been an important source of uranium for the EU, representing 1 to 3.7% of the total natural uranium delivered annually to EU reactors between 2005 and 2009 (see Table 2.8). However, contracts with EU utilities came to an end in 2010. 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, and Urenco UK is constructing a tails management facility.

Table 2.8. Russian supply of re-enriched tails to EU end users

Year	Re-enriched tail deliveries (tU)	Percentage of total natural uranium deliveries
2007	388	1.8
2008	688	3.7
2009	193	1.1
2010	0	0.0

Source: ESA *Annual Report*, 2011.

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 DOE's high assay tails. The resulting LEU is to be used to fuel Northwest Energy's Columbia generating station through 2028. Northwest Energy is also to provide some LEU created in this process to TVA starting in 2015.

As noted above, GE-Hitachi Global Laser Enrichment proposed to build and operate a tails processing plant using Silex laser enrichment technology at the closed Paducah gaseous diffusion enrichment plant. Successful development of laser enrichment could potentially result in an additional supply of uranium to the market in the longer term. However, GE-Hitachi Global Laser Enrichment recently announced plans to slow development of its laser technology because of poor market conditions. Some other commercial enrichment providers (e.g. Urenco) have indicated an interest in using centrifuge enrichment capacity for tails re-enrichment.

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

Additional information on the production and use of re-enriched tails is not readily available. However, the information provided in questionnaire responses (see Table 2.9) indicates that its use has been limited between 2014 and 2016.

Table 2.9. **Re-enriched tails production and use**

(tonnes of equivalent natural U)

Country	Pre-2014	2014	2015	2016	Total to 2016	2017 (preliminary)
Production						
France	N/A	N/A	N/A	N/A	N/A	N/A
United States	5 678	0	0	0	5 678	0
Use						
Belgium[(a)]	345	0	0	0	345	0
Finland	843	0	0	0	843	0
France	N/A	N/A	N/A	N/A	N/A	N/A
Sweden[(b)]	1 697	0	200	200	2 097	200
United States	1 940	0	0	0	1 940	0

N/A = Data not available.

(a) Purchased for subsequent re-enrichment.

(b) 2017 edition of *NEA Nuclear Energy Data*.

Underfeeding

The potential for *underfeeding* of enrichment plants is also a source of secondary supply, which has become more important in the last few years. Overcapacity in the enrichment market since the Fukushima Daiichi accident has provided incentive to operators to "underfeed" enrichment facilities by extracting more ^{235}U from the uranium feedstock. This 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 tails re-enrichment contribute up to 7 000 tU of supply per year (WNA, 2017).

In recent years, secondary supply has shown a downward trend resulting from the end of the "Megatons to Megawatts" agreement. However, the level of secondary supply is currently around 11 000 tU/yr and is likely to remain at over 8 000 to 10 000 tU/yr for the next two decades (WNA, 2017).

Uranium market developments

Uranium price developments

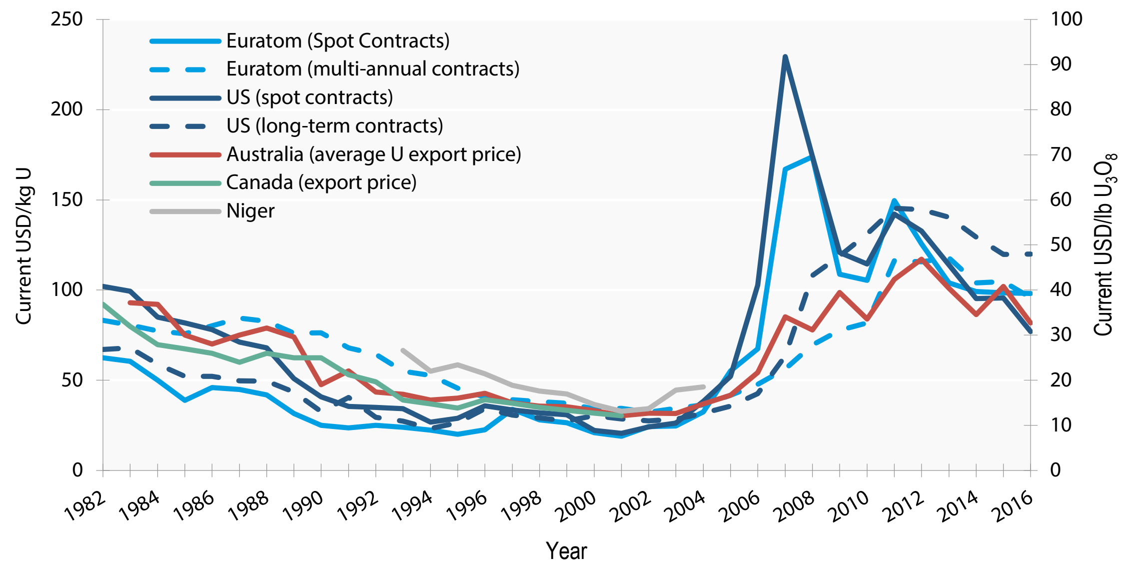
Some national and international authorities (Australia, the United States and Euratom), publish price indicators to illustrate uranium price trends for both long-term and short-term (spot price) contract arrangements. Australian data record average annual prices paid for exports, whereas Euratom (ESA) 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 2.9 displays this mix of annual prices reported for both short-term and longer-term purchases and exports.

The overproduction of uranium, which lasted through 1990 (see Figure 2.7), 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 began to increase, eventually rising to levels not seen since the 1980s, then rising more rapidly through 2005 and 2006 with spot prices reaching a peak through 2007 and 2008, then falling off rapidly, recovering somewhat in 2011 and declining in 2012 (see Figures 2.9 and 2.10). In contrast, EU and US long-term price indices continued to rise until 2011 before levelling off in 2012 and then starting to decline until 2017. Fluctuations in these indicators do not rival the peak in spot market in 2007 and 2008 or the degree of declining prices since 2011 since 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. Depending on the nature of the purchases (long-term contracts versus spot market), the information available indicates that prices ranged between USD 77/kgU and USD 120/kgU (USD 30/lb U_3O_8 and USD 46/lb U_3O_8) at the end of 2016.

In addition to this information from government and international sources, spot price indicators for immediate or near-term delivery (less than one year) that 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). While the trend of increasing prices outlined above is evident for spot market transactions since 2002, and in particular after 2004, the spot price shows more volatility than long-term price indicators since 2006 (see Figure 2.10). In June 2007, the spot market price reached as high as USD 136/lb U_3O_8 (USD 354/kgU) before declining to USD 40.50/lb U_3O_8 (USD 105/kgU) in February 2010. It recovered to USD 72.25/lb U_3O_8 (USD 188/kgU) at the end of January 2011, before declining to USD 24/lb U_3O_8 (USD 62/kgU) at the end of 2017 (see Figure 2.10).

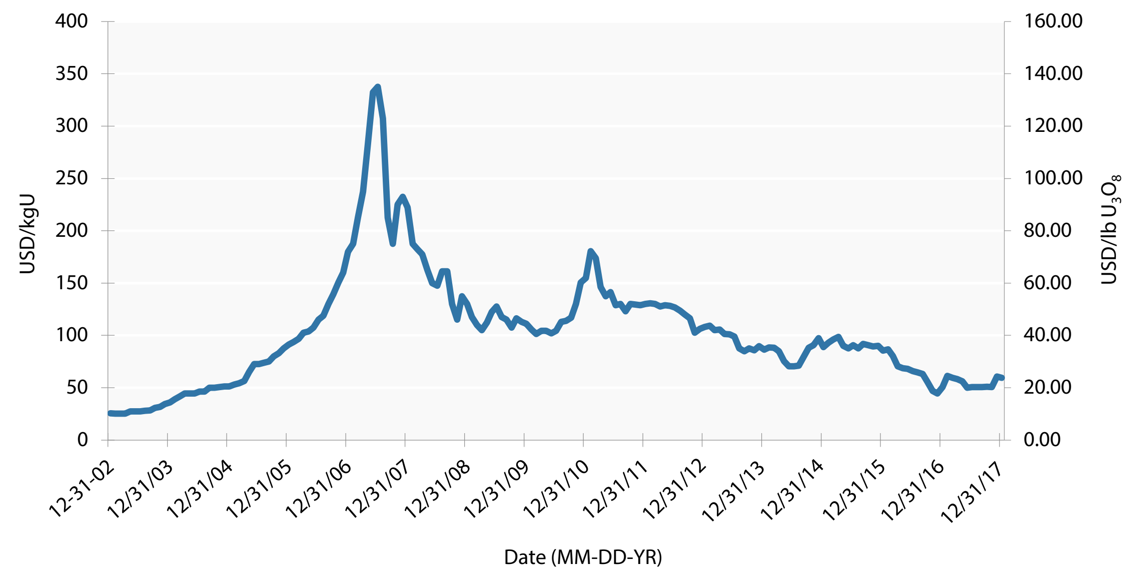
Figure 2.9. **Uranium prices for short- and long-term purchases and exports (1982-2017)**



Source: Australia, Canada, ESA, Niger and the US EIA.

1. Euratom (ESA) prices refer to deliveries during that year under multi-annual contracts.
2. Beginning in 2002, Natural Resources Canada (NRCan) suspended publication of export prices pending policy review. Niger has also suspended publication of export prices since 2004.

Figure 2.10. **Uranium spot price dynamics**
(TradeTech Exchange Value trend, 2002-2017)



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

1. 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 2017, 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. The influence of speculators in the market helped accelerate upward price movement at this 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 the USD 40/lb U_3O_8 (USD 104/kgU) to USD 50/lb U_3O_8 (USD 130/kgU) range in 2009. 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 accident precipitated an initial rapid decline in price that continued more gradually through to the end of 2016. Reactor requirements dropped considerably, largely because reactors were shut down in Germany, Japan and the United States. 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 2017. 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.

The uranium market was also impacted by macroeconomic trends. The strengthening of the US dollar in recent years, especially in relation to the currencies of major uranium producers (e.g. Canadian dollar, Kazakh tenge, Russian rouble and South African rand) contributed to the uranium price volatility. Non-US mining companies have benefited from USD appreciation against these currencies, as most of their operating costs, including labour, are in their domestic currencies. This allowed them to keep operating the mines despite falling uranium market prices, expressed in US dollars. The uranium market is also sensitive to the falling oil and natural gas prices. On the supply side, lower fuel costs mean savings for uranium producers. However, on the demand side, it can lead to premature shutdowns of operating nuclear reactors and a strong competition for potential new build.

Regarding the uranium market, evolution could be pushed further by developments on both the demand and supply side. Demand factors include Japanese restarts and successful global new builds. On the supply side, uranium production levelling off in the short term, as well as possible limitations on government inventories are viewed as critical considerations. In the longer-term outlook there is a general agreement among international organisations that nuclear growth is likely to continue. Asia and the Middle East are the most critical markets for new reactors, and new uranium production will be needed in the coming decades. However, new uranium supply capacity would need the right price signals for producers to make investments.

Policy measures in the EU and uranium prices

Since its establishment in 1960 under the Euratom Treaty, the ESA has pursued a policy of diversification of sources of nuclear fuel supply in order to avoid overdependence on any single source. Within the EU, all uranium purchase contracts by EU end users (i.e. nuclear utilities) must be approved 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 and continues with efforts to promote transparency and predictability in the market.

Nuclear materials for EU reactors came from diverse sources in 2016 (ESA, 2017). Niger-origin uranium supplied 22% of the natural uranium included in fuel loaded in the EU reactors, followed by Canada (20.6%), Russia (19.3%), Kazakhstan (15.8%) and Australia (13.2%). European uranium delivered to EU utilities originated in the Czech Republic, covering approximately 1.5% of the EU's total requirements. These deliveries were made under terms and conditions contained in a number of contracts of variable duration, with 71% of total deliveries covered under long-term contracts and 29% under spot market contracts (purchase/sale by an EU utility/user). In 2016, the ESA processed a total of 107 contracts and amendments, of which 63% were new contracts and 37% where between intermediaries.

Since uranium is sold mostly under long-term contracts and the terms are not made public, the ESA traditionally published 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.

In 2016, the MAC-3 average price index was EUR 87.11/kgU (USD 37.09/lb U_3O_8), a decrease of 3% from 2015, and the long-term contract price decreased by 9% over the same period to EUR 86.62/kgU (USD 36.88/lb U_3O_8). The average spot price for deliveries in 2016 decreased only by 0.2% from 2015 to EUR 88.56/kgU (USD 37.71/lb U_3O_8), whereas in 2017 the average spot price dropped by 38% from 2016 to EUR 55.16/kgU (USD 23.97/lb U_3O_8), (see Table 2.10). In 2016, spot price data and the multi-annual contract prices were widely distributed. On average, the multi-annual contracts that led to deliveries in 2016 had been signed 8 years earlier, in contrast to spot contract deliveries, which are concluded over a maximum period of 12 months (ESA, 2017).

Table 2.10. **ESA average natural uranium prices (2011-2017)**

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

Source: ESA, 2017, 2018.

Since uranium is priced in US dollars, fluctuation of the EUR/USD exchange rate influences the level of the price indices calculated. In 2015, depreciation of the EUR/USD exchange rate resulted in an increase of ESA spot and long-term prices expressed in euros while the USD-denominated prices for the two indices did not change significantly. In 2016, the annual average EUR/USD rate stood at 1.11, which was the same level as in the previous year.

Supply and demand to 2035

Market conditions are the primary driver of decisions to develop new or expand existing primary production centres. Market prices have generally increased since 2003, and even with declining prices since the onset of the financial crisis and following the Fukushima Daiichi accident, plans for increasing production capability continued through 2017. A number of countries, notably Australia, Brazil, Canada, Kazakhstan, Namibia, Niger and Russia, have plans for significant additions to future production capability. Some other countries, notably Botswana, Mauritania, Mongolia, Tanzania and Zambia, 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 secondary sources are expected to decline somewhat in availability.

However, with rising mining and development costs and the long pause in nuclear development following the Fukushima Daiichi accident, along with the continuing decline of market prices through 2017, delays in some of the planned mine developments have been announced and more could follow should prices decline further. Uranium production has also slowed at a number of existing facilities because of poor market conditions. The most significant of these changes was the suspension of Canada's McArthur River mine and Key Lake mill, following a series of production cuts to Kazakh production, a reduction to production in Niger and cessation of production at the Langer Heinrich project in Namibia. Meanwhile, many in situ leaching mines in the United States (e.g. Nichols Ranch, Lost Creek) are facing a situation in which no new capital is being invested into developing new wellfields. A return to more favourable market conditions should see at least some of the delayed projects or the mines in care and maintenance reactivated in order to ensure supply to a growing global nuclear fleet. Since several of these projects have advanced through regulatory and other development steps, the time required to bring these facilities into production could be reduced overall, and production will likely be able to respond more rapidly to increasing demand.

Despite some uncertainties and challenges in raising investment for mine development, producers have moved to increase production capability in recent years and governments are laying the groundwork (e.g. legislation and regulations) for mine development in countries that have not previously hosted uranium production. However, should uranium demand increase as projected, producers would still face a number of significant and unpredictable issues in bringing new production facilities on stream, including geopolitical and policy factors (e.g. from the ban on new uranium mine development in Western Australia, to terrorist attacks in Niger), technical challenges and risks at some facilities, the development of more stringent regulatory requirements and also heightened expectations of governments hosting uranium mining (e.g. increased taxes and contributions to regional socio-economic development).

As reactor requirements are projected to rise through 2035, an expansion of production capability is also projected to occur (see Figure 2.11a). As of 1 January 2017, these mining expansion plans, if successfully implemented, would cover high case demand requirements throughout this period, even without secondary supplies. The secondary supplies have met from 1% to 50% of annual requirements between 2000 and 2017 (see Figures 2.11 and 2.7). As noted above, secondary sources can be expected to continue to be a source of supply for some years to come, despite a general downward trend.

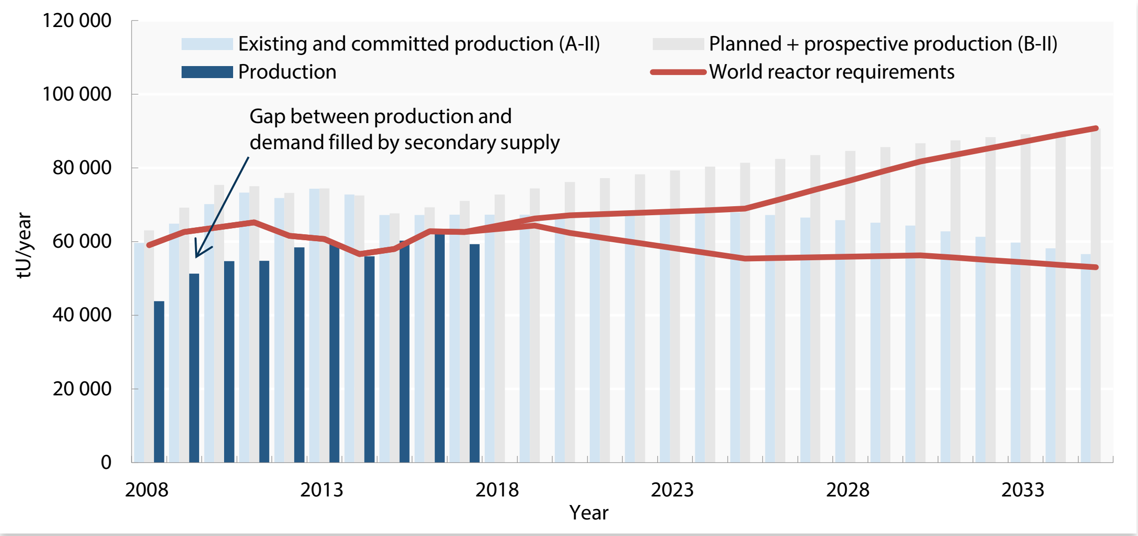
If all existing and committed mines produce at or near stated production capability, high case demand is projected to be met through 2025 (without taking into account the secondary supplies). If planned and perspective production capability is included, high case demand requirements are projected to be met through 2035. Planned capability from all existing and committed production centres is projected to satisfy low case requirements through 2035 and about 60% of high case requirements in 2035. With the inclusion of planned and prospective production centres, primary production capability would more than satisfy low case requirements through 2035. However, real mine production is rarely more than 85% of mine production capability and, as noted above, several challenges will need to be overcome in order for all planned and prospective uranium projects to be successfully brought into production. Figure 2.11b summarises the supply/demand picture with global production capability at 85% recovery. In this case, a gap is identified for the high case reactor requirements scenario starting in 2025, which potentially could be filled with secondary supply.

The total identified uranium resource base in 2017 is more than adequate to meet even high case projections of growth in nuclear generating capacity. Meeting high case demand requirements would consume less than 25% of the total 2017 identified resource base by 2035 (resources recoverable at a cost of <USD 130/kgU). With the appropriate market signals, as significant new nuclear generating capacity is added, additional resources of economic interest are likely to be identified with additional exploration efforts.

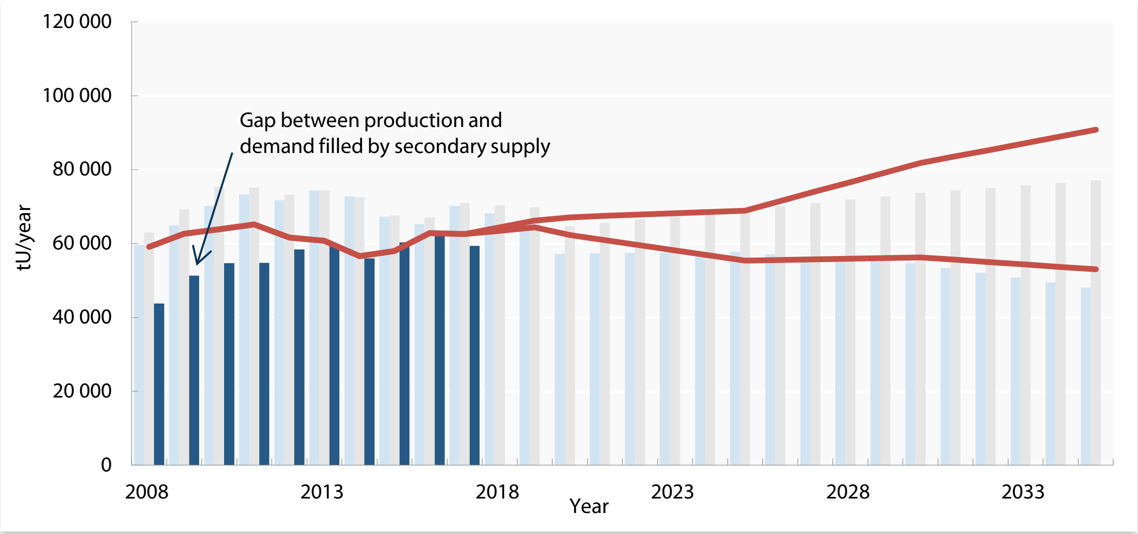
The gap between production and requirements from 2008 (and earlier) to 2014 has been met by drawing down secondary supplies. In 2014, producers almost closed the gap between world production and reactor requirements, albeit with requirements temporarily depressed owing to reactor closures and the idling of reactors in Japan following the Fukushima Daiichi accident. However, it should be noted that production capability is not production. Maintaining production at the level required to meet reactor requirements in the coming years, particularly in light of declining market prices for uranium through 2016 and 2017, will be a challenge.

Figure 2.11. **Projected world uranium production capability to 2035 (supported by identified resources at a cost of <USD 50/lb U_3O_8) compared with reactor requirements***

(a) 100% of total production capability



(b) 85% of total production capability



Source: Tables 1.24 and 2.4.

* Includes all existing, committed, planned and prospective production centres supported by reasonably assured resources and inferred resources recoverable at a cost of <USD 130/kgU (USD 50/lb U_3O_8). Does not include the secondary supply forecast.

World production has never exceeded 89% of reported production capability (NEA, 2006), and since 2003, has varied between 70% and 84% of full production capability. In addition, delays in the establishment of new production centres can reasonably be expected, especially in the prevailing risk-averse investment environment. As always, technical and geopolitical challenges in the operation and development of mine and mill facilities will need to be effectively dealt with. These factors can be expected to reduce and/or delay development of planned and prospective centres. Hence, even though the industry has responded vigorously to the market signal of generally higher prices since 2003 compared to the previous 20 years, additional primary production will likely be required. After 2017, secondary sources of uranium are generally expected to decline somewhat in availability and reactor requirements will have to be increasingly met by primary production. Therefore, despite the significant additions to production capability reported here, bringing facilities into production in a timely fashion remains important. To do so, strong uranium market conditions will be fundamental to bringing the required investment to the industry.

A key uncertainty of the uranium market continues to be the availability and the mobility of secondary sources, particularly the level of stocks available and the length of time remaining until those stocks are exhausted. Information on secondary sources of uranium, especially inventory levels, is in general not publicly available. However, the possibility that at least a portion of the potentially large inventory (including from the military) will continue to make its way to the market after 2017 cannot be discounted. These uncertainties complicate investment decisions on new production capability. Another limiting factor for investment decisions is that uranium demand outlook in the near to medium term is driven primarily by the large number of reactors that are scheduled to close (e.g. Europe and the United States), which offset the positive growth from new nuclear power plants in other countries (e.g. China).

It is clear that the generally stronger market of recent years (2003-2011), compared to the last two decades of the 20th century has driven exploration activity, thus building up an important uranium resources base. However, history shows that periods of low prices for uranium and reliance on secondary supplies have had dramatic impacts on the industry in terms of consolidation of producers and significant reductions in primary production capability. Given the extent of known uranium resources, the challenge in the coming years is likely to be less one of adequacy of resources than adequacy of production capacity development resulting from poor market conditions and flat uranium demand outlook in the near to medium term.

The long-term perspective

Uranium demand is fundamentally driven by the number of operating reactors, which ultimately is driven by the demand for electricity. The role that nuclear energy will play in helping meet projected electricity demand will depend on government policy decisions affecting nuclear development and how effectively a number of factors discussed earlier are addressed (e.g. economics, safety, security of energy supply, waste disposal, environmental considerations). Public acceptance of the technology in some countries in the wake of the Fukushima Daiichi accident remains an issue that needs to be addressed.

Several international agencies have noted that if governments follow the current path of energy policy, severe climate change impacts can be expected, and greenhouse gas emissions from electricity production are at the heart of this issue (IAEA, 2018a; IEA/NEA, 2015; NEA, 2015). In setting a goal of stopping growth in emissions by 2020, several policy measures have been proposed: implementation of select energy efficiency policies, limiting the use of inefficient coal power plants, reducing methane emissions from upstream oil and gas facilities, phasing out fossil fuel subsidies and increasing investment in renewable energy technologies. The 2017 World Energy Outlook (IEA, 2017) notes that global energy demand is set to grow by 40% from 2017 to 2040 in the central scenario (New Policies Scenario), driven primarily by India. Overall, developing countries in Asia account for two-thirds of global energy growth, with the rest coming mainly from the Middle East, Africa and Latin America. It was noted that compared with the past 25 years, the way in which the world meets its growing energy needs changes dramatically in the New Policies Scenario, with the lead now being taken by natural gas, by the rapid rise of renewables and by energy efficiency (IEA, 2017a). The outlook for nuclear power has decreased since the 2016 report, but China continues to lead a gradual rise in output, overtaking the United States by 2030 to become the largest producer of nuclear-based electricity. Despite some positive signs that a low-carbon transition is under way, energy-related CO_2 emissions are projected to increase slightly by 2040 in the New Policies Scenario. The "World Energy Investment 2017" report (IEA, 2017b) outlines that nuclear energy can make a significant contribution to decarbonisation, but the industry must receive clear and consistent policy support for existing and new capacity with nuclear also included in clean energy incentive schemes.

The expansion of nuclear power is mainly policy driven and can be limited by public opposition and long-permitting processes. Nuclear power plants also face challenges due to their large upfront capital costs and complex project management requirements (IEA/NEA, 2015). However, nuclear energy can play a key role in decarbonising electricity systems by providing a stable source of low-carbon baseload electricity. Recognising the security of supply, reliability and predictability that nuclear power offers and promoting incentives for all types of low-carbon electricity production are key conditions for a faster deployment of nuclear power. In addition, the NEA study, *The Full Costs of Electricity Provision* (NEA, 2018), outlines the most recent research on the social and environmental impacts of electricity generation that are not captured by market prices. It discusses and tries to quantify different impacts of electricity provision such as climate change, local pollution, impacts of accidents, or land use. It concludes that air pollution, climate change and system costs constitute the largest uninternalised costs (NEA, 2018).

Several alternative uses of nuclear energy also have the potential to increase nuclear power installation worldwide, including desalination and heat production for industrial and residential purposes. The prospect of using nuclear energy for desalination on a large-scale is attractive since desalination is an energy intensive process that can make use of either the heat from a nuclear reactor and/or the electricity produced (NEA, 2008). About one-third of the world's population lives in water stressed areas, with a majority in Sub-Saharan Africa, the Middle East and South Asia, and with climate change, access to fresh water could become increasingly challenging (IAEA, 2013). In recent years, several governments have been actively evaluating the possibility of using nuclear energy for desalination (e.g. China, Jordan, Libya and Qatar), building on experience gained through the operation of integrated nuclear desalination plants in India, Japan and Kazakhstan. Global installed desalination capacity has more than doubled between 2006 and 2016, with the majority operating on fossil fuels.

Cogeneration, combining industrial heat applications with electricity generation, is not a new concept; some of the first civilian reactors in the world were used to supply heat as well as electricity. District heating using heat generated in reactors has been used in some countries for decades. Industrial process heating has also been used and potential for further development exists, but the extent to which reactors will be used for such applications will depend on the economics of heat transport, international pressure to reduce CO_2 emissions and national desires to reduce dependence on imported fossil fuels, as well as competition with alternative heat or combined heat and power technologies (NEA, 2008). Participants at a workshop held in 2013 to identify technical and economic challenges to increased usage concluded that there is a proven record of operating non-electric applications of nuclear energy in the field of district heating and desalination and other areas, and although feasibility studies, lab-scale or prototype testing have been undertaken, significant industrial experience is lacking. It was also noted that since the public and decision makers are not sufficiently aware of the potential of non-electric applications of nuclear energy, better communication practices should be developed (NEA/IAEA, 2013).

Energy use for transport, which is projected to continue to grow rapidly over the coming decades, is also a major source of greenhouse gas emissions. Both electric and hydrogen-fuelled vehicles are seen as potential replacements for those powered by fossil fuels. Nuclear energy offers baseload electricity production that could be used to power electric vehicles; it also has the potential of producing hydrogen on a massive scale that could make this alternate energy carrier available with significantly less greenhouse gas emissions compared to current methods of hydrogen production (IAEA, 2013).

SMRs, with capacities generally in the range of 30-300 MWe, could be suitable for areas with small electrical grids and for deployment in remote locations. SMRs offer smaller upfront investment costs and reduced financial risks compared to larger reactors typically being built today (1 000-1 700 MWe) and may be deployed as alternatives to larger nuclear power plants in locations where such plants cannot be built, or to fossil-fired plants of similar sizes. The technical feasibility, the economic aspects and the factors affecting the competitiveness of SMRs are described in a recent NEA report (NEA, 2016). A number of SMR designs are under development (e.g. SMART in Korea, ACP100 in China), and others are under construction in Argentina (CAREM), in Russia (KLT-40s) and in China (HTR-PM). The US DOE began a cost-sharing programme in 2012 under a licensing technical support programme that has provided funding for domestic SMR vendors. NuScale submitted the first ever Design Certification Application for an SMR to the US Nuclear Regulatory Commission (NRC) in December 2016.

Technological developments also promise to be a factor in defining the long-term future of nuclear energy and uranium demand. In recent years, the nuclear sector has been aggressively developing reactor fuels that are more robust and have improved performance during normal operation and in accident conditions. Several fuel vendors are developing such fuels. The first assemblies using advanced fuel cladding materials have already been loaded into the US commercial reactors. Advancements in reactor and fuel cycle technology are not only aimed at addressing economic, safety, security, non-proliferation and waste concerns, but also at increasing the efficiency of uranium resource use. The introduction and use of advanced reactor designs would also permit the use of other types of nuclear fuel, such as uranium-238 and thorium, thereby expanding the available resource base. Fast neutron reactors are being developed to make more efficient use of the energy contained in uranium.

Many national and several major international programmes are working to develop advanced technologies, for example the Generation IV International Forum (GIF) and the IAEA International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO).

GIF brings together 14 countries and Euratom. The United Kingdom became the 15th GIF member in 2018. Since its launch in 2000, GIF has been working to carry out the research and development needed to establish the feasibility and performance capabilities of the next generation (Gen IV) reactor designs. These designs have stated objectives of safety, economics, sustainability and non-proliferation. In 2002, GIF reviewed 130 proposals and selected six nuclear energy system concepts to be the focus of continued collaborative research and development. These concepts include the sodium-cooled fast reactor, the very-high-temperature reactor, the supercritical-water-cooled reactor, the lead-cooled fast reactor, the gas-cooled fast reactor and the molten salt reactor. In 2016, the GIF Technology Roadmap was updated, taking into account plans to accelerate the development of some technologies by deploying prototypes and demonstrators within the next decade. Many of the Gen IV concepts also have the potential to provide heat in addition to electricity, and therefore target other energy market sectors (such as hydrogen production).

Established in 2000, the objective of INPRO is to help to ensure that nuclear energy is available to contribute, in a sustainable manner, to energy needs in the 21st century. Many member states along with the European Commission are engaged in this project. Holders and users of nuclear technology are being brought together to consider international and national actions that would produce the innovations required in nuclear reactors, fuel cycles or institutional approaches. INPRO assists member states in building national long-range nuclear energy strategies and making informed decisions on nuclear energy development and deployment.

In the long-term future, new reactor designs may bring fundamental changes to the nuclear fuel landscape, and thus to uranium demand.

Conclusion

As documented in this volume, sufficient uranium resources exist to support continued use of nuclear power and significant growth in nuclear capacity for electricity generation in the long term. Identified recoverable resources[7], including reasonably assured resources and inferred resources, are sufficient for over 130 years, considering annual uranium requirements of about 62 825 tU (data as of 1 January 2017). Exploitation of the entire conventional resource[8] base would increase this to well over 245 years, though uranium exploration and development, motivated by significantly increased demand and market prices, would be required to move these resources into more definitive categories.

The uranium resource base described in this document is more than adequate to meet projected growth requirements to 2035. Meeting projected low case requirements to 2035 would consume about 20% of the identified resources available at a cost of <USD 130/kgU and about 15% of identified resources available at a cost of <USD 260/kgU. Meeting high case growth requirements to 2035 would consume about 25% of identified resources available at a cost of <USD 130/kgU and about 20% of identified resources available at a cost of <USD 260/kgU. Given the limited maturity and geographical coverage of uranium exploration worldwide, there is considerable potential for the discovery of new resources of economic interest. As clearly demonstrated in the last few years, with appropriate market signals, new uranium resources can be readily identified and mined.

As noted in this report, there are also considerable unconventional resources, including phosphate deposits and black schists/shales that could be used to significantly lengthen the time that nuclear energy could supply energy demand using current technologies. However, more research and innovation effort and investment would need to be devoted to better defining the extent of this potentially significant source of uranium and developing cost-effective extraction techniques.

Deployment of advanced reactor and fuel cycle technologies could also significantly add to world energy supply in the long term. Moving to advanced technology reactors and recycling fuel could increase the long-term availability of nuclear energy from hundreds to thousands of years.

Sufficient nuclear fuel resources exist to meet energy demands at current and increased demand well into the future. However, to reach their full potential, considerable exploration, innovative techniques and investment will be required in order to develop new mining projects in a timely manner and to facilitate the deployment of promising technologies.

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7. Identified resources include all cost categories of reasonably assured resources and inferred resources for a total of about 7 988 600 tU (see Table 1.2).

8. Total conventional resources include all cost categories of reasonably assured, inferred, prognosticated and speculative resources for a total of about 15 519 200 tU (see Tables 1.2 and 1.14). This total does not include secondary sources or unconventional resources, e.g. uranium from phosphate rocks.

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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.

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* (www-nfcis.iaea.org). 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.

Thirty-six member countries submitted a response to the questionnaire and the NEA/IAEA drafted five country reports. As a result, there are a total of 41 national reports in the following section.

Algeria

Uranium exploration and mine development

Historical review

Over the past 40 years, uranium exploration in Algeria, which began with the launching of the mineral prospecting programme in the Hoggar region, went through an initial phase (1969-1973) marked by a significant investment effort, which 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, very swiftly identified the uranium mining potential of the Hoggar region, which has highly promising geological and metallogenic properties.

The aerial magnetic and spectrometric survey of the entire national territory carried out in 1971 lent fresh direction and impetus to uranium exploration. The processing of the data collected in this survey identified potential regions for further uranium prospecting, including Eglab, Ouggarta and the Tin Serinine sedimentary basin (South Tassili; where the Tahaggart deposit was discovered), as well as individual sectors in Tamart-n-Iblis and Timouzeline.

While these developments were taking place, uranium prospecting entered into a new phase (1973-1981) primarily aimed and focused on the assessment of reserves and the exploitation of previously discovered deposits.

Despite a very sharp slowdown in prospecting activities in the following phase (1984-1997), the work undertaken in the immediate vicinity of the previously discovered deposits and in other promising regions revealed indications of uranium deposits and radiometric anomalies in the Amel and Tesnou zones situated in the north-west and north respectively of the Timgaouine region.

Surveys conducted in the Tin Seririne basin (Tassili south Hoggar) provided a basis on which to establish a geological map and revealed also the distribution of uranium-bearing minerals in Palaeozoic sedimentary formations.

Recent and ongoing uranium exploration and mine development activities

No uranium prospecting or mine development work was carried out between January 2015 and January 2017.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Reasonably assured resources in Algeria are of two geological categories: 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 category includes vein deposits linked to the faults traversing the Pan-African batholith in the Timgaouine region, represented by the Timgaouine, Abankor and Tinef deposits of the south-west Ahaggar.

The second type is unconformity-related deposit represented by the Tahaggart, which is associated with the weathering profile (regolith) developed at the interface between the Pre-Cambrian basement and the Palaeozoic cover, and to the conglomerates at the base of the Palaeozoic sedimentary sequence in the Tin Seririne basin (south-east 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 resources in any other category than RAR.

Uranium production

Historical review

Algeria does not produce uranium.

Regulatory regime

The protection of the environment in relation to mining activities is covered by the following legislation:

- Law No. 14-05 of 24 February 2014 on mining activities;
- Law No. 03-10 of 19 July 2003 on the protection of the environment for sustainable development.

Uranium policies, uranium stocks and uranium prices

National policies relating 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 the uranium resources in Algeria.

Algeria's uranium resources can only be exploited in a sustainable manner as part of an integrated development of the nuclear sector and its main applications. The latter include, in particular, nuclear power generation and seawater desalination plants, together with applications in medicine, agriculture, water resources and industry.

With regard to 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.

Gaining control over the uranium cycle and its applications would require the acquisition of technical expertise that can only be gained through ambitious research, development and training programmes. Through its nuclear research centres, Algeria currently has the appropriate tools in place to start work in the future, either alone or through bilateral or multilateral co-operation on various research, development and training programmes.

It is in a spirit of openness and transparency that Algeria applied itself to the task of putting in place the most supportive and appropriate institutional and regulatory framework to provide a basis on which to pursue the energy development of the country, including a Mining Act, Electricity Act, and Oil and Gas Act.

To improve the mining sector and boost research, mining and exploration, the government resorted to the amendment of the Law 01-10 from 3 July 2001 by the enactment of Law 14-05 of 24 February 2014.

This new mining law aims to create better conditions for the revival of the sector through adequate funding for research and exploration of new economically exploitable mining deposits.

Uranium stocks

None.

Reasonably assured conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Proterozoic unconformity				2 000
Granite-related				24 000
Total				26 000

* In situ resources.

Reasonably assured conventional resources by production method

(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

* In situ resources.

Reasonably assured conventional resources by processing method

(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

* In situ resources.

Installed nuclear generating capacity to 2035

(MWe net)

2015	2016	2017		2020		2025		2030		2035	
		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

Argentina

Uranium exploration and mine development

Historical review

Uranium exploration activities in Argentina began in 1951-1952, leading 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 deposits in Patagonia.

During the 1960s, the Schlagintweit and La Estela vein 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.

The National Atomic Energy Commission (CNEA) selected the Cerro Solo sandstone-type uranium-molybdenum deposit to perform an assessment project in 1990, based on the deposit's promising grade. Mineralised layers are distributed in fluvial sandstone conglomerates belonging to the Cretaceous Chubut Group, at depths of 50 to 130 m.

An intensive exploration programme was developed to define the main morphological features of the orebodies and the mineralisation model, to update resource estimates, and to select preliminary mining-milling methods to carry out an economic assessment of the project.

From 1990 to 1997, exploration was conducted in the vicinity of the Cerro Solo deposit (Chubut Province), where more than 56 000 m was 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 a content of recoverable uranium resources estimated at 4 600 tU of reasonably assured resources and inferred resources.

These results allowed a pre-feasibility study of the U-Mo deposit. As a consequence, CNEA developed a programme to complete a preliminary economic assessment of the Cerro Solo deposit, including a geological model revision and ore resources estimate, mining and milling methods and their costs, cash flow and risk analysis, and the exploration and evaluation of the surrounding areas.

Recent and ongoing uranium exploration and mine development activities

Government

As a result of the policy to reactivate the nuclear programme announced in August 2006 by the national government, active exploration/evaluation on the Cerro Solo ore deposits have been undertaken since 2007. From 2007 to 2014, a total of 44 469 m has been drilled into the main mineralised areas in the Pichiñán district, including 4 030 m of core, which has been sampled for hydrometallurgical analyses. As of December 2012, the in situ identified uranium resources are 6 405 tU.

CNEA owns 64 exploration licences in Argentina, considering both requested and conceded exploration permits areas, statements of discovery, and ore deposits. They are located within the provinces of Salta, Catamarca, La Rioja, San Juan, Mendoza, La Pampa, Río Negro, Chubut and Santa Cruz.

The most relevant uranium ore deposit in the assessment/exploration stage in Argentina is Cerro Solo, located in Chubut Province.

In order to have a better knowledge of the uranium resources located at Cerro Solo, exploration and assessment works have continued through drilling programmes. In 2013, in Sector B, 18 assessment drillings were carried out, totalling 2 329 m. In 2014, towards the west of Sector C and over the east border of Sector B, 7 drill programmes, for a total of 914 m with core sample recovery, were undertaken. Subsequently, drilling was undertaken at La Volanta, located at the west of the aforementioned sectors, where a total of 1 666 m was drilled in ten exploration drill holes.

Within the period 2007-2014, a total of 36 931 m was drilled in 385 holes in the Cerro Solo Uranium District (former Pichiñán Este). It is worth mentioning that all drill holes were logged using caliper, long and short resistivity, spontaneous potential and gamma ray. Some tests were also performed with a sonic probe and a recently acquired gamma-ray spectrometry probe.

To facilitate the proposed uranium concentrate production from mineralised sectors B and C of Cerro Solo deposit, data including topographic, mineralised-levels and geological-mining information in digital and analogical format, were shared with the Raw Materials Production Management.

To define the hydrometallurgical extraction line of uranium and molybdenum mineral, laboratory-scale sample testing is nearly complete and further up-scale testing is being planned.

In situ uranium conventional resources (RAR and IR) estimated in sectors B and C of Cerro Solo deposit is 5 776 tU.

Other areas under study at Chubut Province are the Sierra Cuadrada Uranium District, located in south-eastern part of the province, where at least four uranium mineralised areas were recognised. Three of them: Sierra Cuadrada, Sierra Cuadrada Sur and La Meseta are defined as "statements of discovery" (SD), which means that there is a legal document certifying the discovery of these new mines or mining areas; and the last one, which has not been defined as an "SD", is the Unión exploration area.

In the Sierra Cuadrada Uranium District, a regional geological survey was carried out in an area of 4 000 ha with geological–radiometric data collection within three semi-regional profiles. Thereafter, four drill holes were drilled at SD Sierra Cuadrada (two holes) and Sierra Cuadrada Sur (two holes).

Two hundred kilometres north of the Cuadrada District, a discovery was made at the SD Mirasol Chico and El Cruce, where uranium ore is related to fluvial and lacustrine deposits of Cretaceous age. In the "SD" El Cruce, radiometric prospection works were followed by four drill holes with core sample recovery, resulting in 1 231 m, and logged with downhole tools to obtain electric profiles. The core samples were used to obtain lithological, chemical and radiometric determinations.

Finally, at SD Mirasol Chico the geological-topographic map was updated, covering an area of 2 000 ha, providing a base map to plan the 2015 drilling programme. Also with this aim, some points of access were conditioned and some locations for the drilling were built.

Regarding environmental preservation in the areas where exploration is conducted, monitoring networks are being implemented, adjusting the number of sampling points according to the knowledge and progress of the stage of the mining project.

From 2012 to 2016, the main activities at Cerro Solo ore deposit were related to environmental baseline studies and the development of hydrometallurgical tests. Among the first ones, hydrological, palaeontological, socio-economic studies, air quality, flora and fauna and pedological studies have been completed. Others such as archaeological and radiometric are being developed.

In the south of Argentina (Santa Cruz province), the main exploration works have focused on shallow low-grade uranium anomalies in six areas defined as a surficial deposit (calcrete-type), and within the Laguna Sirven area the focus is on defining the extension and continuity of uranium mineralisation to depths between 0.5 and 3 m.

At Laguna Sirven, laboratory hydrometallurgical tests have demonstrated that if the fine fraction can be separated (about 35% of the total volume) and concentrated by screening, the original grade could be doubled.

In the Urcal and Urcuschun deposits, located in La Rioja Province, uranium mineralisation is associated with limestone deposits from the Ordovician-aged San Juan Formation and is associated with chert and fault and fracture planes. It is also related to a sedimentary sequence from the Carbonic-Permian Paganzo Group. Exploration activities included vertical and semi-regional detailed geological profile surveys, geological and topographic map updating, and re-examination of old mining activities. Samples from mineralised zones have been taken for metallogenic studies.

In the second stage, activities were focused on geophysical exploration by means of standard geoelectrical methods and through the implementation of the dipole-dipole method. Those works were the foundations for the design of the current drilling programme.

In the SD Alipán I, Velasco Range, La Rioja Province (defined as a granite-related uranium-type, Perigranitic subtype deposit), systematic geochemical studies in new trenches were continued; two geological profile surveys with samples of water, rock and sediments were carried out, and geophysical exploration (audio-magnetotelluric and geoelectrical) to obtain structural and lithological information in depth was introduced. As a result, it was determined that the mineralised block occupies a “sloping” position towards the east over the oxidised sterile block.

For this area, there were 18 planned drillings, but only 3 of them have been executed to date (for a total of 885 m). The other 15 planned drillings were not undertaken due to anti-mining actions that have been carried out by local authorities and non-governmental organisations since 2013.

Over the eastern side of Velasco Range, towards the north of SD Alipán I, a new area of exploration, called Lucero exploration area, is being studied. There, results are encouraging and three zones with anomalies and evidence of surface uranium minerals were defined.

Gamma radiometric exploration airborne test surveys have been carried out with CNEA’s equipment in four sites within the Córdoba Ranges, reintroducing the application of an exploration technique that was halted for decades.

In Vaquería Range, Salta Province, and San Buenaventura Range, Catamarca Province, an area of over 100 000 ha, which corresponds to 12 exploration areas, was liberated because it did not have the frequency and concentration of uranium mineralisation associated with Cretaceous-aged sandstone deposits that was expected.

At the Mina Franca deposit, classified as a granite-related, perigranitic subtype uranium deposit, located in Fiambalá Range, Catamarca Province, surface systematic radiometric studies and structural-metallogenic mapping has been undertaken, while mineralogical analysis in the central and south sectors of Mina Franca are also being carried out. In 2015, surface geological reconnaissance activities are expected to be completed, which will provide the structural geological base map that will be used to plan a drill programme to define mineralisation at depth.

Simultaneously, a monitoring plan for water and sediment modules has been implemented as part of the baseline environmental survey. Moreover, communication programmes related to exploration activities in Fiambalá Range, and nuclear technology applications are being conducted in neighbouring populations and provincial offices.

With the aim of studying mineralisation behaviour in detail in the north and centre sectors of the Don Otto deposit, Salta Province, which has been classified as Cretaceous-aged sandstone-type uranium deposit, geophysical techniques (geoelectrical and magnetotelluric methods) were applied in order to collect subsoil data about the existing stratigraphic and structural sequence. Other activities conducted in the district included geomorphological studies, identification of depositional settings, lithological facies and ichnofacies and an exploration drilling programme.

Evidence of uranium found in oil wells – and, to a lesser extent, known from surface data – is under analysis in five exploration areas near Catriel town, Río Negro Province. Mineralisation is related to sedimentary deposits within the Neuquén Basin, and therefore could be classified as a sandstone-type uranium deposit. Exploration developed during the last two years has involved the application of geophysical techniques including an audio-magnetotelluric (AMT) study and vertical electrical sounding (VES). These studies were complemented with geochemical exploration and geological radiometric reconnaissance programmes in semi-regional profiles. The studies were aimed at obtaining a wider knowledge about subsoil geology and identified uranium anomalies. A drilling programme has been implemented.

Similar activities as those aforementioned were also carried out recently in four exploration areas within the area of Las Mahuidas.

Within the exploration area in Gobernador Ayala, La Pampa Province, some semi-regional geological recognition activities, including geochemical surveys and geophysical studies (AMT and VES) have been conducted. Information obtained from seven VES surveys were correlated to oil drilling records and revealed that there is a radiometric anomaly at a depth of less than 200 m. With this information, a drilling programme has been planned for the near future.

Private industry

There are six private uranium exploration companies in Argentina: Meseta Exploraciones S.A. (U3O8 Corp); Sophia Energy S.A.; Minera Cielo Azul S.A. (Blue Sky Corp); Cauldron Minerals Ltd; Gaia Energy Argentina S.A. and UrAmerica Ltd, all of which are currently members of the *Cámara Argentina de Empresas de Uranio* (CADEU – Argentine Chamber of Uranium Companies). CADEU reports 38 employees related directly to the industry (and 26 indirectly) at the end of 2012. No new data has been reported for 2016.

The information about private exploration expenditures must be taken as only partially complete, as the industry is not required to report these expenditures to the government.

Of all private companies mentioned above, only Meseta Exploraciones S.A. (MEXSA), Sophia Energy S.A. and UrAmerica Ltd were working with certain continuity during the last few years. The first two companies mentioned undertook uranium exploration in the south of the Chubut Province and in the north sector of Santa Cruz province, where exploration was focused on shallow low-grade uranium anomalies defined as a calcrete-type deposit.

In the Laguna Salada Project technical report of MEXSA, a subsidiary company of U3O8 Corporation, the following uranium resources were reported: 2 420 tU as indicated resources (reasonably assured resources), 1 460 tU as indicated resources and 21 330 tU as inferred resources. Initial metallurgical results show uranium and vanadium grades can be increased between 3 to 11 times by simple screening, followed by rapid uranium-vanadium extraction using alkaline leaching in the Guanaco area of the deposit, while acid leach is very effective in the Lago Seco area.

The other company, UrAmerica Ltd, undertook an intensive underground exploration programme supported by drilling of 250 holes, for a total of approximately 24 000 m, on neighbouring areas of the Cerro Solo ore deposit, in the Chubut Province. They report 7 350 tU as inferred resources. As reported by UrAmerica Ltd., about 75% of the uranium resources evaluated are in confined aquifers. Therefore, further geological and hydrological studies will be addressed to determine the amenability to in situ leaching mining.

More recently, Blue Sky Corp addressed the emphasis of the company's exploration in the newly delineated Amarillo Grande project in Río Negro Province, where the properties controlled by Blue Sky has defined a corridor of surficial-type U deposits of the district. The initial exploration efforts, which included geophysical surveys, were positive and as a result a drilling programme is under way.

Uranium resources

From governmental studies, there are no changes in reasonably assured, inferred and prognosticated resources since the last edition (2016 Red Book). However, resources of the private sector have been updated and reported.

To assess the uranium favourability and estimate the potential resources by the application of quantitative methods (e.g. US National Uranium Resource Evaluation) the country was divided into 61 investigation units (IU). These areas, which cover 1 450 000 km^2 of the country, were delineated on basis of the geotectonic context and the petrological, mineralogical and geochemical characteristics. Speculative uranium resources account for 79 450 tU according to the resource assessment that has been completed in 5 IU and which are considered the units with the most uranium potential (i.e. Salta Group Basin, Pampean Ranges, Paganzo Basin, San Rafael Basin and Chubut Group Basin).

In addition, qualitative methodologies based on spatial modelling and mineral systems concepts have been applied to determine uranium exploration targets.

Some prospective studies have been conducted, notably related to uranium from phosphates (unconventional resources). In the framework of an IAEA Coordinated Research Project preliminary studies are under way for the assessment of the uranium potential of phosphate rocks and testing low-grade phosphate ores extraction.

Uranium production

Historical review

Argentina produced uranium from the mid-1950s until 1999 with a total of seven commercial-scale production centres and a pilot plant that operated between 1953 and 1970. The closure of one of the last of these facilities in 1995 (Los Colorados) resulted in a change in the ownership structure of uranium production in Argentina, and since 1996 the uranium mining industry has been wholly owned by CNEA. The last facility that remained operative at that time, San Rafael, was placed on standby in 1997. No uranium has been produced since then, neither privately nor by state. Between the mid-1950s and 1997, cumulative uranium production totalled 2 582 tU.

Status of production facilities, production capability, recent and ongoing activities and other issues

Production projects

Argentina produced about 120 tU/year for about 20 years to provide raw material to fuel the nuclear power plants Atucha I and Embalse, with ore from different sites distributed throughout the national territory. But in the late 1990s, the decline in the international price of uranium made domestic production no longer competitive and the decision to shut down the remaining production plants and import uranium was taken. However, changes in recent years have caused CNEA to review its plans and consider reopening production facilities. These changes include mainly the uncertainties in future external supply and the increase in domestic uranium requirements upon the full capacity operation of the Atucha II reactor, which was reached in 2015. In addition, the potential addition of two new nuclear power plants and the development of the new CAREM-25 reactor will further increase the domestic uranium requirement, which would be approximately 500 tU/year in the medium-term future.

The San Rafael Mining-Milling Complex (CMFSR) Remediation and Reactivation Project

Once 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 of 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 this proposal, arguing that CNEA must first remediate the open-pit water and the milling wastes stored in drums before restarting the production. In response, 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) that prohibits the use of sulphuric acid, among other chemicals, in mining activities.

Currently, CNEA is carrying out the construction of evaporation ponds and defining the basic engineering of the simultaneous treatment of open-pit water and milling wastes stored in San Rafael complex. To date, three effluent evaporation ponds have been finished and one more is under construction. Besides, an update of the EIA 2006 (EIA, 2013) has been presented to the provincial control authorities, which is currently under review by the provincial authorities.

CNEA secured sufficient funds for the rehabilitation works of uranium production facilities from the Bank for Investment Projects in the Ministry of Economy. Having an approved budget means that more time and resources can be devoted to addressing the remediation and rehabilitation works. These activities involve the removal of obsolete facilities, construction of effluent ponds, purchase of equipment and facilities, and other associated activities. Before the rehabilitation of uranium production in San Rafael, however, it is necessary to obtain both provincial approval and agreement to amend the provincial law that prevents the use of sulphuric acid. To overcome this law’s restriction, there are plans to change the technology in use to alkaline leaching.

The Cerro Solo Project

CNEA continues developing feasibility studies for the proposed mining of the Cerro Solo deposit (Chubut Province). Several laboratory-scale tests have been carried out to determine the most economically competitive milling process. Since the deposit contains molybdenum in addition to uranium, identifying an appropriate and feasible process is not trivial. Molybdenum not only could be used as a valuable by-product, but also its presence in the leachate could poison the exchange resins, so another process, like liquid-liquid extraction, may be used. For this reason, all preliminary investigations have been critical steps for development of a profitable production plan. Recently, the conceptual engineering has been defined.

In the mining sector, a conceptual study was conducted using specific software for geological modelling. A pre-technical economic feasibility study was completed, with prior validation of all information (tonnages, grade, geotechnical, geostructural and hydrogeological) with some surface works.

Currently, governmental funds are intended to be used to carry out the basic engineering studies of both the mining operation and also the processing plant.

Besides technical considerations, a Chubut provincial Law 5001/03 that prevents open-pit mining is still 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 mining regulatory framework for this jurisdiction.

Ownership structure of the uranium industry

In Argentina, the uranium industry is currently 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.

Uranium production centre technical details

(as of 1 January 2017)

	Centre #1	Centre #2
Name of production centre	San Rafael Mining-Milling Complex	Cerro Solo Deposit
Production centre classification	Standby	Planned
Date of first production	1976	NA
Source of ore:		
Deposit name(s)	Sierra Pintada	Cerro Solo
Deposit type(s)	Volcanic-related, synsedimentary	Sandstone, paleochannel
Recoverable resources (tU)	6 000	N/A
Grade (% U)	0.107	N/A
Mining operation:		
Type (OP/UG/ISL)	OP	OP-UG
Size (tonnes ore/day)	550	N/A
Average mining recovery (%)	90	N/A
Processing plant:		
Acid/alkaline	Acid	Acid
Type (IX/SX)	IX	SX
Average process recovery (%)	78	N/A
Nominal production capacity (tU/year)	150	200
Plans for expansion	Yes	N/A
Other remarks	Standby since 1997	Preliminary stage

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

The strategic plan submitted by CNEA includes the development of a new production centre in the Chubut Province, in the area of the Cerro Solo deposit.

Production and/or use of mixed oxide fuels

Argentina neither produces MOX fuel nor uses it in its nuclear power plants.

Production and/or use of re-enriched tails

The Mock-up facility for uranium enrichment located in Pilcaniyeu Technological Complex (Bariloche) is a pilot plant that was already operating in the 1980s and the beginning of 1990s, until it was deactivated in 1995. The project was relaunched in 2006, restarting its activities in 2007.

The start-up of the operations took place in March 2014, enabling Argentina to produce enriched uranium by gaseous diffusion technology. CNEA aims to use this technology for supplying NPPs currently in operation, plus the projected ones. Furthermore, CNEA is currently developing other technologies such as ultra-centrifuge and laser.

Environmental activities and socio-cultural issues

Environmental impact assessments

In Argentina, production permits are subject to both national and provincial legislation. At this moment, environmental studies are being undertaken in two major uranium production projects.

The San Rafael Mining-Milling Complex Remediation Project (Mendoza Province)

As stated in the 2016 edition of the Red Book, an update of the 2004 EIA (2006 EIA and MGIA-2013) was presented to the authorities of the province of Mendoza. This study addresses only the treatment of solid wastes, currently in temporary storage, and open-pit mine water. The original proposal (2006 EIA) received technical approval, but not final approval because it lacked the statutory public hearing, which is due to be held as soon as the 2013-MGIA edition receives technical endorsement. Nevertheless, CNEA has continued with some improvements to preserve the environment along with establishing additional security measures:

- Effluent pond "DN 8-9"

The construction of an evaporation pond (5 hectares) with a double liner waterproof high-density polyethylene (HDPE) geo-membrane with a leakage detection system has been completed, and hydraulic tests have been successfully accomplished. It is currently being used to manage open-pit water.

- Effluent pond "DN 5"

Civil works for ground stabilisation have been completed. The design of this precipitation facility complex aims to treat open-pit water; engineering details have been submitted to the local authorities to determine the corresponding allowance and to continue with the works. These ponds sum up an operative capacity of approximately 12 000 m^3 and will have security drainage systems and double waterproofing HDPE geo-membrane to control leaks. These ponds are designed for providing the necessary conditions (residence time) to generate As and Ra precipitates before they are conducted to the effluent pond "DN 8-9" for final disposal.

- Other remediation activities

Other activities related to waste management are been carried out, such as cisterns, waterproofing, design of wastewater treatment systems, repairing facilities and the installation of pipes for pumping effluents between the quarries and the processing and treatment facilities.

Cerro Solo ore deposit (Chubut Province)

As requested by the provincial authorities, environmental baseline studies are being developed by CNEA through contracts with universities and institutes, and some parts of the studies (archaeological, palaeontological and socio-economic impact) have already been presented to the provincial authorities. In addition, CNEA continues with social communication activities, offering information on mining activities to the neighbourhoods located near the proposed mining projects and areas of exploration.

Monitoring

The San Rafael Mining-Milling Complex Remediation Project (Mendoza Province)

CNEA currently has an intense monitoring programme, which includes:

- Surface water: systematic sampling of surface water – run-off, upstream and downstream of the facilities are undertaken to follow the evolution of possible pollutants concentration (U, As, Ra, among others) inside and outside CNEA's influence area.
- Groundwater: systematic sampling of groundwater within a redesigned well network inside the complex is being carried out.
- Air pollution: particulate matter and radon emissions are periodically sampled within key locations of the complex.
- Open-pit water: systematic sampling of open-pit water is being carried out in every pit.

Cerro Solo ore deposit (Chubut Province)

The sampling work includes 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). Air pollution samples include particulate matter and radon emissions measurements.

Effluent management

The San Rafael Mining-Milling Complex Remediation Project (Mendoza Province)

The construction of the "DN 8-9" evaporation pond and the "DN 5" facility for treating open-pit water, aims to reduce pollutants and meet provincial water quality standards. Moreover, the design and implementation of a domestic wastewater treatment system is under study.

Site rehabilitation

The San Rafael Mining-Milling Complex Remediation Project (Mendoza Province)

In general, CNEA is submitting technical proposals to rehabilitate those areas of the complex that will not be used for uranium production in the future. Topics of these projects include: former tailings dump, open-pits rehabilitation and waste rock management, among others.

Uranium Mining Environmental Restoration Programme

Currently, 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. The sites being studied are: Malargüe (Mendoza Province), Córdoba (Córdoba Province), Los Gigantes (Córdoba Province), Huemul (Mendoza Province), Pichiñán (Chubut Province), Tonco (Salta Province), La Estela (San Luis Province), and Los colorados (La Rioja Province). PRAMU seeks to improve the current conditions of the tailings deposits and mines and 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, etc.). The local regulation co-exists with national legislation related to mining activities and environmental protection.

National regulations

- Law No. 25 675: "General Environmental Law" establishes minimum standards for achieving a 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: Obligation of submitting 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 and states that their specific functions are the administration, control and promotion of the mining industry in all its phases and throughout the territory of the province.
- Law No. 7 722 prohibits on the territory of the Mendoza Province, the use of chemicals such as cyanide, mercury, sulphuric acid, and other similar toxic substances in metalliferous mining, including prospecting, exploration, exploitation and industrialisation of metal ores obtained by any extraction method.
- Resolution No. 778/96 of the General Department of Irrigation (DGI) regulates all activities that may affect the quality of surface water and groundwater in the territory of the Province of Mendoza.

Chubut provincial regulations

Law XVII-No. 68 prohibits open-pit methods for metal mining activity in the province of Chubut, as well as the use of cyanide in mining production processes. It also mentions the need of zoning in the territory of the province for the exploitation of mineral resources with an approved production model for each case.

Uranium requirements

The uranium requirements listed below correspond to an estimation made in the Strategic Nuclear Energy Planning 2010-2030 and the reactivation of the Argentine Nuclear Energy Plan launched in 2006. As of 2013, the nuclear plan includes:

- extending the life of Embalse NPP (in progress);
- extending the life of Atucha I NPP;
- construction of the 4th and 5th NPPs (planned);
- development and construction of a small modular nuclear power reactor (CAREM) (in progress);
- reactivation of uranium enrichment (in progress);
- reactivation of uranium mining industry.

The most important update in Argentine nuclear production was the start-up of Atucha II (745 MWe), reaching first criticality at the end of 2014.

Also proposed is the expansion of the nuclear energy network, which would be covered by the construction of the 4th and 5th NPPs consisting of one PHWR-type reactor (CANDU 6) of 700 MWe and a PWR-type reactor of 1 150 MWe.

In addition, CNEA is currently carrying out the construction of the CAREM-25 (25 MWe) small modular reactor prototype and is planning to build another two larger units, CAREM-150 (150 MWe by 2032).

Embalse has been out of the electricity generation system for two years for refurbishment tasks designed to extend its useful life for a term of 30 years, which will include an increase in its power by an additional 35 MWe. Within the 2019-2020 period, Atucha I will be inoperative and at that time will undergo facility refurbishment.

Supply and procurement strategy

Argentina is carrying out an exploration programme and it is developing projects for restarting domestic uranium production to achieve self-sufficiency in uranium supply.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

The Nuclear Activity Law of 1997 establishes the respective roles of CNEA and the Nuclear Regulatory Authority. It also provides for the participation of both public and private sectors in uranium exploration and development activities.

The National Mining Code of 1994 states that the government has the first option to purchase all uranium produced in Argentina and that export of uranium is dependent upon first guaranteeing domestic supply. It also regulates development activities to ensure the use of environmental practices that comply with international standards.

Uranium stocks

Nowadays, CNEA does not have the responsibility of ensuring the uranium concentrate stock. The uranium dioxide producing company (Dioxitek S.A.) and the nuclear power plants operator (Nucleoeléctrica Argentina S.A., NA-SA) hold the responsibility of guaranteeing a uranium stock for at least two years of Argentina's nuclear power plants operation.

Uranium prices

There is no uranium market in Argentina.

Uranium exploration and development expenditures and drilling effort – domestic

(in Argentine pesos [ARS])

	2014	2015	2016	2017 (preliminary)
Industry* exploration expenditures	N/A	N/A	N/A	22 500 000
Government exploration expenditures	34 500 000	53 331 800	60 200 000	16 000 000
Total expenditures	34 500 000	53 331 800	60 200 000	38 500 000
Industry* exploration drilling (m)	N/A	N/A	N/A	5 000
Industry* exploration holes drilled	N/A	N/A	N/A	40
Government exploration drilling (m)	3 494	2 752	1 114	0
Government exploration holes drilled	24	27	6	0
Total drilling (m)	3 494	2 752	1 200	5 000
Total number of holes drilled	24	27	6	40

* Non-governmental.

Reasonably assured conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Sandstone		2 890	4 600	4 600	72
Volcanic-related		2 240	4 000	4 000	72
Surficial			2 420	2 420	70
Total		5 130	11 020	11 020	

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)			180	180	72
Open-pit mining (OP)*		5 130	10 840	10 840	72
Total		5 130	11 020	11 020	

* Industry share of 22% with a recovery factor of 70%.

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 (%)
Heap leaching* from UG	0	0	180	180	72
Heap leaching* from OP	0	5 130	8 420	8 420	72
Unspecified	0		2 420	2 420	70
Total		5 130	11 020	11 020	

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

Inferred conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Sandstone	1 950	2 200	11 360	12 410	72
Volcanic-related	480	1 800	6 170	6 170	72
Surficial			1 460	1 460	70
Total	2 430	4 000	18 990	20 040	

Inferred conventional resources by production method

(tonnes U recoverable, assuming 72% mining and milling recovery)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Open-pit mining (OP)	2 430	4 000	11 390	12 440	72
Underground mining (UG)			250	250	72
Unspecified			7 350	7 350	72
Total	2 430	4 000	18 990	20 040	

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	2 430	4 000	9 930	10 980	72
Heap leaching from OP			1 460	1 460	70
Heap leaching from UG			250	250	72
Unspecified			7 350	7 350	72
Total	2 430	4 000	18 990	20 040	72

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
N/A	13 810	13 810

Speculative conventional resources

(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
N/A	79 450*	N/A

* Estimated over five investigation units.

Historical uranium production by deposit type

(tonnes U in concentrate)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Volcanic-related	1 600.0	0	0	0	1 600.0	0
Sandstone	729.2	0	0	0	729.2	0
Granite-related	252.5	0	0	0	252.5	0
Total	2 581.7	0	0	0	2 581.7	0

Historical uranium production by production method

(tonnes U in concentrate)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Open-pit mining[1]	1 858.7	0	0	0	1 858.7	0
Underground mining[1]	723.0	0	0	0	723.0	0
Total	2 581.7	0	0	0	2 581.7	0

1. Pre-2012 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 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Conventional	752.7	0	0	0	752.7	0
Heap leaching*	1 829.0	0	0	0	1 829.0	0
Total	2 581.7	0	0	0	2 581.7	0

* Also known as stope leaching or block leaching.

Uranium industry employment at existing production centres

(person-years)

	2014	2015	2016	2017 (expected)
Total employment related to existing production centres	85	82	65	58
Employment directly related to uranium production	0	0	0	0

Short-term production capability

(tonnes U/year)

2017				2020				2025			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	0	0	0	0	0	0	0	0	0	NA	NA

2030				2035			
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

Net nuclear electricity generation

	2015	2016	2017
Nuclear electricity generated (TWh net)	6.52	7.68	7.00 (estimated)

Installed nuclear generating capacity to 2035

(MWe gross capacity)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
1 213	884	1 107	1 107	1 460	1 460	2 200	2 682	3 470	4 072	4 890	5 950

Annual reactor-related uranium requirements to 2035 (excluding MOX)

(tonnes U)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
157	107	127	127	140	194	292	359	530	624	799	988

Armenia

Uranium exploration

Historical review

On 23 April 2007, the Director-General of Rosatom (a state corporation of Russia) and the Armenian Minister of Ecology Protection signed a protocol on the realisation of uranium exploration work in Armenia.

Based on this protocol, an Armenian-Russian joint venture, CJ-SC Armenian-Russian Mining Company (ARMC), was established in April 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 has been completed. The document *Geologic Exploration Activity for 2009-2010* aimed at the uranium ore exploration in Armenia was published and approved. According to this document, in the Spring of 2009, field work related to uranium ore exploration started in the province of Syunik.

Geological prospecting works were carried out on the 1st Voghchi zone of the Pkhrut-Lernadzor licensed area in 2011. Geologic prospecting identified some anomalies. All plans for geologic prospecting in 2011 were fulfilled by January 2012. In 2012, legislated works were implemented.

Exploration of the block 1st Voghchi zone identified reserves of uranium ores classified in category C2. Calculations of inferred resources of the Voghchi zone of the Pkhrut deposit indicated that the deposit is prospective.

In 2013, the Armenian-Russian joint venture was suspended.

Uranium production

In 2007, the Armenian government decided that Armenia would enter into 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.

Armenia does not produce uranium.

Uranium requirements

There have been no changes to Armenia's nuclear energy programme during the past two years. The country's short-term uranium requirements remain the same and are based on the operation of one VVER-440 unit (Armenian-2). A detailed forecast for uranium requirements was carried out, taking into account the designed lifetime for this reactor, which has an installed capacity of about 407.5 MWe.

According to the Armenian energy sector development plan, construction of a new nuclear unit is envisaged by 2025, according to the high-level forecast. The Ministry of Energy Infrastructures and Natural Resources released the "Armenia New Nuclear Unit Environmental Report" in April 2011.

Long-term requirements depend on the country's policy in the nuclear energy sector. On 23 October 2013, the President of the Republic of Armenia signed an executive order on the Approval of the Concept of Ensuring the Energy Security of Armenia. On 31 July 2014, the Armenian government adopted the Action Plan on Implementation of the Energy Security Measures. Long-term development of the Armenian energy sector (i.e. up to 2036) was approved by the government on 10 December 2015. According to this document there is a need for a new nuclear power plant with a capacity of up to 600 MWe for ensuring the necessary level of energy security and energy independence by 2027.

Supply and procurement strategy

Nuclear fuel for the reactor of the Armenian NPP is supplied by Russia. Armenia's nuclear fuel requirements has remained unchanged for the past two years. The procurement strategy has remained unchanged and the country's uranium supply position continues to be based on fuel procurement from Russia. The requirements for the new unit will depend on the reactor type.

Net nuclear electricity generation

	2015	2016
Nuclear electricity generated (TWh net)	2.57	2.2

Installed nuclear generating capacity to 2035

(MW(e) net)

2015	2016	2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High
375	375	375	375	375	375	600	600	600	600

Annual reactor-related uranium requirements to 2035 (excluding MOX)

(tonnes U)

2015	2016	2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High
64	64	64	64	64	64	129	129	129	129

Australia

Uranium exploration

Historical review

Australia has maintained involvement in the uranium industry since its inception and the nation 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 for the commodity were relatively high. Uranium exploration budgets have generally declined since that time and only one major greenfields discovery has been documented since 1980 with the discovery of Kintyre in Western Australia by Conzinc Riotinto of Australia (CRA) in 1985. Despite the lack of major recent greenfields discoveries, the resource base has grown through significant brownfields extensions to known resources and some new occurrences delineated proximal to these with similar geology.

Discovered by Western Mining in 1975 and owned/operated by BHP Billiton (BHP) since 2005, the Olympic Dam mine in South Australia is the world's largest single uranium resource, with continuous production maintained since 1988. Australia's uranium has usually been produced from a small number of mines (often three, stemming at times from the Labor Party's Three Mines Policy), though production has shifted localities over time. Mining has proceeded at: Mary Kathleen and Westmoreland in Queensland; Radium Hill, Mount Painter, Honeymoon, Four Mile and Beverley in South Australia; along with Ranger, Narbalek and Rum Jungle in the Northern Territory.

Most of Australia's uranium resources occur in two main types of deposits: either breccia complex deposits such as Olympic Dam or unconformity-related deposits such as Ranger or Kintyre. Other categories include: sandstone uranium deposits, for example Honeymoon; surficial (calcrete) deposits such as 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.

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 Commonwealth and relevant state or territory governments, augmenting Australia's favourable geological settings. Exploration expenditure for uranium dropped from AUD 44.0 million in 2015 to AUD 23.4 million in 2016, though the Australian Bureau of Statistics reported a moderate upswing in the 2016 December quarter, revealing the potential for a slightly stronger forecast for 2017. Uranium exploration tended to be around known resources in Western Australia, the Northern Territory, South Australia and Queensland.

Western Australia (WA)

- Mulga Rock

The sandstone-hosted Mulga Rock resource was discovered by Japanese government-owned Power Reactor and Nuclear Fuel Development Corporation (PNC) Exploration in 1979. It is located 240 kilometres east of Kalgoorlie in Western Australia and consists of four deposits: Ambassador, Emperor, Princess and Shogun. After meeting development approval requirements in Western Australia and then securing Commonwealth government approval in March 2017, Vimy Resources announced that development work for the Mulga Rock Uranium project commenced on 10 March 2017.

The project involves shallow open-pit mining of four polymetallic deposits with commercial grades of uranium situated in sandstone-hosted carbonaceous material. The project has a life of mine of 17 years and is anticipated to produce 1 360 tonnes of uranium oxide concentrate annually. Following extraction of the uranium, other metal concentrates will be produced containing copper, zinc, nickel, scandium and cobalt.

- Yeelirrie

The surficial calcrete-hosted Yeelirrie uranium resource, located about 420 km north of Kalgoorlie in Western Australia, was discovered by Western Mining in 1972. Yeelirrie is suited to open-cut mining technology due to the proximity of the resource to the land surface and most of the ore will not require drilling or blasting. Cameco acquired the Yeelirrie project from BHP in 2012 and has worked to obtain approval to develop the project since acquisition.

During the project assessment process for Yeelirrie, Western Australia's Environment Protection Authority recommended against approval because there was potential for the loss of stygofauna and troglofauna species in the project area. Taking into account broader economic and social matters, as well as environmental factors, the Western Australian government granted approval to mine at Yeelirrie in January 2017. The approval is subject to 17 conditions, with Cameco required to undertake further research to minimise impacts on the subterranean species. According to Cameco, the potential risks can be mitigated and these project advancements position the company well, should favourable market conditions eventuate.

- Kintyre

The unconformity-related Kintyre uranium deposit was discovered by CRA in 1985 and has a resource of more than 21 000 tU. Following other commercial transactions, Kintyre was acquired by Cameco in 2008 (with a 30% interest held by Mitsubishi Development). Kintyre is located in the East Pilbara region of Western Australia, approximately 260 km north-east of Newman at the western edge of the Great Sandy Desert. The Kintyre resource is suited to open-pit mining technology; the uppermost parts of the resource are 50 m below surface, though there is no outcrop. Cameco continues to advance Kintyre while considering market conditions. The company signed an Indigenous Land Use Agreement with traditional owners, the Martu people, in 2012. Cameco secured environmental approval for the Kintyre project in 2015 from the Commonwealth and Western Australian governments, subject to conditions covering radiation, ground and surface water, terrestrial fauna and mine closure.

- Wiluna Area

Toro Energy's Wiluna project is based around a planned processing facility 30 km south of the town of Wiluna. The surficial calcrete-hosted regional resource consists of six deposits: Centipede, Lake Way, Millipede, Lake Maitland, Dawson Hinkler and Nowathanna. The Wiluna area resource of over 38 000 tonnes of uranium oxide (32 310 tU) would be sufficient to operate the proposed mine for more than 20 years. Mining of the Centipede and Lake Way uranium deposits and construction of the processing facility was approved by the Western Australian Environment Minister in 2012 and the Commonwealth Environment Minister in 2013. Following assessment of Toro's expanded Wiluna project proposal encompassing the Lake Maitland and Millipede resources, Western Australian government approval was granted in January 2017 and the company is working to also finalise Commonwealth environmental approval for the expanded proposal. The project would be developed through open pits, utilising alkaline leach technology and in pit tailings disposal.

Following the Western Australian state election in March 2017, the incoming government restated its policy banning new uranium mines. The newly elected Premier and Mines Minister confirmed the policy position prior to the election that those uranium projects with "all necessary approvals in place for operation" would be permitted to proceed, pending further advice from the state Department of Mines and Petroleum.

South Australia (SA)

South Australia has five approved uranium mines: Olympic Dam, Honeymoon, Beverley, Beverley North and Four Mile, only two of which continued production during 2016.

- Olympic Dam

BHP's breccia complex-hosted Olympic Dam is Australia's largest mine, contributing around two-thirds of Australia's uranium production. Plans for a large expansion at Olympic Dam have been scaled back, although BHP plans to gradually increase production capacity and commence new underground operations in the "Southern Mining Area" of the resource in 2018, under existing approvals. While production is planned to remain stable output may increase due to improved resource grades. During 2016, unplanned power outages in South Australia constrained output from Olympic Dam.

- Beverley and Four Mile

The Beverley, Beverley North and Four Mile mines use in situ recovery to extract uranium from sandstone-hosted deposits. The mines are located around 550 km north of Adelaide. The Beverley and Beverley North mines have been on care and maintenance since early 2014 but retain approval to operate. Production is currently focused on the nearby Four Mile mine, from which leach solution is processed at the Beverley processing plant.

- Honeymoon

Operated by Boss Resources, the sandstone-hosted Honeymoon deposit is currently in care and maintenance; however, it is remains approved for mining, and exploration and metallurgical test work continues. Additional resources were identified at Jason's deposit resulting in a total published resource of over 24 000 tU, adjusted to exclude previous production from the resource. The company proposes to undertake test leach processing late in 2017.

Northern Territory (NT)

- Ranger

The Ranger mine, operated by Energy Resources of Australia (ERA – majority owner Rio Tinto) is the only operating uranium mine in the Northern Territory. The Ranger deposit is classified as an unconformity-related resource in the Pine Creek Inlier. Continuous production and export of uranium oxide concentrate has been maintained from Ranger since operations commenced in 1980. Mining operations ceased in 2012, with ongoing production from 2013 maintained through stockpiled ore material. The mine is a significant employer of indigenous people in the Ranger area, holding a range of positions in the operation.

Mining of Ranger Open Pit 1 ceased in 1994, and with work continuing intermittently around other activities, the operator began filling the pit with tailings and then waste rock. A laterite clay cap was placed over the pit surface in 2016. Open Pit 3 was exhausted in 2012 and following initial waste rock disposal will be filled with approximately 26 million tonnes of tailings transferred from the tailings storage facility by a custom built dredge "Jabiru".

- Queensland (Qld)

Queensland hosts more than 80 known sites that contain valuable amounts of uranium, mainly in the remote northwest of the state. In March 2015, the incoming Queensland government announced it intended to reinstate a ban on uranium mining. The ban had been repealed in 2012 by the previous government following a period of over 30 years during which no uranium mining had been undertaken in the state.

New South Wales (NSW)

Uranium exploration was prohibited in New South Wales for 26 years until the then state government overturned the ban in 2012. A ban on uranium mining and the construction or operation of nuclear reactors for the production of electricity remains in place. Six companies were invited by the government to apply for uranium exploration licences. One company submitted an application to explore for uranium north of the town of Broken Hill, but subsequently withdrew the application in April 2016.

Uranium exploration and development expenditures – abroad

Through 2015 and 2016, several Australian-listed mineral companies undertook exploration activities for uranium in Canada, Kyrgyzstan, Malawi, Namibia, Peru and Tanzania.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

At 1 January 2017, Australia's total identified resources of uranium recoverable at a cost of less that USD 130/kg U amounted to 1 818 299 tU, a slight increase compared to the estimate for 1 January 2015. Over the two-year period additional resources were defined at known deposits and the prevailing market conditions for uranium combined with increases in the costs of mining and milling uranium ores in recent years resulted in some resources being shifted to higher cost categories. Furthermore, reclassification due to changes in access to known resources has been incorporated. Capital costs have risen and labour costs in the mining industry increased at a higher rate than for other sectors of the economy as a result of a period of rapid growth in the Australian mining sector.

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. Mining losses derived from company reports were generally 5 to 10% for open-cut mines, around 15% for underground mining methods and over 20% for in situ recovery.

Metallurgical recovery rates achieved by operating uranium plants were reported in company annual reports and these deductions were applied to JORC reserve and resource figures. These losses ranged from 14 to 28%. For in situ recovery (ISR) operations, 25% losses were applied for acid leach and 35% for alkaline leach.

Although there are more than 35 deposits with identified resources recoverable at costs of less than USD 130/kg U, the vast majority of Australia's resources are within the following six individual deposits:

- Olympic Dam, the world's largest uranium deposit, and low-grade occurrences at Carrapateena in South Australia;
- Ranger and Jabiluka in the Alligator Rivers Region of the Northern Territory;
- Kintyre and Yeelirrie in Western Australia.

At the Olympic Dam mine, uranium is a co-product of copper mining; in addition gold and silver are also recovered. At the proposed Carrapateena mine, uranium would not be recovered and the metal would report to tailings.

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 or publish estimates of Australia's unconventional uranium resources. Estimates are not made for Australia.

Uranium production

Historical review

The current phase of Australian uranium production commenced in 1976 and current exports are around six thousand tonnes of uranium (tU) per annum or around 9% of the global market. Uranium produced in Australia is exported to countries in North America, Asia and Europe for use as fuel in nuclear power stations to generate electricity.

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.

Status of production capability and recent and ongoing activities

At 1 January 2017, Australia had three operating uranium mines: Ranger (Northern Territory), Olympic Dam and Four Mile (South Australia) with that operation's pregnant solution being processed at the Beverley plant. The operator of the Mulga Rock Uranium project in Western Australia, Vimy Resources, announced in March 2017 that work had commenced on-site in order to expedite development once the final investment decision is made and full-scale construction started. Honeymoon in South Australia, operated by Boss Resources, maintains the necessary approvals, but remains on care and maintenance.

Total uranium mine production for 2016 was estimated by the Commonwealth Department of Industry, Innovation and Science to be 6 313 tonnes, a 21% increase on the 5 000 tonnes produced in 2014.

Olympic Dam

Olympic Dam's production of payable metal in concentrate for 2016 was 3 232 tonnes of uranium (tU), a slight increase on the 3 161 tU for 2015, and a 4% decrease on the 3 351 tU produced in 2014. Based on a reserve life of 47 years and more than one million tonnes of uranium resource, the Olympic Dam uranium deposit is the largest single deposit in the world. The Olympic Dam deposit is 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 wholly BHP owned underground mine and plant utilises long-hole open stoping technology and cemented aggregate fill, with integrated metallurgical processing.

BHP is not proceeding with plans for a large single step expansion of Olympic Dam, however, the company has announced increased efforts to concentrate on removing bottlenecks and gradually expanding production. An application for assessment was lodged with the Commonwealth and South Australian governments in July 2014 to construct and operate a demonstration plant on the existing mining lease at Olympic Dam.

BHP is undertaking laboratory trials of heap leach technology to review various options and inputs to improve the technology's robustness, economics and to understand environmental performance in terms of radiation progeny with the objective of employing less capital-intensive mineral processing technology. Results recorded from these laboratory trials have been effective so far and the company and is yet to make an investment decision for the on-site trial. BHP also announced that smelting test work using concentrates produced from laboratory heap leach trials and existing operations would be undertaken in Finland to inform future on-site smelting processes.

Power outages experienced in the South Australian supply network impacted upon 2016 production from Olympic Dam as a consequence of resulting shut downs.

Ranger

ERA has produced uranium at Ranger since 1981, with more than 110 000 tonnes of uranium oxide concentrate (93 280 tU) produced. The Ranger uranium mine produced 1 993 tU in 2016, a 17% increase on the 1 700 tU produced in 2015 and double the 994 tU produced in 2014. Mining of Ranger Pit 3 concluded in December 2012. Although mining has now ceased, stockpiled ore continued to be processed at the main metallurgical plant and the laterite treatment plant.

Ranger 3 Deeps was discovered in 2009 and is estimated to contain over 34 000 tonnes of uranium oxide (28 830 tU). ERA invested around AUD 120 million into an exploration decline, which was commenced in 2012 and completed in 2014, providing access to the resource for further analysis and assessment. ERA's majority owner (68.4%) Rio Tinto announced in 2015 that after careful consideration the company did not support further study or the future development of Ranger 3 Deeps due to economic challenges facing the project. The Gundjeihmi Aboriginal Corporation advised ERA in 2016 that the Mirarr Traditional Owners do not support the creation of a new Ranger Authority, which would provide the regulatory mechanism to enable mining after 2021. The existing Ranger Authority allows for mining and processing activities until 8 January 2021 and access for rehabilitation activities until January 2026.

Beverley/Beverley North

The sandstone-hosted Beverley resources, located east of the Flinders Ranges in South Australia, commenced operations in 1990. Production from Beverley started in late 2000 making it Australia's first operating ISR mine. Operated by Heathgate Resources, production from Beverley and Beverley North ceased in early 2014 and the project is now on care and maintenance. Processing of the product from the Four Mile mine is continuing at the Beverley plant. Government approvals for Beverley and Beverley North remain and, should commercial conditions change, the company could recommence production from these resources.

Four Mile

The Four Mile resource comprises two significant sandstone-hosted uranium deposits, Four Mile East and Four Mile West operated by Heathgate Resources on behalf of Quasar Resources. 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 is trucked to the Beverley processing plant for elution, precipitation and drying of the uranium concentrates.

The initial phase of ISR mining operations has allowed for production rates to be maintained, thus providing revenue and enabling consideration of production facility expansion.

Honeymoon

Operated by Western Australia-based Boss Resources since the company acquired it from Uranium One (Rosatom – the Russian state-owned nuclear industry operator) in 2015, Honeymoon remains on care and maintenance. Uranium One's production from the sandstone-hosted Honeymoon resource ceased in November 2013, however, government approvals remain in place, so operations could resume if market conditions permit.

Mineral exploration has continued to be undertaken by Boss Resources in the Yarramba and Billeroo palaeochannels with new resources identified at Goulds Dam and Jason's deposit. Boss Resources completed an expansion study and announced commencement a pre-feasibility study for Honeymoon in 2016. The investment by Boss in the research to improve use of resin and ion-exchange technology at Honeymoon, along with consideration of a larger processing plant facility aims to improve future economic outcomes with the objective of moving to a resumption of production.

Uranium production centre technical details

(as of 1 January 2017)

	Centre #1	Centre #2	Centre #3	Centre #4
Name of production centre	Ranger	Olympic Dam	Beverley/B. North	Honeymoon
Production centre classification	Existing	Existing	Existing	Existing
Date of first production	1981	1988	2000	2011
Source of ore:				
Deposit name(s)	Ranger	Olympic Dam	Beverley, Pepegoona, Pannikan	Honeymoon, Kalkaroo, Goulds
Deposit type(s)	Proterozoic unconformity	Polymetallic Fe-oxide Breccia Complex	Sandstone	Sandstone
Recoverable resources (tU)	56 077	918 256	12 593	15 825
Grade (% U)	0.06	0.025	0.18	0.109
Mining operation:				
Type (OP/UG/ISR)	OP (stockpiled)	UG	ISR	ISR
Size (t ore/year)	4.5 Mt	12 Mt	NA	NA
Average mining recovery (%)	90	85	65[(c)]	65[(c)]
Processing plant:				
Acid/alkaline	Acid	Acid	Acid	Acid
Type (IX/SX)	SX	FLOT, SX	IX	SX
Size (t ore/year); for ISR (litre/hour)	2.5 Mt/yr	12 Mt/yr	1.62 ML/h	Not reported
Average process recovery (%)	88	72	(c)	(c)
Nominal production capacity (tU/year)	4 660	3 820	850	340
Plans for expansion	No	No	Yes	No
Other remarks	(a)	(b)	(d)	

(a) Processing of lateritic ores in a separate plant with capacity to produce 400 t of uranium oxide concentrate (340 tU) per annum.

(b) BHP has proposed trials of heap leach technology, which should assist the company in assessing less capital-intensive mineral processing technology for ore mined underground.

(c) Recovery includes combined losses due to ISR mining and hydrometallurgical processing.

(d) Approval has been granted to extend the capacity of the Beverley plant to produce 1 500 t of uranium oxide concentrate (1 270 tU) per year when the company decides it is commercially viable to do so. Satellite ISR operations are proceeding at the Pepegoona and Pannikan (including Four Mile) deposits. Uranium resins from satellite ion-exchange plants are trucked to Beverley for further processing.

Uranium production centre technical details *(cont'd)*

(as of 1 January 2017)

	Centre #5	Centre #6	Centre #7	Centre #8	Centre #9
Name of production centre	Four Mile	Mulga Rock	Yeelirrie	Wiluna	Kintyre
Production centre classification	Existing	Under development	Planned	Planned	Planned
Date of first production	2014	Planned 2018	Not known	Not known	Not known
Source of ore:					
Deposit name(s)	Four Mile	Princess, Shogun, Ambassador	Yeelirrie	Centipede, Lake Way	Kintyre
Deposit type(s)	Sandstone	Sandstone	Calcrete	Calcrete	Proterozoic unconformity
Recoverable resources (tU)	18 580	20 662	40 286	29 077	18 048
Grade (% U)	0.32	0.08	0.13	0.088	0.58
Mining operation:					
Type (OP/UG/ISR)	ISL	OC	OP	OP	OP
Size (tonnes ore/year)	NA	NA	NA	2 Mt per year	NA
Average mining recovery (%)	65	65	NA	90	NA
Processing plant:					
Acid/alkaline	Acid	Acid	Alkaline	Alkaline	Alkaline
Type (IX/SX)	(e)		(f)	IX	NA
Size (t ore/year); for ISR (litre/hour)	NA	NA	NA	NA	1 700
Average process recovery (%)	NA	NA	NA	85	80
Nominal production capacity (tU/year)	(e)	1 150	NA	850	NA
Plans for expansion	No	No	No	Yes	No
Other remarks	(e)			(g)	

(e) The Four Mile resource comprises Four Mile East and Four Mile West. Uranium-bearing resin from Four Mile is trucked to the Beverley processing plant for elution, precipitation and drying as uranium concentrate.

(f) Cameco is investigating several options for processing the ores including tank leaching with ion exchange and heap leaching with ion exchange.

(g) Planned production of 1 200 t per year of $UO_4.2H_2O$, which equates to 850 tU per year.

Ownership of uranium production

Australia's uranium mines are owned and operated by a range of domestic and international companies:

- The Ranger uranium mine is owned by Energy Resources of Australia Ltd (ASX: ERA); Rio Tinto currently holds 68.4% of ERA shares with the remaining capital held publicly.
- The Olympic Dam mine is fully owned by BHP, listed on the Australian Stock Exchange (ASX: BHP).
- The Beverley and Beverley North mines are fully owned by Heathgate Resources Pty Ltd, a wholly owned subsidiary of General Atomics (United States). The Four Mile project, which commenced production in 2014, is fully owned by Quasar Resources Pty Ltd, an affiliate of Heathgate Resources, and is similarly a wholly owned subsidiary of General Atomics.
- Boss Resources (ASX: BOE) finalised acquisition of the Honeymoon mine from Uranium One (Rosatom) in 2015.

Employment in existing production centres

Total employment at Australia's uranium mines fell from 4 481 employees in 2015 to 3 630 employees in 2016. Employment in uranium mining is anticipated to increase to around 4 488 employees in 2017. Employment in mineral exploration for uranium has been in steady decline, consistent with declining commercial exploration expenditures.

Potential future production centres

Mulga Rock, Western Australia

The sandstone-hosted Mulga Rock resources (Shogun, Ambassador, Princess and Emperor) are located south-west of the Tropicana gold mine in Western Australia. The operator, Vimy Resources (ASX: VMY), has approvals in place for development and announced in 2017 that work had commenced on the project. Mining will proceed by traditional open-cut methods with the ore subsequently crushed to a suitable particle size, beneficiated and then treated using an on-site acid leach and precipitation plant. Vimy plans production from Mulga Rock to average 1 360 tonnes of uranium oxide concentrate (1 155 tU) per annum over 16 years, based on the current identified resource.

Wiluna, Western Australia

The Wiluna project comprises two approved shallow (less than 8 m deep) calcrete-hosted deposits, Lake Way and Centipede, which are 15 and 30 km south (respectively) of Wiluna, Western Australia. The project is wholly owned by Toro Energy Limited, an Australian-listed company (ASX: TOE). Toro has completed detailed engineering design and commercial studies as part of a definitive feasibility study for the Centipede and Lake Way components of the Wiluna project. Mining will utilise open-pit technology, taking into account the outcomes of the Public Environmental Review. It is proposed to use alkaline agitated leaching in tanks at elevated temperatures to process the ore. Production is estimated to be 820 t of uranium oxide concentrate (695 tU) per year, with a recovery rate over 80%.

The proposed expanded Wiluna project includes another four regional deposits: Millipede, Lake Maitland, Dawson Hinkler and Nowathanna, with a total resource of over 35 000 tonnes of uranium oxide sufficient for more than 20 years of mining at around 850 tU per year. The Western Australian government approval for the expanded project was granted in January 2017, with Commonwealth environmental approval progressing. Development would utilise open pits, alkaline leach technology and in pit tailings disposal.

Kintyre, Western Australia

Located 260 km north-east of the iron ore mining town of Newman, the Kintyre uranium project is at the edge of the Great Sandy Desert and near the Karlamilyi (Rudall River) National Park. The proposed Kintyre mine is 70% owned by Cameco Australia, with the remainder held by Mitsubishi (a global integrated business listed on the Tokyo and other stock exchanges) following acquisition of the project from Rio Tinto in 2008. Kintyre's likely production is around 2 700 tU per annum, with and estimated mine life of 15 years. Cameco has advanced development of the project, with approval of an Indigenous Land Use Agreement and Environmental Review and Management Programme. The company has continued work to identify additional resources and is working towards developing the resource.

Yeelirrie, Western Australia

Discovered in 1972, the Yeelirrie deposit, 70 km south-west of Wiluna, Western Australia, is one of Australia's larger undeveloped uranium deposits. It occurs in calcretes within a palaeochannel and is at shallow depths down to 15 m. Yeelirrie is wholly owned by Cameco Australia, a subsidiary of the Cameco Corporation listed on the Toronto (CCO) and New York Stock Exchanges (CCJ), which produces uranium from mines in Canada, the United States and Kazakhstan. Cameco acquired Yeelirrie from BHP in 2012. Average production from the Yeelirrie project would be nearly 3 300 tU per annum over 19 years, utilising open-cut mining and alkaline leach technology.

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 requires the proponents of uranium mines to undertake rigorous and comprehensive environmental impact assessment processes, incorporating public comments on the proposal. Depending upon the detail of the action referred and potential environmental impacts, Commonwealth assessment is conducted under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Assessment under the EPBC Act is usually undertaken bilaterally with relevant state and territory authorities; and includes 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 ensures that the concerns and cultural needs of Aboriginal people are respected.

Recent environmental assessments include:

- BHP's proposal to raise the wall height of Tailings Storage Facility 4, from 30 m to 40 m did not require Commonwealth environmental approval (February 2015). BHP announced plans in 2016 to increase production through an underground expansion into the higher-grade Southern Mining Area at Olympic Dam, after indefinitely postponing the development of an open-pit mine, which received environmental approval in 2012.
- Cameco's Kintyre project obtained Western Australian state environmental approval in March 2015 and Commonwealth environmental approval in April 2015.
- Vimy Resources' Mulga Rock project received Western Australian state environmental approval in December 2016 and Commonwealth environmental approval in March 2017.
- Toro Energy Limited's Wiluna Extension project and Cameco's Yeelirrie project remain under assessment through Commonwealth approvals processes. The Wiluna Extension and Yeelirrie projects Both the Wiluna Extension and Yeelirrie projects secured Western Australian state environmental approvals in January 2017 for mine development.

Site rehabilitation

ERA announced in 2015 that the Ranger 3 Deeps underground mining project would not proceed to Final Feasibility Study; it remains in care and maintenance. ERA will continue to process stockpiled ore until late December 2020, carrying out progressive rehabilitation activities, before commencing full rehabilitation in January 2021. ERA submitted a draft Mine Closure Plan in December 2016 to the Australian and Northern Territory governments and relevant stakeholders, outlining its proposed plans for rehabilitating the Ranger mine site for review.

Industry/government collaboration activities

The Uranium Council (UC), formerly the Uranium Industry Framework (UIF), was established by the Australian government in 2009 to develop a sustainable Australian uranium mining sector in line with world's best practice in environmental and safety standards. Membership of the UC comprises representatives of the Commonwealth, state and territory government agencies, industry and industry associations. The UC made a submission in 2015 to the South Australian Royal Commission into the nuclear fuel cycle in response to Issues Paper One Exploration, Extraction and Milling. The UC’s submission reviewed its (and the UIF’s) work undertaken in three key areas: health and safety, regulation and environment protection, and community engagement. The submission also provided the following publications developed in response to UC (or UIF) initiatives:

- “Safe and Effective Transport of Uranium” leaflet (2007);
- *Guide to Safe Transport of Uranium Oxide Concentrate* (2012);
- *Uranium Oxide Concentrate (UOC) Transport Strategy 2013*;
- *Australia’s In Situ Recovery Uranium Mining Best Practice Guide: Groundwaters, Residues and Radiation Protection* (2010);
- *Environmental Protection: Development of an Australian Approach for Assessing Effects of Ionising Radiation on Non-Human Species* (2010);
- *Review of Regulatory Efficiency in Uranium Mining* (2008);
- consolidated *Indigenous Engagement Factsheets*.

Further information on the UC can be found at: https://archive.industry.gov.au/resource/Mining/AustralianMineralCommodities/Uranium/Pages/UraniumCouncil.aspx.

National Energy Resources Australia (NERA) is one of six growth centres established by the Australian government under the Industry Growth Centres Initiative. Through a national focus, NERA’s roles is to grow collaboration and innovation to assist the energy resources industry (oil and gas, coal and uranium) manage cost structures and productivity, direct research to industry needs, deliver the future work skills required and promote fit for purpose regulation. To do this, key strategies include:

- supporting collaborative and innovative research;
- building a resilient and agile supply chain through small and medium-sized enterprises and research sector collaboration;
- promoting industry sustainability through developing a greater understanding of social, environmental, economic and operational consequences of industry activity;
- promoting fit for purpose regulation.

To date, NERA has developed a Sector Competitiveness Plan and in association with Accenture, undertaken the Australian Uranium Industry Competitiveness Assessment. These reports have outlined several challenges facing the Australian uranium industry, but also have identified a number of opportunities to assist the industry in becoming more globally competitive.

Further information on NERA can be found at: www.nera.org.au.

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 a number of codes and guides relating to uranium mining and associated processes:

- RPS C-1 *Code for Radiation Protection in Planned Exposure Situations* (2016);
- RPS C-2 *Code for the Safe Transport of Radioactive Material* (2014);
- RPS G-1 *Guide for Radiation Protection of the Environment* (2015);
- RPS 9 *Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing* (2005);
- RPS 9.1 *Safety Guide for Monitoring, Assessing and Recording Occupational Radiation Doses in Mining and Mineral Processing* (2011);
- 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).

ARPANSA continues to develop frameworks providing guidance on 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 completed and a draft report developed, which is undergoing final review prior to publication.

The Australian government released the 2016 edition of the Leading Practice Sustainable Development Program for the Mining Industry (LPSDP) in November 2016. 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:

https://archive.industry.gov.au/resource/Programs/LPSD/Pages/default.aspx.

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 by Australia's Prime Minister 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 relating to uranium

Australian policy states that Australian uranium can only be sold to countries with which Australia has a nuclear co-operation agreement, to make sure that countries are committed to peaceful uses of nuclear energy. They must also have safeguards agreements with the International Atomic Energy Agency (IAEA), including an Additional Protocol.

The Australian government supports the development of a sustainable Australian uranium mining sector in line with world's best practice environmental and safety standards. Uranium exploration and mining is currently permissible in South Australia, the Northern Territory and Western Australia. New South Wales overturned legislation prohibiting uranium exploration in 2012, although no exploration approvals have yet been granted; uranium mining remains prohibited. In March 2015, Queensland stated it planned on reinstating the ban on uranium mining, which had been overturned in October 2012 by the previous state government. Victoria currently prohibits uranium exploration and mining. In March 2017, the incoming Western Australian government restated its commitment to place a ban on future uranium activities; however, it also stated that mines that had been approved to begin construction by the previous government would be able to proceed.

The State Government of South Australia established a Nuclear Fuel Cycle Royal Commission in March 2015 to examine the potential for nuclear power in the state and the report was finalised in May 2016. The Commission investigated the potential for the expansion of exploration and extraction of minerals, the undertaking of further processing of minerals and manufacture of materials containing radioactive substances, the use of nuclear fuels for electricity generation and the storage and disposal of radioactive waste.

The Royal Commission found that South Australia could profit from the importation and storage of other countries' radioactive waste and that uranium enrichment and nuclear power were unlikely to be profitable in the state. One of its key recommendations was for further consideration of an international high-level radioactive waste repository. However, subsequent public review processes (through two Citizen's Juries) did not support the findings of the Royal Commission and debate on the issues continues in the state.

The Australian government's control over uranium exports reflects both national interest considerations and international obligations. The Commonwealth government is committed to ensuring that Australian uranium is only used for peaceful purposes by enforcing strict safeguards policy. Australia's uranium export policy requires recipient states to have concluded a bilateral nuclear co-operation agreement (NCA) with Australia and to have in place an Additional Protocol with the International Atomic Energy Agency (IAEA). Since 2015, NCAs with India and the United Arab Emirates have become operational. A NCA with Ukraine has also been signed, but is yet to enter into force.

Under Regulation 9 of Australia's Customs (Prohibited Exports) Regulations 1958, export of goods listed in Schedule 7 of the Regulations is prohibited unless permission is obtained from the Minister for Industry, Innovation and Science or an authorised person. Goods listed in Schedule 7 include minerals, ores and concentrates containing more than 500 parts per million (ppm) 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 2016 was USD 31.45/lb U_3O_8, (uranium oxide concentrate) with exports governed by a combination of contract specifications. Average export prices for the last five years are as follows:

	2016	2015	2014	2013	2012	2011
Average export value (AUD/lb U_3O_8)	42.26	52.18	31.97	37.36	43.36	40.10
(USD/lb U_3O_8)	31.45	39.26	33.20	38.80	45.03	40.73

Uranium exploration and development expenditures and drilling effort – domestic

(AUD millions)

	2014	2015	2016	2017 (expected)
Industry* exploration expenditures	39.5	44.0	23.4	Est. 27.5
Government exploration expenditures	0	0	0	0
Industry* development expenditures	NA	NA	NA	NA
Government development expenditures	0	0	0	0
Total expenditures	NA	NA	NA	NA
Industry* exploration drilling (m)	NA	NA	NA	NA
Industry* exploration holes drilled	NA	NA	NA	NA
Industry* exploration trenches (m)	NA	NA	NA	NA
Industry* exploration trenches	NA	NA	NA	NA
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 exploration trenches	0	0	0	0
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)	NA	NA	NA	NA
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)	NA	NA	NA	NA
Total number of holes drilled	NA	NA	NA	NA

* Non-government,

Source: Australian Bureau of Statistics 8412.0.

Uranium exploration and development expenditures – non-domestic

	2014	2015	2016	2017 (expected)
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
Total expenditures	NA	NA	NA	NA

* Non-government.

Reasonably assured conventional resources by deposit type
(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Proterozoic unconformity	NA	NA	118 600	130 600
Sandstone	NA	NA	60 578	71 578
Polymetallic Fe-oxide breccia complex	NA	NA	988 980	1 086 947
Granite-related	NA	NA	0	200
Intrusive	NA	NA	3 100	4 300
Volcanic-related	NA	NA	2 700	5 200
Metasomatite	NA	NA	21 200	21 200
Surficial	NA	NA	74 621	80 621
Total	NA	NA	1 269 779	1 400 646

Reasonably assured conventional resources by production method
(tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Underground mining (UG)	NA	NA	118 600	130 600
Open-pit mining (OP)	NA	NA	101 621	111 521
In situ recovery (ISR)	NA	NA	60 578	71 578
Co-product and by-product	NA	NA	988 980	1 086 947
Total	NA	NA	1 269 779	1 400 646

Reasonably assured conventional resources by processing method
(tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional from UG	NA	NA	1 107 580	1 217 547
Conventional from OP	NA	NA	101 621	111 521
In situ recovery (ISR)	NA	NA	60 578	71 578
Total	NA	NA	1 269 779	1 400 646

Inferred conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Proterozoic unconformity	NA	NA	48 300	52 800
Sandstone	NA	NA	86 350	106 800
Polymetallic Fe-oxide breccia complex	NA	NA	371 800	426 100
Intrusive	NA	NA	800	5 000
Volcanic-related	NA	NA	1 000	1 500
Metasomatite	NA	NA	14 600	16 900
Surficial	NA	NA	25 670	45 100
Total	NA	NA	548 520	654 200

Inferred conventional resources by production method

(tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Underground mining (UG)	NA	NA	48 300	52 800
Open-pit mining (OP)	NA	NA	42 070	68 500
In situ recovery (ISR)	NA	NA	86 350	106 800
Co-product and by-product	NA	NA	371 800	426 100
Total	NA	NA	548 520	654 200

Inferred conventional resources by processing method

(tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional from UG	NA	NA	420 100	478 900
Conventional from OP	NA	NA	42 070	68 500
In situ recovery (ISR)	NA	NA	86 350	106 800
Total	NA	NA	548 520	654 200

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
NA	NA	NA

Speculative conventional resources
(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
NA	NA	NA

Historical uranium production by deposit type
(tonnes U in concentrates)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (est.)
Proterozoic unconformity	113 943	994	1 700	1 993	118 630	1 700
Sandstone	7 600	655	775	1 088	10 118	1 000
Polymetallic Fe-oxide breccia complex	59 876	3 351	3 161	3 232	69 620	3 100
Metamorphite	7 531	0	0	0	7 531	0
Intrusive	721	0	0	0	721	0
Total	189 671	5 000	5 636	6 313	206 620	5 800

Historical uranium production by production method
(tonnes U in concentrates)

Product method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (est.)
Open-pit mining*	121 357	994	1 700	1 993	126 044	1 700
Underground mining*	838				838	
In situ recovery (ISR)	7 600	655	775	1 088	10 118	1 000
Co-product/by-product	59 876	3 351	3 161	3 232	69 620	3 100
Total	189 671	5 000	5 636	6 313	206 620	5 800

* Pre-2010 totals may include uranium recovered by heap and in-place leaching, historical data confirmed to 1976.

Historical uranium production by processing method
(tonnes U in concentrates)

Processing method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (est.)
Conventional	189 124	4 345	4 861	5 225	203 555	4 800
In situ recovery (ISR)	547	655	775	1 088	3 065	1 000
Total	189 671	5 000	5 636	6 313	206 620	5 800

Ownership of uranium production in 2016*

Domestic		Foreign		Totals	
Government/private		Government/private			
(tU)	(%)	(tU)	(%)	(tU)	(%)
2 298	36.4	4 015	63.6	6 313	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 2016.

Uranium industry employment at existing production centres

(person-years)*

	2014	2015	2016	2017 (est.)
Total employment related to existing production centres	5 805	4 481	3 630	4 488
Employment directly related to uranium production	3 872	3 121	2 499	3 135

* These figures are estimated and take into account total employment at BHP's Olympic Dam polymetallic operations also including contractors employed at the mine. A definitive breakdown of employees working for BHP's uranium mining operations was not available.

Short-term production capability

(tonnes U/year)

2016				2017				2020			
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	6 313	6 313	NA	NA	5 800	5 800	NA	NA	6 000	7 000

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	6 000	7 000	NA	NA	6 000	8 000	NA	NA	6 000	10 000

Total uranium stocks

(tonnes natural U-equivalent)

Holder	Natural uranium stocks in concentrate	Enriched uranium stocks	Depleted uranium stocks	Reprocessed uranium stocks	Total
Government	Nil	Nil	Nil	Nil	Nil
Producer	NA	Nil	Nil	Nil	NA
Utility	Nil	Nil	Nil	Nil	Nil
Total	Nil	Nil	Nil	Nil	Nil

Bolivia

Uranium exploration and mine development

Historical review

The first studies of uranium were made by Kozlowski (1923), M. Pérez (1963), S.J. Kriz and C. Cherroni (1965), and Everden et al. (1965) that based on absolute ages, correlated the Cretaceous and Tertiary formations of the Altiplano region.

In 1965, the initial prospecting of radioactive minerals was carried out by Servicio Geologico de Bolivia (GEOBOL), which included airborne radiometry and magnetic of the Cordillera de Los Frailes. In 1969, the Bolivian Commission of Nuclear Energy (COBOEN) began the application of methods of ground radiometry in the area of Sevaruyo, investigating Cretaceous and Tertiary sedimentary rocks and obtaining only a few results of interest. In 1970, the exploration for uranium minerals was focused on volcanic rocks of the Los Frailes Formation with positive results that led to the discovery of the Cotaje deposit and several anomalies such as Huancarani, Torko, Los Diques, Tholapalca and others.

Between 2009 and 2011, the National Geological and Mining Technical Survey (SERGEOTECMIN), as part of a framework and specific agreement, initially signed a contract with the Prefecture of Potosí and afterwards with the Departmental Autonomous Government to conduct exploration.

During the period 2009-2010, the SERGEOTECMIN conducted a radiometric prospecting study in the sectors that had been previously investigated by the COBOEN. Tholapalca, Asunción and Coroma Este were defined as the areas with the most uranium interest and regional geological mapping, sampling and chemical analyses were carried out.

In 2011, more detailed geological exploration studies were carried out including a diamond drilling programme at the Tholapalca and Coroma Este sites.

Recent and ongoing uranium exploration and mine development activities

In the period 2015-2016 no uranium exploration activities or mine developments were carried out.

Uranium exploration and mine development expenditures (domestic and non-domestic)

Since 2014, there has been no investment in uranium exploration or drilling.

Uranium resources

In 2009, the Prefecture and later on the Governorate of Potosí (2010-2011), made the economic investment to carry out a diamond drilling survey. These studies were carried out with the objective of assessing uranium resources and other representative elements in the areas of Tholapalca and Coroma Este of the Cotaje deposit (Potosí Department, Antonio Quijarro Province). This massive volcanic deposit is hosted in Miocene – Oligocene dacitic tuff.

After completion of the aforementioned exploration works, there has been no mining development of the deposit so far.

Speculative conventional resources

(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
		1 718

Brazil

Uranium exploration and mine development

Historical review

Systematic prospecting for radioactive minerals by the Brazilian National Research Council began 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 progressed due to increased financial resources. Additional 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).

In 1991, Industrias Núcleares do Brasil S.A (INB) uranium exploration activities were brought to a halt according to the Brazilian nuclear development programme reorganisation of 1988. Since then limited work has been done towards the extension of Lagoa Real province resources.

Recent and ongoing uranium exploration and mine development activities

During 2015/2016 exploration efforts were focused on favourable albititic areas in the north part of the Lagoa Real province

Expenditures totalled BRL 5.2 million (Brazilian reals) during that period, with 16 800 m drilled. For 2017, expected expenditures are BRL 2 million, corresponding to 4 500 m of drilling.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Brazil’s conventional identified uranium resources are hosted in the following deposits:

- Poços de Caldas (Osamu Utsumi mine) with the orebodies A, B, E and Agostinho (collapse breccia pipe-type);
- Figueira and Amorinópolis (sandstone);

- Itataia, including the adjoining deposits of Alcantil and Serrotes Baixos (phosphate);
- Lagoa Real, Espinharas (metasomatite);
- Campos Belos (metamorphite);
- Others including the Quadrilátero Ferrífero with the Gandarela and Serra des Gaivotas deposits (paleo-quartz-pebble conglomerate).

No additional resources were identified during the 2015-2016 period.

Undiscovered conventional resources (prognosticated and speculative resources)

Based on exploration activities in the Rio Cristalino (Proterozoic unconformity) area and additional resources at the Pitinga site (granite-related), in situ prognosticated resources are estimated to amount to 300 000 tU.

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 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 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 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. 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) is currently the only uranium production facility in operation in Brazil.

Status of production facilities, production capability, recent and ongoing activities and other issues

The open-pit part of the Cachoeira deposit was entirely mined out in 2014. The licensing process of the underground part is under way and the production expected to start in 2021.

The expansion of Lagoa Real, Caetité unit to 670 tU/year is progressing but the operation has been delayed to around 2021. The expansion involves replacement of the current heap leaching (HL) process by conventional agitated leaching. The overall investment in this expansion is estimated to amount to USD 90 million.

Production in 2015 was 44 tU. There was no production at the Caetité site in 2016.

Since 2014 INB has been working on the development of the Engenho deposit with the first production scheduled for 2018. Initially Engenho was planned as an additional source for increased production at the Caetité plant but is currently the only ore source for the plant due to the delay in the operation of Cachoeira underground mine.

Ownership structure of the uranium industry

The Brazilian uranium industry is 100% government-owned through INB.

Employment in the uranium industry

See table.

Future production centres

The phosphate/uranium project of Santa Quitéria, an INB-Brazilian fertiliser producer partnership agreement, is under development. In 2012, the project applied for a construction licence, expected to be granted in 2018. The operation is now scheduled to begin in 2021.

The Engenho deposit, located 2 km from the currently mined Cachoeira deposit is under development and is expected to feed Caetité mill after 2018.

Uranium production centre technical details

(as of 1 January 2015)

	Centre #1	Centre #2	Centre #3
Name of production centre	Caetité	Santa Quitéria	Caetité
Production centre classification	Planned	Planned	Existing
Date of first production	2021	2023	2018
Source of ore:			
Deposit name(s)	Cachoeira	Santa Quitéria	Engenho
Deposit type(s)	Metasomatite	Phosphate	Metasomatite
Recoverable resources (tU)	10 100	76 100	6 500
Grade (% U)	0.3	0.08	0.2
Mining operation:			
Type (OP/UG/ISL)	UG	OP	OP
Size (tonnes ore/day)	1 000	6 000	1 000
Average mining recovery (%)	90	90	90
Processing plant:			
Acid/alkaline	Acid	Acid	Acid
Type (IX/SX)	SX	SX	HL/SX
Size (tonnes ore/day)			
Average process recovery (%)	90	75	80
Nominal production capacity (tU/year)	340	970	300
Plans for expansion (yes/no)	No	Yes	Yes
Other remarks	OP operation from 1999 to 2014	By-product phosphoric acid	To be sent to Caetité mill

Environmental activities and socio-cultural issues

Licences in Brazil are issued by the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) and by CNEN.

The closure of Poços de Caldas in 1997 brought to an end 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 300 million. In the meantime, some measures have been taken to reduce environmental impact, such as: uranium recovery from acid drainage (resin); heavy metals precipitation (ozone) and surface drainage optimisation. INB, regulators and the central government are involved on the consolidation of a “work plan” for the remediation.

The licensing of Santa Quitéria Uranium/Phosphate Project is split into a non-nuclear part involving milling and phosphate production and a nuclear part involving uranium concentrate production. INB has applied for local construction licences under the guidelines established by IBAMA and CNEN.

Regulatory regime

Licences are issued by IBAMA, according to Brazilian environment law and CNEN regulations.

Government policies and regulations established by CNEN include basic radiation 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 tailings 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 International Commission on Radiological Protection (ICRP) and IAEA recommendations are used.

CNEN is in charge of nuclear research and regulation and currently controls INB as a major stakeholder. Due to the future growth of the Brazilian nuclear programme, the creation of a separate independent nuclear regulatory agency is under study by the federal government.

Uranium requirements

Brazil's present uranium requirements for the Angra 1 nuclear power plant, a 630 MWe pressurised water reactor, are about 150 tU/yr. The Angra 2 nuclear power plant, a 1 245 MWe PWR, requires 220 tU/yr. The start-up of the Angra 3 nuclear power plant (a similar design to Angra 2), scheduled initially for 2016, had the construction halted in 2015 and is currently scheduled to be operating in 2026. Once in operation, this will add another 220 U/yr to annual domestic demand.

The long-term electricity energy supply plan includes about 5 000 MWe generated from nuclear sources by 2030. A new version "The 2050 Plan", to be issued this year, will establish the sector guidelines.

Supply and procurement strategy

All domestic production is destined for internal requirements. The shortfall between demand and production is met through market purchases. In the period 2015/2016, INB acquired 610 tU.

The planned production increases are intended to meet all reactor requirements, including the Angra 3 unit and all units foreseen in the long-term planned expansion of nuclear energy for electricity generation.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

INB, a 100% government-owned company, is in charge of fuel cycle activities, which are conducted under state monopoly. Currently INB is working on the increase of uranium concentrate production and towards full implementation of the fuel cycle activities 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 [Brazilian real])

	2012	2013	2014	2015	2016	2017 (expected)
Industry* exploration expenditures	0	0	0	0	0	
Government exploration expenditures	2 500 000	3 500 000	0	700 000	4 500 000	2 000 000
Total expenditures	2 500 000	3 500 000	0	700 000	4 500 000	2 000 000
Government exploration drilling (m)	5 200	7 500	0	2 300	14 500	4 500
Government exploration holes drilled	41	45	0	32	117	40
Total drilling (m)	5 200	7 500	0	2 300	14 500	4 500
Total number of holes drilled	41	45	0	32	117	40

* Non-government.

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	25 400	50 800	50 880	50 880
Collapse breccia-type	500	500	500	500
Metasomatite	82 300	82 300	82 300	82 300
Phosphate	76 100	76 100	76 100	76 100
Total	184 300	209 700	209 700	209 700

* No changes in resources in the period 2015/16 due to absence of mining activities.

** In situ resources.

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)	72 900	72 900	72 900	72 900	90 (mine); 90 (process)
Open-pit mining (OP)	9 900	9 900	9 900	9 900	90 (mine); 90 (process)
Co-product and by-product	101 500	126 900	126 900	126 900	70 (process)
Total	184 300	209 700	209 700	209 700	

* In situ resources.

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	72 900	72 900	72 900	72 900	90 (mine); 90 (process)
Conventional from OP	8 100	8 100	8 100	8 100	90 (mine); 90 (process)
Heap leaching** from OP	1 800	1 800	1 800	1 800	90 (mine); 90 (process)
Unspecified	101 500	126 900	126 900	126 900	70 (process)
Total	184 300	209 700	209 700	209 700	

* In situ resources.

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

Inferred conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Sandstone		13 000	13 000	13 000	90 (mine); 80 (process)
Paleo-quartz-pebble conglomerate		15 000	15 000	15 000	90 (mine); 80 (process)
Granite-related		0	67 700	67 700	70 process
Metamorphite		1 000	1 000	1 000	90 (mine); 80 (process)
Collapse breccia-type		26 400	26 400	26 400	90 (mine); 80 (process)
Metasomatite		5 000	5 000	5 000	90 (mine); 80 (process)
Phosphate		44 600	44 600	44 600	70 process
Total		104 900	172 600	172 600	

* In situ resources.

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)		3 400	3 400	3 400	90 (mine); 80 (process)
Co-product and by-product		44 600	112 300	112 300	70 (process)
Unspecified		56 900	56 900	56 900	70 (average)
Total		104 900	172 600	172 600	

* In situ resources.

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		3 400	3 400	3 400	90 (mine); 80 (process)
Unspecified		101 500	169 200	169 200	70 (average)
Total		104 900	172 600	172 600	

* In situ resources.

Prognosticated conventional resources
(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
300 000	300 000	300 000

Speculative conventional resources
(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
N/A	N/A	500 000

Historical uranium production by deposit type
(tonnes U in concentrates)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Collapse breccia-type	1 097	0	0	0	1 097	0
Metasomatite	3 020	55	44	0	3 119	60
Total	4 117	55	44	0	4 216	60

Historical uranium production by production method
(tonnes U in concentrates)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Open-pit mining*	4 117	55	44	0	4 216	60
Total	4 117	55	44	0	4 216	60

* 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 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Conventional	1 097	0	0	0	1 097	0
Heap leaching*	3 020	55	44	0	3 119	60
Total	4 117	55	44	0	4 216	60

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

Ownership of uranium production in 2016

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)

	2014	2015	2016	2017 (expected)
Total employment related to existing production centres	620	620	680	680
Employment directly related to uranium production	340	310	310	310

Short-term production capability (tonnes U/year)

2017				2020			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
340	340	340	340	300	300	300	300

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
300	1 600	300	1 600	N/A	1 600	N/A	1 600	N/A	1 600	N/A	1 600

Net nuclear electricity generation

	2015	2016
Nuclear electricity generated (TWh net)	13.9	15.10

Installed nuclear generating capacity to 2035
(MWe net)

2013	2014	2015		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
1 875	1 875	1 875	1 875	1 875	1 875	1 875	1 875	3 120	5 120	3 120	N/A

Annual reactor-related uranium requirements to 2035 (excluding MOX)
(tonnes U)

2013	2014	2015		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
400	400	400	400	400	400	400	400	550	1 000	550	N/A

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 deposits were discovered in the Athabasca Basin and later developed. Saskatchewan is now the sole producer of uranium in Canada.

Recent and ongoing uranium exploration and mine development activities

During 2015 and 2016, exploration efforts continued to focus on areas favourable for the occurrence of deposits associated with Proterozoic unconformities in the Athabasca Basin of Saskatchewan, and to a much lesser extent, similar geologic settings in the Thelon Basin of Nunavut. Very little exploration activity occurred in other areas of Canada in 2015 and 2016.

Surface drilling, as well as geophysical and geochemical surveys, continued to be the main tools used to identify new uranium occurrences, define extensions of known mineralised zones and to reassess previously discovered deposits.

Exploration activity has led to new uranium discoveries in the Athabasca Basin. Notable recently discovered large high-grade uranium deposits include Phoenix/Gryphon (Denison Mines Inc.), Triple R – (Fission Uranium Corp.), Arrow (Nex-Gen Energy Corp.) and Fox Lake (Cameco Corp.).

Domestic uranium exploration expenditures were CAD 170 million in 2015, down 7.6% from 2014 exploration expenditures of CAD 184 million. In 2015, overall Canadian uranium exploration and development expenditures amounted to CAD 491 million. Less than one-fifth of the overall exploration and development expenditures in 2015 can be attributed to advanced underground exploration, deposit appraisal activities and care and maintenance expenditures associated with projects awaiting production approvals.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2017, Canada's total identified conventional uranium resources recoverable at a cost of <USD 80/kgU amounted to 310 400 tU, a decrease of 3.5% from the 2015 estimate of 321 800 tU, primarily due to mining depletion. Canada's total identified uranium resources recoverable at a cost of <USD 130/kgU were 514 400 tU as of 1 January 2017, an increase of 1% compared to the 2015 estimate of 509 000 tU. These increases are primarily due to new resources being identified as a result of recent exploration activity. 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 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.

All of Canada's identified conventional uranium resources recoverable at <USD 40/kgU are in existing or committed production centres. 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 97%, 60% and 51%, respectively.

Undiscovered conventional resources (prognosticated and speculated resources)

Prognosticated and speculated resources have not been a part of recent resource assessments; hence there are 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 deposit was reopened in 1942 in response to uranium demand for the Manhattan Project. A ban on private exploration and development was lifted in 1947, 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 had 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 of uranium production shifted increasingly to Saskatchewan. The last remaining Ontario uranium mine closed in mid-1996.

Status of production capability and recent and ongoing activities

All active uranium production centres are located in northern Saskatchewan. Current Canadian uranium production is at a record level but remains well below the full licensed production capacity of the uranium mills. Production in 2016 was 14 039 tU, 5.6% above 2015 production of 13 325 tU. Canadian uranium production is forecast to be at around 14 000 tU in 2017 as the Cigar Lake mine reaches full production.

Cameco Corporation is the operator of the McArthur River mine, a Cameco (70%), Areva (30%) joint venture, which is the world's largest uranium mine in terms of annual production and has the world's largest high-grade uranium deposit. Ore from the mine is transported 80 km southward to the Key Lake mill where 7 292 tU and 6 893 tU were recovered from McArthur River ore in 2015 and 2016, respectively. Ground freezing is used to reduce water inflow from the overlying rock formation and the high-grade ore (>10% U) is extracted using raise bore mining. 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 by road to the Key Lake mill. Remaining identified resources for McArthur River mine are currently 146 400 tU with an average grade of 8% U.

The Key Lake mill is a Cameco (83%) and Areva (17%) joint venture operated by Cameco. The mill maintained its standing as the world's largest, producing 7 341 tU and 6 928 tU in 2015 and 2016, respectively. These totals represent a combination of the uranium extracted from high-grade McArthur River ore and from stockpiled, mineralised Key Lake special waste rock that is blended to produce a mill feed grade of about 5% U. In addition, uranium refinery wastes from Ontario were processed at Key Lake, producing 14 tU and 17 tU in 2015 and 2016, respectively.

The McClean Lake production centre, operated by Areva, is a joint venture between Areva (70%), Denison Mines Inc. (22.5%) and Overseas Uranium Resources Development (Canada) Co. Ltd, a subsidiary of Overseas Uranium Resources Development Corporation of Japan (7.5%). Open-pit mining was completed in 2008 and ore containing 2 500 tU was stockpiled to provide mill feed. Production in 2009 and 2010 amounted to 2 045 tU and was obtained from processing the higher-grade ore from the stockpile. The 500 tU of ore remaining in the stockpile was not economic to process so the mill was placed into care and maintenance in July 2010. Production from the McClean Lake JEB mill resumed in 2014 to process low-grade ore from the stockpile and high-grade ore from the Cigar Lake mine. Production from the McClean Lake ore stockpile was 4 tU in 2015, with no production recorded in 2016. Production from Cigar Lake ore increased from 4 345 tU in 2015 to 6 666 tU in 2016. Annual production is expected to increase to 6 900 tU in 2017 as the Cigar Lake mine reaches full production.

The Rabbit Lake production centre, wholly owned and operated by Cameco, produced 1 621 tU and 428 tU in 2015 and 2016, respectively. Production at Rabbit Lake was suspended in mid-2016 due to low uranium prices and the facility was placed in care and maintenance. Production could resume when uranium prices recover. Exploratory drilling at the Eagle Point mine during the last several years has increased identified resources to 27 400 tU at an average grade of 0.58% U. An environmental assessment is under way on a proposal to expand tailings storage capacity to allow additional ore to be processed, should operations resume in the future.

Cigar Lake, with identified resources of 121 300 tU at an average grade of 14.5% U, is the world's second-largest high-grade uranium deposit. The mine began operation in March 2014 and is a Cameco (50.025%), Areva (37.1%), Idemitsu (7.875%) and Tokyo Electric Power Company (TEPCO) (5%) joint venture operated by Cameco. When in full production in 2017, the mine is expected to have a full annual production capacity of 6 900 tU. Ground freezing is used to reduce groundwater inflow and ore is extracted using an innovative jet bore mining method. The high-grade ore slurry is then shipped by road to the McClean Lake (JEB) mill for processing. The McClean Lake mill produced 4 345 tU and 6 666 tU from Cigar Lake ore in 2015 and 2016, respectively.

Ownership structure of the uranium industry

Cameco Corporation and Areva Canada Resources Inc. (Areva) 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 Areva. Cameco is the majority owner and operator of the Cigar Lake mine, in which Areva, Idemitsu and TEPCO have minority ownership. Areva is the majority owner and operator of the McClean Lake production centre in which Denison Mines Inc. and Overseas Uranium Resources Development (Canada) Co. Ltd. have minority ownership.

Uranium production centre technical details
(as of 1 January 2017)

	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	Existing	Suspended	Existing	Planned
Date of first production	1999/1983	1999	1975	2014	N/A
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)	146 400 tU	6 300 tU	31 800 tU	121 400 tU	3 700 tU
Grade (% U)	11.5	1.5	0.61	14.0	0.78
Mining operation:					
Type (OP/UG/ISR)	UG	UG/OP	UG	UG	OP
Size (tonnes ore/day)	~200	N/A	N/A	~200	N/A
Average mining recovery (%)	N/A	N/A	N/A	N/A	N/A
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

Direct employment at Canada's uranium mines and mills industry totalled 1 867 in 2015 and 1 616 in 2016. Total employment, including contract employees, was 2 676 in 2015 and 2 246 in 2016. The reduction in employment in 2016 is primarily the result of suspension of operations at Rabbit Lake in response to low uranium prices.

Future production centres

Two uranium mining projects in Saskatchewan could enter into production within the next decade, should uranium prices increase, extending the lives of the existing mills. Ore from the proposed Midwest mine would provide additional feed for the McClean Lake mill. Ore from the proposed Millennium mine would be processed at the Key Lake mill.

There are several other exploration projects in the Athabasca Basin, which have recently identified large high-grade uranium deposits that may develop into proposals for new mines. In the western Athabasca Basin, the Arrow Deposit (Nex-Gen Energy Ltd.) and the Triple R deposit (Fission Uranium Corp.) are the two largest undeveloped uranium deposits in Canada. Recent large uranium discoveries in the eastern Athabasca Basin include the Phoenix and Gryphon deposits (Denison Mines Corp.), and the Fox Lake deposit (Cameco Corp.). Continued exploration work on these and other deposits is expected to increase resources further.

There is also a possibility of mines being developed outside of Saskatchewan, however uranium prices would have to increase substantially. Areva has proposed to develop the Kiggavik and Sissons deposits in Nunavut, should market conditions improve and mining becomes 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

In December 2007, Areva Resources Canada Inc. announced a decision to proceed with an economic feasibility study and to commence the regulatory process to obtain approval for the development of the Kiggavik Project in Nunavut. The deposits have an estimated 44 000 tU with an average grade of 0.47% U. An environmental impact statement was submitted to the Nunavut Impact Review Board in May 2012 as part of the Canadian Nuclear Safety Commission (CNSC) licensing process. A final environmental impact assessment was submitted in 2014. In 2015, the Board recommended that the project not be approved due to uncertainty in the environmental assessment. Areva had not defined a start date for the project as market conditions would have to improve for the project to be economic. The Board felt that it would be difficult to determine the environmental effects of the project without a definitive starting date. The Board's recommendation was accepted by the federal government in July 2016. Areva may reapply to develop the deposit when a more definite start date for the project becomes available.

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 2015 and 2016. 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. Areva conducts monitoring of the site on a quarterly basis.

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 was no regulatory requirement 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 under way to remediate these sites.

Uranium requirements

In 2016, nuclear energy provided about 15% of Canada's total electricity needs (including approximately 60% in Ontario and 33% in New Brunswick) and should continue to play an important role in supplying Canada with power in the future. Canada has a fleet of

22 CANDU pressurised heavy water reactors, of which 19 are currently in full commercial operation (18 in Ontario and 1 in New Brunswick). The only unit in Quebec was shut down at the end of December 2012 and two units in Ontario have been placed in guaranteed safe shutdown state.

In Canada, the responsibility for deciding on 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.

Canada's CANDU nuclear reactors are designed to provide electricity generation for about 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 successfully completed and the reactors returned to service in the fall of 2012. Furthermore, as laid out in Ontario's 2013 Long-term Energy Plan (2013 LTEP), Ontario is proceeding with plans to refurbish four nuclear units at Darlington Nuclear Generating Station and six at Bruce Nuclear Generating Station (two at Bruce A and four at Bruce B). On 15 October 2016, refurbishment of the first Darlington unit got under way and all four Darlington units are planned to be refurbished by 2026. Similarly, the first Bruce unit refurbishment is expected to commence in 2020 and all six Bruce units refurbished by 2033.

The Pickering Nuclear Generating Station, Ontario's first commercial-scale nuclear power plant, will not be refurbished once it reaches the end of its safe operating life. Ontario's 2013 LTEP assumed that Pickering would operate until 2020. In January 2016, Ontario approved a plan to complete technical assessments and seek regulatory approvals for continued operation of Pickering up to 2022/2024. Two of the six operating Pickering units would be shut down in 2022, with the remaining four units shut down in 2024. Ontario will make a final decision on continued Pickering operation after all necessary regulatory approvals have been completed.

In 2012, Canada's nuclear regulator, the CNSC, granted a site preparation licence for nuclear new build at Darlington following approval of the environmental assessment. However, due to lower expected growth in demand for electricity, Ontario has deferred a decision on construction of new nuclear reactors.

Supply and procurement strategy

Approximately 15% 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, requires nuclear energy corporations to establish a Nuclear Waste Management Organization (NWMO) to safely and securely manage nuclear fuel waste over the long term.

Adaptive phased management (APM) was chosen as Canada's approach for safely managing nuclear fuel waste over the long term. The APM involves the containment and isolation of nuclear fuel waste 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. The 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 an informed willing host community 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 the waste. By the end of 2014, the NWMO had actively engaged with 21 communities in Ontario and Saskatchewan, including First Nations and Métis communities that had expressed an interest in hosting the waste management facility. The ultimate success of the project depends upon community engagement and lasting partnerships.

As of April 2017, seven candidate communities, all in Ontario, remain involved in the NWMO siting process. Detailed field work to address the scientific and technical aspects, as well as the social dimensions of site selection, will proceed over the next several years. Field studies, borehole drilling, airborne surveys, environmental mapping, socio-economic studies and other assessments will be carried out to determine the suitability of sites and the willingness of communities. The NWMO will continue to build and strengthen its working relationships with participating communities as this process advances.

The Nuclear Liability and Compensation Act (NLCA), which entered into force on 1 January 2017, replacing the Nuclear Liability Act of 1976, strengthens 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 permits Canada to implement the IAEA Convention on Supplementary Compensation for Nuclear Damage.

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 act, operators of nuclear installations are absolutely and exclusively liable for civil nuclear damage to a limit of CAD 1 billion, an amount phased in from CAD 650 million in 2017, to CAD 1 billion in 2020. All suppliers or contractors providing parts or services to the nuclear installation are thereby indemnified.

The act also contains a mechanism for periodic updating of the operator's liability; expanded categories of compensable damage to address environmental damage, economic loss, and costs related to preventive measures; and a longer limitation period for submitting compensation claims for bodily injury.

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)

	2014	2015	2016 (preliminary)	2017 (expected)
Industry* exploration expenditures	184	170	174	139
Government exploration expenditures		0	0	0
Industry* development expenditures	384	321	213	243
Government development expenditures		0	0	0
Total expenditures	563	491	387	382
Industry* exploration drilling (m)	329 263	399 660	N/A	N/A
Industry* exploration holes drilled	N/A	N/A	N/A	N/A
Government exploration drilling (m)	0	0	0	0
Government exploration holes drilled	0	0	0	0
Industry* development drilling (m)	132 179	84 500	N/A	N/A
Industry* development holes drilled	N/A	N/A	N/A	N/A
Government development drilling (m)	0	0	0	0
Government development holes drilled	0	0	0	0
Subtotal exploration drilling (m)	329 263	399 660	N/A	N/A
Subtotal exploration holes drilled	N/A	N/A	N/A	N/A
Subtotal development drilling (m)	132 179	84 500	N/A	N/A
Subtotal development holes drilled	N/A	N/A	N/A	N/A
Total drilling (m)	461 442	484 160	N/A	N/A
Total number of holes drilled	N/A	N/A	N/A	N/A

* Non-government.

Reasonably assured conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Proterozoic unconformity	255 930	275 190	403 680	543 003
Sandstone			6 000	6 000
Paleo-quartz-pebble conglomerate				5 255
Metasamotite				38 626
Total	255 930	275 190	409 680	592 884

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)	255 660	274 920	373 092	522 824	N/A
Open-pit mining (OP)	270	270	36 588	70 060	N/A
Total	255 930	275 190	409 680	592 884	

Reasonably assured conventional resources by processing method

(tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional from UG	255 660	274 920	373 092	517 569
Conventional from OP	270	270	36 588	70 060
In-place leaching*				3 153
Heap leaching** from UG				2 102
Total	255 930	275 190	409 680	592 884

* 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

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Proterozoic unconformity	7 560	35 200	98 678	205 775
Sandstone			6 044	12 241
Paleo-quartz-pebble conglomerate				18 947
Metasomatite				16 520
Total	7 560	35 200	104 722	253 483

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)	7 560	35 200	79 415	208 026	N/A
Open-pit mining (OP)			25 307	45 457	N/A
Total	7 560	35 200	104 722	253 483	

Inferred conventional resources by processing method

(tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional from UG	7 560	35 200	79 415	189 079
Conventional from OP			25 307	45 457
In-place leaching*				11 368
Heap leaching** from UG				7 579
Total	7 560	35 200	104 722	253 483

* Also known as stope leaching or block leaching.

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

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
50 000	150 000	150 000

Speculative conventional resources

(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
700 000	700 000	0

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Proterozoic unconformity	299 453	9 127	13 311	14 022	335 913	13 985
Paleo-quartz-pebble conglomerate	144 182				144 182	
Intrusive	6 088				6 088	
Metasomatite	25 098				25 098	
Other/unspecified*	0	9	14	17	40	15
Total	474 821	9 136	13 325	14 039	511 321	14 000

* Uranium recovered at Key Lake mill from recycling uranium refinery wastes.

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Open-pit mining*	119 044	44	0	0	119 088	0
Underground mining*	355 777	9 092	13 325	14 039	392 233	14 000
Total	474 821	9 136	13 325	14 039	511 321	14 000

* Pre-2013 totals may include uranium recovered by heap and in-place leaching. Post-2013 underground mining totals includes uranium recovered at Key Lake mill from recycling uranium refinery wastes.

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Conventional	473 821	9 136	13 325	14 039	510 321	14 000
In-place leaching*	1 000				1 000	
Total	474 821	9 136	13 325	14 039	511 321	14 000

* Also known as stope leaching or block leaching.

Ownership of uranium production in 2016

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
0	0	8 634	61.5	4 547	32.4	858	6.1	14 039	100

Uranium industry employment at existing production centres

(person-years)

	2014	2015	2016	2017 (expected)
Total employment related to existing production centres	2 874	2 676	2 246	2 000
Employment directly related to uranium production	1 829	1 867	1 616	1 400

Net nuclear electricity generation

	2015	2016
Nuclear electricity generated (TWh net)	96.0	99 p

Short-term production capability

(tonnes U/year)

2017				2020				2025			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
18 700	18 700	18 700	18 700	18 700	18 700	18 700	18 700	12 330	18 850	12 330	18 850

2030				2035			
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	18 850	12 330	18 850

Installed nuclear generating capacity to 2035

(MWe net)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
14 000	13 000 p	12 000	12 000	10 000	N/A	8 000	N/A	10 000	N/A	11 000	N/A

Annual reactor-related uranium requirements to 2035 (excluding MOX)

(tonnes U)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
1 775	1 830	1 535	1 535	1 385	N/A	1 200	N/A	1 330	N/A	1 370	N/A

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	N/A	0	0	0	N/A
Utility	N/A	0	0	0	N/A
Total	N/A	0	0	0	N/A

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 Organization, 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, 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 detection of 80 uranium occurrences, stimulating further study of the 12 most promising uranium 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 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 rare earth elements 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 rare earth 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 REOs 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 rare earth oxides 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 rare earths.

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 rare earths, as well as yttrium have been obtained.

In 2003, regional reconnaissance was undertaken for uranium and rare earths 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.

Recent and ongoing uranium exploration and mine development activities

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 atomic 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.

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. Using a recovery factor of 75%, total identified recoverable resources are 1 447 tU in the <USD 260 kg/U category.

Surface deposits

(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		

Uranium resources by deposit type

(tonnes U)

Deposits, areas and other resources	RAR + IR	PR + SR	SR*
Surface deposits	68.0	123.5	
Metasomatic deposits	1 762.8	4 060.0	
Cenozoic volcanogenic deposits	100.0	5 000.0	
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 – Polymtallic deposits, Cretaceous	--	--	100
Favourable areas:			
A – Acid volcanism, Tertiary	--	--	500
B – Jurassic-Cretaceous intrusives	--	--	500
C – Volc. acid-sedimentary, Cretaceous	--	--	200
D – Palaeozoic magmatism. Main Cordillera	--	--	50
E – Sedimentary-volcanic, Middle Cretaceous	--	--	100
F – Palaeozoic plutonism, Nahuelbuta	--	--	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.

Metasomatic deposits

(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		

Unconventional resources and other materials

(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 of little current value. Studies need to be done to validate or eliminate these figures.

1. The Sagasca deposit is exhausted, 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.

Volcanogenic deposits

(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			

REE = rare earth elements.

Unconventional resources and other materials

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		

The uranium present in copper oxide ores could be recovered from the leaching solutions. These processes were trialled at the pilot level 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 unofficial. 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 mineralisations 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.

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.

Areas of uranium occurrences:

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 (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. Paleozoic plutonism, Nahuelbuta Range, regions VIII and IX – potential: 300 tU.
G. Acid and intermediate sedimentary clastic volcanism, Tertiary and Tertiary [sic], Main Cordillera, regions VII, VIII and IX – potential: 300 tU.

Uranium production

Outside of 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).

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.

Undiscovered conventional resources (prognosticated and speculative resources)

Deposit	Type	Prognosticated tonnes U	Speculative tonnes U	Grade % U	Rocks hosting age
Cenozoic surface Deposits[1]	Surface	108.5	15.0		Diatomite, volcanic ash with organic material. Pliocene – Pleistocene.
Cretaceous metasomatics[2]	Metasomatics	1 715	2 345	0.025-0.17	Intrusive, volcanic and metasomatic rocks. Upper Cretaceous.
Cenozoic volcanogenics[3]	Volcanic	500	0	0.085-0.15%	Tuffs with high magnetite and haematite content. Mineralisation of secondary REE minerals observed. Oligocene Pleistocene.
Total		2 323.5	2 360		

REE = rare earth elements.

1. Salar Grande (100 t), Pampa Camarones (4 t), Prosperidad – Quillagua (24 t).

   No new uranium prospecting has been done in the area of Cenozoic surface deposits.

2. Diego de Almagro Anomaly-2 (1 400 t); Diego de Almagro Alignment (1 500 t); Agua del Sol (50 t), Sierra Indiana (30 t), Sector Estación Romero: Carmen prospect (50 t) and Productora Prospect (800 t), Tambillos district (100 t), Sector Pejerreyes – Los Mantos (130 t).

   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 conditions 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).

Identified conventional resources (reasonably assured and inferred resources)

Deposit	Type	RAR tonnes U	IR tonnes U	Grade % U_3O_8	Rocks, hosting age
Cenozoic surface deposits[1]	Surface	28	40	0.023	Diatomite, volcanic ash with organic material (Pliocene – Pleistocene)
Cretaceous metasomatics[2]	Metasomatics	720	1 043	0.028-0.20	Intrusive, volcanic and metasomatic rocks (upper Cretaceous)
Cenozoic volcanogenics[3]	Volcanic	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 t), Mina Neverman (?), Boca Negra (3 t), Manuel Jesús (2.5 t), Mina Casualidad (?), Mina San Agustín (?), Quebrada Vítor (?), Pampa Chaca (2 t), Pampa Camarones (3.5 t), Quebrada Amarga (2 t), Quillagua (22 t), Prosperidad (?), Chiu Chiu (5 t).

Metasomatic deposits:

2. Estación Romero 326 t (Carmen and Productora prospects), Cerro Carmen prospect (1 391.8 t), Agua del Sol (15 t), Sector Pejerreyes – Los Mantos (20 t), Tambillos district (10 t). 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.

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.

Reasonably assured conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Volcanic-related	0	0	0	540
Surficial	0	0	0	21
Total	0	0	0	561

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 (%)
Unspecified	0	0	0	561	75
Total	0	0	0	561	75

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 (%)
Unspecified	0	0	0	561	75
Total	0	0	0	561	75

Inferred conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Volcanic-related	0	0	0	75
Metasomatite	0	0	0	782
Surficial	0	0	0	30
Total	0	0	0	887

Inferred conventional resources by production method

(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

(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

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	0	2 324

Speculative conventional resources

(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	N/A	2 360

Reasonably assured unconventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Copper deposit	0	0	0	754
Phosphorite	0	0	0	415
Total	0	0	0	1 169

Reasonably assured unconventional resources by mining method

(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

(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

Prognosticated unconventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	0	1 818

Speculative unconventional resources

(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

Before the 1990s, uranium exploration in China mostly focused on granite or volcanic-related hydrothermal deposits in Jiangxi, Hunan and Guangdong and Guangxi in South China. Decades of exploration by the Bureau of Geology (BOG), a subsidiary of China National Nuclear Corporation (CNNC), resulted in the identification of the majority of the ore fields (deposits) for example, Xiangshan, Xiazhuang, Zhuguang and Lujing. In those deposits the uranium ore bodies mainly occur in intermediate to acidic magmatic rocks (granite and volcanic rocks). Besides a few large ones, most of the deposits are relatively small, usually middle to low grade. Additionally, the deposits are mostly located in remote mountain areas so mining costs are higher. At the beginning of 1990s, when China initiated its nuclear energy programme, the demand for uranium for China's NPPs increased very little. In the mid-1990s, uranium exploration in China slowed down because of the decrease of national investment in uranium exploration.

From the middle to the end of the 1990s, as NPP construction accelerated in coastal areas, the demand for uranium steadily increased in response. In this period, the national financial expenditures for uranium exploration went up gradually, year by year. However, both the number of projects and the areas of exploration were limited. In order to meet the demand of uranium resources for the mid-term and long-term development plan of national nuclear energy, China changed the targets and distribution of uranium exploration from conventional mining deposits of hard rocks in southern China to in situ leachable deposits in Meso-Cenozoic basins in northern China at the beginning of the 21st century, focusing on sandstone-type uranium deposits suitable for ISL mining. Regional geological surveys and drilling evaluations were mainly carried out in Yili, Turpan-Hami and Junggar Basins in Xinjiang and in Erlian, Ordos and Songliao Basins in Inner Mongolia. After more than ten years' exploration, the investigation and evaluation for uranium resources in Yili, Ordos, Erlian, Songliao, Jungar, Tarim, Bayingebi, Badanjilin, Qadam, Yanqi, Haylar and other basins have been successful, with the discovery of several medium-large uranium deposits; From 2000 to 2006, the annual drilling footage gradually increased from 40 000 m to 250 000 m. Since 2006, investment in uranium exploration had further increased, and drilling footage peaked to 900 000 m in 2012. In recent years, the supply and demand relationship changed because of the lowering of the global uranium price. Uranium exploration expenditures remained high in China before 2015, but notably fell between 2015 and 2016.

Since 2008, besides CNNC, which has been the major organisation involved in uranium exploration in China, Uranium Resources Co. Ltd, a subsidiary of China General Nuclear Power Corporation (CGNPC), has also been active in domestic uranium exploration, and consequently carried out uranium exploration projects in the north margin of Tarim Basin, Xinjiang and in Guangdong Province. Additionally, Liaohe Oilfield of China National Petroleum Corporation (CNPC) has been developing uranium exploration in Tongliao District, Inner Mongolia.

Recent and ongoing uranium exploration and mine development activities

Domestic uranium exploration was relatively stable and consistent between 2015 and 2016. The budget had decreased in comparison to 2013 and 2014, nonetheless overall better progress and results were achieved in uranium exploration. The exploration focused on sandstone-type uranium deposits in north China, where the deposits discovered in the earlier stages were further expanded and uranium mineralisation and new uranium ore fields were discovered in new areas and new strata in Songliao, Jungar, and Erlian Basins. Preliminary exploration indicated they had large potential. Meanwhile, uranium exploration was carried out in the deeper parts and on the periphery of the known hard rock-type uranium ore fields in south China, which resulted in some increases of the resources/reserves. However, no new large, high-grade and low-cost uranium deposit was discovered.

The exploration, including regional uranium potential assessment and further works on previously discovered mineralisation and deposits in northern China has principally been focused on the Yili, Turpan-Hami, Junggar and Tarim Basins of the Xinjiang Autonomous Region; the Erdos, Erlian, Songliao, Badanjili and Bayingebi Basins of Inner Mongolia; the Caidamu Basin in Qinghai Province and the Jiuquan Basin in Gansu Province. Geophysical methods, including radiation surveys and geo-electromagnetics were combined with drilling and shallow seismic methods for the assessments. Further drillings were carried out in mineralised areas in order to identify in situ leach (ISL) amenable sandstone-type deposits, as well as conventional mining of mudstone-type deposits and sandstone-type deposits with low permeability.

The exploration work in southern China is mainly directed at identifying metallogenic belts relating to volcanic-type and granite-type deposits, mostly focused in the Xiangshan and Taoshan uranium orefields in Jiangxi Province, the Xiazhuang and Zhuguang uranium orefields in Guangdong Province, the Miaoershan uranium orefield in the Guangxi Autonomous Region, the Dawan uranium orefield in Hunan Province, and the Ruoergai area of Sichuan Province. Potential deposits in carbonaceous siliceous pelitic rocks were the secondary targets in this exploration campaign.

The total drilling footage completed in the last two years amounted to over 1 360 000 m (about 740 000 m in 2015 and 620 000 m in 2016). As a result, uranium resources in northern China such as those contained in the Yili, Erdos, Erlian, Tuha, Songliao Basins have increased. In addition, significant progress has also been achieved in old uranium ore fields of southern China, such as the Taoshan, Lujing, Zhuguangnanbu and Miaoershan uranium ore fields.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Between 2015 and 2016, some new resources categorised as RAR and IR have been added to China's uranium resource base. These additional resources are mainly due to the ISL-amenable sandstone-type deposits. However, as a result of declining uranium price and shift of priority for prospecting, the total identified resources in the hard rocks have decreased. A new resources classification and estimation have been made taking into account fluctuations in the uranium price. As of 1 January 2017, the identified uranium resources in China totalled 370 900 tU (in situ), distributed in 21 uranium ore fields of 13 provinces or autonomous regions, as listed in the following table.

No.	Location (province + place/name)		tU
1	Jiangxi	Xiangshan	30 000
		Ganzhou	34 000
		Taoshan	12 500
2	Guangdong	Xiazhuang	15 000
		Zhuguangnanbu	22 000
		Heyuan	4 000
3	Hunan	Xiangcaodawan	9 000
4	Guangxi	Ziyuan	11 000
5	Xinjiang	Yili	42 000
		Tuha	10 000
6	Inner Mongolia	Erdos	79 000
		Erlian	50 000
		Tongliao	15 400
		Bayingebi	8 500
7	Hebei	Qinglong	8 000
8	Yunnan	Tengchong	6 000
9	Shaanxi	Lantian	2 000
10	Gansu	Longshoushan	2 000
11	Zhejiang	Dazhou	3 000
12	Liaoning	Benxi	500
13	Sichuan	Ruoergai	7 000
Total (in situ)			370 900

Undiscovered conventional resources (prognosticated and speculative resources)

China has very good potential for the discovery of additional uranium resources. According to the prediction and evaluation for metallogenic potential of uranium resources conducted systematically by several institutes in China, there are more than 2 million tU of potential uranium resources in China. Favourable areas include the Erlian Basin of Inner Mongolia, which was identified in the last few years. Other areas such as the Tarim and Junggar Basins in the Xinjiang Autonomous Region and the Songliao Basin in north-east China are regarded as favourable target areas. More uranium resources may also be added to the known uranium deposits in southern China as prospecting and exploration continues. With further exploration in uranium metallogenetic prospective areas, more uranium resources are expected to be discovered.

Unconventional resources and other materials

There are unconventional uranium resources associated with phosphate rocks. However, no systematic appraisal of unconventional uranium resources has been conducted in China.

Uranium production

Historical review

The more than 50 years history of China's uranium industry has included both a boom in activities during the first two decades and a decline in the late 1980s to 1990s. In the early 2000s, there was a surge in activities, driven principally by the ambitious new NPP construction programme announced by the Chinese government and the increased uranium spot price. As a result, uranium production was rejuvenated.

As uranium demand for NPPs is projected to increase rapidly in the coming decade, China responded by accelerating the pace of domestic uranium exploitation to ensure uranium supply. Several existing uranium production centres such as Fuzhou and Yining were developed and put into construction to expand their capacity to achieve both stable and increasing production. Additionally, to promote uranium production, the development of other new uranium production centres based on uranium deposits with reliable reserves and favourable technological/economic feasibilities, such as for the Tongliao and Guyuan uranium deposits, were also accelerated. Finally, to construct new uranium production centres in the future, a series of pilot tests and feasibility studies were carried out in some newly discovered ISL-amenable sandstone uranium deposits with abundant reserves, such as Erduos and Erlian.

Uranium production centre technical details

(as of 1 January 2017)

	Centre #1	Centre #2	Centre #3	Centre #4	Centre #5	Centre #6	Centre #7
Name of production centre	Fuzhou	Chongyi	Yining	Lantian	Qinglong	Shaoguan	Tongliao
Production centre classification	Existing	Suspension	Existing	Suspension	Existing	Existing	Existing
Date of first production	1966	1979	1993	1993	2007	1967	2015
Source of ore:							
Deposit name(s)				Lantian	Qinglong		
Deposit type(s)	Volcanic	Granite	Sandstone	Granite	Volcanic	Granite	Sandstone
Resources (tU)	NA	NA	NA	NA	NA	NA	NA
Grade (% U)	NA	NA	NA	NA	NA	NA	NA
Mining operation:							
Type (OP/UG/ISL)	UG	UG	ISL	UG	UG	UG	ISL
Size (tonnes ore/day)	1 000	600	NA	300	200	650	NA
Average mining recovery (%)	92	90	NA	80	85	90	NA
Processing plant:							
Acid/alkaline	Acid	Acid	Acid, alkaline	Acid	Acid	Acid	Alkaline
Type (IX/SX)	IX	IX	IX	IX	SX	IX	IX
Size (tonnes ore/day); for ISL (l/day or l/h)	1 000	600	NA	NA	NA	NA	NA
Average process recovery (%)	90	84	NA	90	92	90	NA
Nominal production capacity (tU/year)	350	200*	800	100*	100	200	200
Plans for expansion	NA	NA	NA	NA	NA	NA	NA
Other remarks	NA	NA	NA	NA	NA	NA	NA

* Capacity prior to suspension.

Status of production capability

Between 2015 and 2016, with the influence of a sustained declining uranium price, Chinese companies engaged in the uranium industry adopted a series of measures to withstand the challenges for sustainable development. First, steps were taken to strengthen the management, which aimed at improving production efficiency and reducing production costs. Secondly, several underground uranium mines with high production costs were closed or suspended provisionally. Lastly, ISL production centres in northern China were built or expanded, and environmentally friendly mines of considerable size were constructed in Xinjiang and Inner Mongolia.

There are currently a total of seven production centres in China: Fuzhou and Chongyi in Jiangxi Province, south-east China; Lantian in Shaanxi Province, north-west China; Qinglong in Hebei Province, northeast China; Shaoguan in Guangdong Province, south China; Yining in the Xinjiang Autonomous Region of north-west China and Tongliao in Inner Mongolia of north-east China. Between 2015 and 2016, production capacity has increased. The proportion of production from underground uranium mines decreased significantly, while production from ISL uranium mines increased and dominated the total production.

- The Fuzhou production centre is an underground mine, which exploits Xiangshan volcanic-type uranium resources with conventional ion-exchange processing.
- The Chongyi production centre in the Jiangxi Province, is an underground mine, which exploits Lujing and Taoshan granite-type uranium resources with a hydrometallurgical process using heap leaching and ion-exchange. This centre suspended production and is currently on care and maintenance due to depressed market conditions and high production costs.
- The Yining ISL production centre is located in Yining, Xinjiang Autonomous Region, and mainly exploits sandstone-hosted uranium resources in Yili and Tuha Basins using an ion-exchange hydrometallurgical process. Construction of the new Mongqiguer ISL project in this centre was completed and will now be in the production stage, thereby increasing the production capacity of the centre significantly.
- The Lantian production centre in the Shannxi Province is an underground mine, which exploits Lantian granite-type uranium resources with an in-place leaching process. This centre suspended production and is currently on care and maintenance due to depressed market conditions and high production costs.
- The Qinglong production centre in the Hebei province is an underground mine, which exploits Qinglong volcanic-type uranium resources with heap leaching and solvent extraction. Currently the Benxi mine belongs to this centre and was closed down and put into decommissioning due to the depletion of resources.
- The Shaoguan production centre in the Guangdong Province is an underground mine, which exploits Xiazhuang and Zhuguang granite-type uranium resources using an ion-exchange process.
- The Tongliao production centre in the Inner Mongolia is an underground mine, which exploits sandstone-hosted uranium resources in southern Songliao Basin using an ion-exchange process.

The uranium production in China in 2015 and 2016 amounted to 1 600 tU and 1 650 tU, respectively. It is expected to remain steady at 1 700 tU in 2017.

Regarding overseas uranium development, CNNC and CGNPC have been involved in several uranium projects mainly distributed in Namibia, Kazakhstan and Niger. CNNC signed an agreement in 2014 to buy a 25% equity stake from Paladin Energy in its flagship Langer Heinrich uranium mine, and had acquired a total of 1 300 tU under the shareholder's equity by the end of 2016. The Azelik uranium project in Niger suspended production and is currently on care and maintenance. The Semizbay and Irkol mines in Kazakhstan, which CGNPC invested in together with Kazatomprom, have provided 4 258 tU to CGNPC under the shareholder's equity at the end of 2016. CGNPC purchased the Husab Project in Namibia in 2012. The project produced its first yellowcake and launched a pilot production in 2016.

Ownership structure of the uranium industry

The uranium industry is owned by state-owned enterprises in China. The Tongliao production centre is a joint venture owned by CNNC and CNPC. All other centres are sole proprietorship enterprises owned by CNNC.

Employment in the uranium industry

The industrial restructuring of domestic uranium production is a response to the pressure of low uranium prices. The underground uranium production centres of southern China with relatively high costs have reduced production and downsized the workforce accordingly and a few centres have suspended production provisionally, pending a change in market conditions. On the other hand, highly automic ISL uranium production centres have been newly built or expanded at the existing centres in northern China. Consequently, employment in this industry has decreased gradually while a steady growth in production capacity has still been achieved.

Future production centres

Industrial tests have been launched on a new mineralisation block of the Tongliao sandstone-hosted uranium deposit in Inner Mongolia and a corresponding expansion is planned at the associated production centre.

ISL tests are being carried out in some parts of the Erdos and Erlian uranium deposits in Inner Mongolia to obtain relative technical parameters and economic indicators for the development of these two deposits.

The ISL tests in three of the above-mentioned deposits achieved good results, which may lead to them to becoming principal centres in the future.

In addition, once the uranium market rebounds, the current sub-economic uranium production centres are expected to be put into operation again.

Uranium requirements

As of 1 January 2017, the total installed capacity of the 35 NPPs in operation in China is 33.6 GWe, accounting for 2.04% of total electricity installed capacity and ranking fourth in the world. Annual uranium requirements amount to about 6 700 tU. The total amount of electricity generated by nuclear power was 210.5 TWh in 2016, accounting for 3.56% of total generated electricity, which represented a 25.07% increase compared with the same period in 2015. Furthermore, an additional 21 NPPs with the capacity of 23.9 GWe are under construction in China.

During the 13th Five-Year Plan period, the Chinese government will promote nuclear power construction, especially in coastal areas and adhering to the principle of development in a clean, low-carbon and eco-friendly way, as well as ensuring safety.

According to the government's nuclear power programme, the total capacity of NPPs will reach between 50 GWe and 58 GWe by the end of 2020. Based on preliminary calculations, uranium requirements will amount to between 10 100 tU and 12 000 tU in 2020, then rise to between 12 300 and 16 200 tU in 2030, and to between 14 400 and 20 500 tU in 2035.

Supply and procurement strategy

In order to meet the demand of NPPs 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. As a supplement and balance to domestic production and supply, international trade will ensure a stable supply with reasonable prices on both the spot and future markets.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Uranium supply should be given more attention by the Chinese government. It should be emphasised that there needs to be a safe and economical and diverse supply that is also reliable. Adequate commercial stocks are also required. Several measures have been taken by the government for supporting the exploration and development of uranium resources, such as stable investment for domestic exploration; allowing non-government organisations to engage in uranium exploration activities; reviewing the restrictions associated with the domestic production regulation (limitation); as well as promoting investment in overseas uranium resources and the establishment of overseas production centres.

Uranium stocks

N/A.

Uranium prices

The uranium price has been gradually streamlined with the international market price in order to follow the global trend of uranium prices. Accordingly, it is priced in China following the fluctuations of the international market.

Uranium exploration and development expenditures and drilling effort – domestic

(USD millions)

	2014	2015	2016	2017 (expected)
Industry* exploration expenditures	55	30	17	12
Government exploration expenditures	127	108	98	97
Industry* development expenditures	15	14	13	13
Government development expenditures	0	0	0	0
Total expenditures	197	152	128	122
Industry* exploration drilling (m)	264 700	163 700	94 500	67 000
Industry* exploration holes drilled				
Government exploration drilling (m)	610 000	580 000	530 000	520 000
Government exploration holes drilled				
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)	874 700	743 700	624 500	587 000
Subtotal exploration holes drilled				
Subtotal development drilling (m)	0	0	0	0
Subtotal development holes drilled	0	0	0	0
Total drilling (m)	874 700	743 700	624 500	587 000

* Non-government.

Uranium exploration and development expenditures – non-domestic

(USD millions)

	2014	2015	2016	2017 (expected)
Industry* exploration expenditures	3.76	7.65	9.29	11.1
Government exploration expenditures				
Industry* development expenditures	759.22	518.66	368.72	180.5
Government development expenditures				
Total expenditures	762.98	526.31	378.01	191.6

* Non-government.

Reasonably assured conventional resources by production method

(tonnes U*)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Underground mining (UG)	8 100	56 000	79 300	79 300
Open-pit mining (OP)	0	0	0	0
In situ leaching acid	21 100	38 200	55 400	55 400
In situ leaching alkaline	29 000	39 600	43 000	43 000
Co-product and by-product	0	0	0	0
Unspecified	0	0	0	0
Total	58 200	133 800	177 700	177 700

* In situ resources.

Reasonably assured conventional resources by processing method

(tonnes U*)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional from UG	8 100	56 000	79 300	79 300
In situ leaching acid	21 100	38 200	55 400	55 400
In situ leaching alkaline	29 000	39 600	43 000	43 000
Total	58 200	133 800	177 700	177 700

* In situ resources.

Inferred conventional resources by production method

(tonnes U*)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Underground mining (UG)	12 300	57 400	85 400	85 400
In situ leaching acid	50 500	80 900	94 600	94 600
In situ leaching alkaline	6 800	12 100	13 200	13 200
Total	69 600	150 400	193 200	193 200

* In situ resources.

Inferred conventional resources by processing method
(tonnes U*)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Conventional from UG	12 300	57 400	85 400	85 400
In situ leaching acid	50 500	80 900	94 600	94 600
In situ leaching alkaline	6 800	12 100	13 200	13 200
Total	69 600	150 400	193 200	193 200

* In situ resources.

Historical uranium production by deposit type
(tonnes U in concentrates)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Sandstone	NA	480	530	1 000	NA	1 050
Granite-related	NA	620	620	200	NA	200
Volcanic-related	NA	450	450	450	NA	450
Total	NA	1 550	1 600	1 650	NA	1 700

Historical uranium production by processing method
(tonnes U in concentrates)

Processing method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Conventional	NA	300	300	350	NA	350
In-place leaching*	NA	70	70	0	NA	0
In situ leaching	NA	480	530	1 000	NA	1 050
Heap leaching**	NA	700	700	300	NA	300
Total	NA	1 550	1 600	1 650	NA	1 700

* 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 production method
(tonnes U in concentrates)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Underground mining[1]	NA	1 070	1 070	650	NA	650
In situ leaching	NA	480	530	1 000	NA	1 050
Total	NA	1 550	1 600	1 650	NA	1 700

1. Pre-2010 totals may include uranium recovered by heap and in-place leaching.

Ownership of uranium production in 2016

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
1 650	100							1 650	100

Uranium industry employment at existing production centres

(person-years)

	2014	2015	2016	2017 (expected)
Total employment related to existing production centres	7 660	7 670	6 750	5 950
Employment directly related to uranium production	6 960	6 970	5 880	5 020

Czech Republic

Uranium exploration and mine development

Historical review

Following its start in 1946, uranium exploration in former Czechoslovakia grew rapidly and 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 entire country. Areas with identified potential were explored in detail using drilling and underground exploration methods.

Exploration continued in a systematic manner until 1989, with annual exploration expenditures in the range of 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 (Vítkov deposit) of the Bohemian massif and around the sandstone-hosted deposits in northern and north-western 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. Following this decision, in 1990, expenditures decreased to about USD 7 million and have declined 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.

Over the past two years, the most significant exploration works were carried out to accurately identify the uranium resources in the deep parts of Rozná deposit (industry exploration expenditures CZK 15.4 million in 2015, CZK 12.6 million in 2016). These exploration works at the Rozná deposit confirmed and specified economically profitable resources until 2017. In the coming year, the geological survey data will be processed and final reports will be completed (the expected amount CZK 0.7 million).

Uranium resources

Historically, most of the known uranium resources of the Czech Republic occurred in 23 deposits, of which 20 have been mined out or closed. Of the three remaining deposits, only Rozná and Stráz are being 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 protection.

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2017, total identified conventional resources (reasonably assured resources and inferred resources) amounted to 118 892 tU. A decrease of 369 tU from previous estimates as of 1 January 2015, due to the mining, delineation and re-evaluation of uranium resources at the relevant deposits.

In detail, the reasonably assured resources recoverable at a cost of <USD 130/kgU amounted to 1 158 tU. These are recoverable resources in existing production centres at the Rozná and Stráz deposits. The reasonably assured resources recoverable at a cost of <USD 260/kgU amounted to 50 723 tU, a decrease of 232 tU compared to the estimates as of 1 January 2015.

Inferred resources at a cost of <USD 130/kgU amounted to 90 tU, a decrease of 16 tU compared with the previous estimates. These resources are tributary to the Rozná and Stráz deposits. Inferred resources recoverable at a cost of <USD 260/kgU amounted to 68 169 tU, a decrease of 137 tU compared to estimations as of 1 January 2015. These high-cost resources are located in the Stráz bloc (the Stráz, Hamr, Osecná-Kotel and Brevniste deposits) and remain strictly protected because of environmental concerns.

Undiscovered conventional resources (prognosticated and speculative resources)

As of 1 January 2017, total undiscovered conventional resources (prognosticated resources and speculative resources) have been decreased to a total of 239 915 tU. Prognosticated resources at a cost <USD 130/kgU amounted to 225 tU, a decrease of 55 tU from previous estimates, are located at the Rozná deposit only. Prognosticated resources at a cost <USD 260/kgU amounted to 222 915 tU, a decrease of 65 tU from previous estimates as of 1 January 2015 due to the delineation and re-evaluation of uranium resources at the Brzkov deposit. 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 of about 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 is not permitted.

Uranium production

Historical review

The history of uranium mining in the Czech Republic dates back 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, all uranium produced in former Czechoslovakia was exported to the former Soviet Union.

The first production came from 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, supported 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 111 765 tU was produced in the Czech Republic during the period 1946-2014, of which about 85% was produced by underground and open-pit mining methods and the remainder was recovered by in situ leaching.

Uranium production centre technical details

(as of 1 January 2017)

	Centre #1	Centre #2
Name of production centre	Dolní Rozínka	Stráz pod Ralskem
Production centre classification	Existing	Existing
Date of first production	1957	1967
Source of ore:		
Deposit name(s)	Rozná	Stráz
Deposit type(s)	Metamorphite	Sandstone
Recoverable resources (tU)	225	933
Grade (% U)	0.171	0.030
Mining operation:		
Type (OP/UG/ISL)	UG	ISL
Size (tonnes ore/day)	550	-
Average mining recovery (%)	91.5	60.0 (estimated)
Processing plant:		
Acid/alkaline	Alkaline	Acid
Type (IX/SX)	IX, CWG	IX
Size (tonnes ore/day) For ISL (mega or kilolitre/day or litre/hour, specify)	530 -	- 540
Average process recovery (%)	90.4	92
Nominal production capacity (tU/year)	300	100
Plans for expansion	No	No
Other remarks	-	Production under remediation process

CWG = crush-wet grind.

Status of production facilities, production capability, recent and ongoing activities and other issues

Two production centres remain in the Czech Republic. One is a conventional deep mine and mill (Rozná) in the Dolní Rozínka uranium production centre (Western Moravia) and the second is a chemical mining centre in Stráz pod Ralskem (Northern Bohemia). Both the Dolní Rozínka and Stráz pod Ralskem production centres are wholly operated by the state-owned enterprise DIAMO.

The Dolní Rozínka centre (Rozná metamorphite deposit, resources of 225 tU, stoping at 1 100 m underground) produced 107 tU in 2015 and 95 tU in 2016. Because the mining of uranium resources located in the deepest boundary parts of the mine became unprofitable, it was decided to terminate the operation and start the decommissioning of the production centre, as of 1 January 2017. Expected uranium production under the decommissioning process in 2017 is 31 tU.

At the Stráz pod Ralskem chemical mining centre (Stráz sandstone deposit, with resources of 933 tU recoverable at cost <USD 130/kgU), the former acid in situ leaching (~180 m underground) production centre, produced 45 tU in 2015 and 43 tU in 2016. Uranium production at this centre results from environmental remediation activities that began in 1996. Production capability during remediation (without acid) has decreased because of lower uranium concentration in solutions. Production in 2017 is expected to

amount to 31 tU. The increase of about 30 tU as compared to the previous two years is merely the result of remediation technologies. In the long term, a gradual decline in production is expected.

Uranium is also obtained from mine water treatment (at existing and former facilities), with a total recovery of 8 tU expected in 2017 (not including U recovery from ISL mining restoration activities).

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.

Employment in the uranium industry

Total employment in the Czech uranium production centres was 2 040 workers in 2015 and 1 955 workers in 2016 (i.e. employment related to production including head office, auxiliary divisions, mining emergency services).

Employment directly related to uranium production at Dolní Rozínka and Stráz pod Ralskem centres was 1 059 in 2015 and 985 in 2016, however some uranium production is associated with remediation. Another significant decrease in the number of workers is expected in the coming years as a result of the closure of the Dolní Rozínka production centre.

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., (CEZ) as the sole owner and operator of NPPs in the Czech Republic, 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 RepU in its reactors.

Environmental activities and socio-cultural issues

Both the environmental activities and the resolution of social issues are the responsibility of the government contraction programme 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 state budget and EU funding.

This programme has been aimed at gradually decreasing employment related to declining uranium production and the development of alternative (mainly environmental) projects to address social issues.

In general, the environmental activities include project preparation, environmental impact assessment, decommissioning, tailings 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 266 million m^3 groundwater and an enclosure of 600 ha surface area.
- Rehabilitation of the tailings impoundments in Mydlovary, Príbram, Stráz pod Ralskem and Rozná (a total of 19 ponds with a total area of 589 ha).
- Rehabilitation (including reprocessing) of the waste rock dumps in Príbram, Hamr, Rozná, Western Bohemia and other sites (a total of 67 dumps with a capacity 38.2 million m^3).
- Mine water treatment from former uranium facilities in Príbram, Stráz, Horní Slavkov, Licomerice, Olsí and others, amounting to a total of approximately 13 million m^3/yr, which results in the recovery of about 9 tU annually.

The major part of environmental expenses (about 85%) is being funded by the state budget, with the remainder financed by the EU (9-12%) and DIAMO (3-6%). Since 1989, CZK 44 743 million (about USD 1.9 billion) has been spent on the environmental remediation projects. The projects, expected to continue until approximately 2040, are expected to cost in total more than CZK 60 000 million (about USD 2.5 billion).

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 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Uranium environmental remediation	38 541	1 907	2 561	1 734	44 743	2 539
Social programme and social security	9 213	263	226	210	9 912	211
Total	47 754	2 170	2 787	1 944	54 655	2 750

Uranium requirements

There are two NPPs with a total of six units in operation in the Czech Republic: the older Dukovany NPP with four VVER-440 reactors, which have been uprated to 510 MWe (gross) in the period 2009-2015, and the younger Temelin NPP with two VVER-1000 reactors, which have been uprated to 1 080 MWe (gross). The sole owner and operator of these NPPs is the Czech power company CEZ, a.s.

Total uranium requirements of both NPPs have been hovering at the level of about 675 tU/year. A gradual increase to more than 700 tU/year is planned as a result of deployment of advanced fuel with a slightly higher amount of enriched uranium in the fuel assemblies at Temelin NPP.

However, due to the additional inspections of welds the operation of both NPPs was significantly influenced by unplanned and extended outages in 2016. These issues caused lower electricity generation and consequently lower uranium requirements as well. In 2016 the total uranium requirements represented 566 tU/year.

Supply and procurement strategy

CEZ has been procuring uranium on the basis of middle and long-term contracts, as well as taking advantage of the current low spot market prices. About one-third of its uranium needs has been currently covered from domestic production of DIAMO. Some uranium has been partially purchased in the world market, and partially purchased in the form of already fabricated fuel, delivered from the Russian fabricator TVEL as a package.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

The reduction programme of the Czech uranium industry from the end of the 1980s has already been formally terminated. An extensive programme of the environmental remediation of former uranium production facilities continues.

On the basis of the government decision (Government Decree No. 1086/2014 Coll.), the existing Rozná uranium deposit was economically mined out by DIAMO until 2017 with no government financial assistance. Upon completion of the uranium extraction at the Rozná deposit, the environmental site remediation will be done with financial participation of the government.

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 of uranium mining that strictly respect environmental protection.

The government of the Czech Republic approved the launch of the legislative process for mining activities by DIAMO at the Brzkov deposit (Vysocina region), however there is significant disagreement by local municipalities and a strong public backlash against the resumption of uranium mining.

Uranium stocks

The Czech power company CEZ maintains uranium stocks at the level of about two and half years of forward reactor consumption in all forms of processed uranium. A substantial portion of these stocks is in the form of already fabricated fuel stored at the NPP sites and this portion will be increased even more in the coming years.

Uranium prices

Uranium prices are not available as they are commercially confidential. In general, uranium prices in supply contracts between the domestic producer DIAMO and CEZ incorporate price indicators from the world market according to agreed formulas.

Uranium exploration and development expenditures and drilling effort – domestic
(CZK millions)

	2014	2015	2016	2017 (expected)
Industry* exploration expenditures	26.3	15.4	12.6	0.7
Government exploration expenditures	0.5	0.0	0.0	0.0
Industry* development expenditures	0.0	0.0	0.0	0.0
Government development expenditures	0.0	0.0	0.0	0.0
Total expenditures	26.8	15.4	12.6	0.7
Industry* exploration drilling (m)	0.0	0.0	0.0	0.0
Industry* exploration holes drilled	0.0	0.0	0.0	0.0
Industry* exploration trenches (m)	0.0	0.0	0.0	0.0
Industry* exploration trenches	0.0	0.0	0.0	0.0
Government exploration drilling (m)	0.0	0.0	0.0	0.0
Government exploration holes drilled	0.0	0.0	0.0	0.0
Government exploration trenches (m)	0.0	0.0	0.0	0.0
Government exploration trenches	0.0	0.0	0.0	0.0
Industry* development drilling (m)	0.0	0.0	0.0	0.0
Industry* development holes drilled	0.0	0.0	0.0	0.0
Government development drilling (m)	0.0	0.0	0.0	0.0
Government development holes drilled	0.0	0.0	0.0	0.0
Subtotal exploration drilling (m)	0.0	0.0	0.0	0.0
Subtotal exploration holes drilled	0.0	0.0	0.0	0.0
Subtotal development drilling (m)	0.0	0.0	0.0	0.0
Subtotal development holes drilled	0.0	0.0	0.0	0.0
Total drilling (m)	0.0	0.0	0.0	0.0
Total number of holes drilled	0.0	0.0	0.0	0.0

* Non-government.

Reasonably assured conventional resources by deposit type
(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	933	49 245
Metamorphite	0	0	225	1 478
Total	0	0	1 158	50 723

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	225	1 478	92
In situ leaching acid	0	0	933	49 245	60
Total	0	0	1 158	50 723	

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	225	1 478	90
In situ leaching acid	0	0	933	49 245	92
Total	0	0	1 158	50 723	

Inferred conventional resources by deposit type
(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	90	369
Total	0	0	90	68 169

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	0	90	369	92
In situ leaching acid	0	0	0	67 800	60
Total	0	0	90	68 169	

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 UG	0	0	90	369	90
In situ leaching acid	0	0	0	67 800	92
Total	0	0	90	68 169	

Prognosticated conventional resources
(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	225	222 915

Speculative conventional resources
(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	0	17 000

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Proterozoic unconformity	N/A	0	0	0	N/A	0
Sandstone	32 864	15	45	43	32 967	36
Granite-related	N/A	0	0	0	N/A	0
Metamorphite*	871**	139	107	95	1 212	31
Metasomatite	N/A	0	0	0	N/A	0
Lignite and coal	N/A	0	0	0	N/A	0
Other/unspecified	N/A	0	0	0	N/A	0
Total	111 611	154	152	138	112 055	67

* Includes uranium recovered from mine water treatment; 10 tU in 2012, 11 tU in 2013 and 8 tU in 2014.

** Historical uranium production is N/A; the total given from 2010 onwards.

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Underground mining*	94 081	139	107	95	94 422	31
In situ leaching	17 530	15	45	43	17 633	36
Total	111 611	154	152	138	112 055	67

* 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 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Conventional	91 372	130	98	87	91 687	23
In-place leaching*	3	0	0	0	3	0
Heap leaching**	125	0	0	0	125	0
In situ leaching	17 530	15	45	43	17 633	36
Other methods***	2 581	9	9	8	2 607	8
Total	111 611	154	152	138	112 055	67

* 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.

Ownership of uranium production in 2016

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
138	100	0	0	0	0	0	0	138	100

Uranium industry employment at existing production centres

(person-years)

	2014	2015	2016	2017 (expected)
Total employment related to existing production centres	2 072	2 040	1 955	1 455
Employment directly related to uranium production	1 105	1 059	985	613

Short-term production capability

(tonnes U/year)

2016				2017				2020			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	0	200	200	0	0	150	150	0	0	50	50

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
0	0	50	50	0	0	50	50	0	0	30	30

Installed nuclear generating capacity to 2035

(MWe net)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
3 940	3 940	3 940	3 940	3 940	3 960	3 960	3 990	3 960	3 990	3 960	6 390

Annual reactor-related uranium requirements to 2035 (excluding MOX)

(tonnes U)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
582	566	700	705	700	705	725	730	725	730	725	1 120

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	<100	0	0	0	<100
Utility	N/A	N/A	0	0	N/A
Total	<100	0	0	0	<100

Denmark/Greenland

Uranium exploration and mine development

Historical review

A brief review of the history of uranium exploration is provided in the previous editions of the Red Book (1998, 2003 and 2014).

Recent and ongoing uranium exploration and mine development activities

Since 2007, Greenland Minerals and Energy Ltd (GMEL) has conducted rare earth elements (REE) – (U-Zn) – exploration activities in the Kvanefjeld area, South Greenland, including drilling of 57 710 m of core; the business concept encompasses uranium and zinc by-products in addition to the main products of REE. The Kvanefjeld Feasibility Study, as well as the environmental and social impact assessments (EIA and SIA), were carried out in 2014-2015 and were submitted together with the exploitation licence application in December, 2015. Uranium will be recovered from leach solutions using industry standard solvent extraction to produce approximately 500 tonnes of U_3O_8 (425 tU) per year. The application is currently being evaluated by the Greenland government.

In 2016, GMEL entered into a Subscription Agreement with Shenghe Resources Holding Co. Ltd., which provided Shenghe the right to acquire 12.5% of the interest in GMEL.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

The Mesoproterozoic Ilímaussaq alkaline complex of South Greenland hosts the REE-U-Zn-F deposit referred to as Kvanefjeld. It is a high-tonnage, low-grade uranium-enriched intrusive deposit, with concentrations around 300 ppm U. Uranium is planned to be mined as a by-product in a potential open-pit mine; the revenue from uranium is estimated by GMEL to account for 5%. 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 are borne by the production of the REE, the primary resource. GMEL has reported uranium specific supply cost of approximately USD 5/lb U_3O_8, which is incremental to the cost of the REE production. The total identified conventional mineral resource inventory for Kvanefjeld is 102 820 tU. Additional inferred mineral resources of 338 Mt ore exist in the Zone Sørensen and Zone 3, related to the Kvanefjeld, equivalent to 125 143 tU. The recoverable uranium resource using the established and pilot plant tested flowsheet is approximately 50%.

Undiscovered conventional resources (prognosticated and speculative resources)

Several uranium occurrences are known in Greenland. However, uranium exploration has been banned since 1985 and up to 2013. Consequently, few uranium resource data are available. An evaluation of the potential for uranium deposits in Greenland is available on http://mima.geus.dk/publikationer/mima-rapport-20141.

Unconventional resources and other materials

Unknown.

Uranium production

Historical review

No uranium has been produced in Greenland, however, 4 500 tonnes of ore was transported to the Risø National Laboratory, Denmark, for test work during the 1980s. Another 30 tonnes of ore was sent to Outokumpu, Finland, in 2014 where a pilot plant operation was conducted through the FP7 EURARE project.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Greenland is part of the Danish Realm. Greenland enjoys autonomous authority in domestic affairs while Denmark remains constitutionally responsible for foreign affairs, defence and security. In 2009, the Act on Greenland Self-Government granted Greenland authority over its natural resources (Mineral Resources Act 2009). The Ministry of Mineral Resources (MMR) is responsible for strategy and policymaking, legal issues, licence assessment, approvals and inspections, and marketing of mineral resources in Greenland.

On 24 October 2013, the Greenland parliament, Inatsisartut, lifted a decades-long moratorium on mining radioactive elements, which has opened the way for potential future exploration of uranium and thorium.

Denmark and Greenland signed an agreement concerning the special foreign, defence and security policy issues related to the possible future mining and export of uranium in Greenland in January 2016. While Denmark is responsible for non-proliferation matters in Denmark, especially safeguards, security and dual-use exports, the agreement establish a framework for a shared approach to ensure compliance with Denmark's international non-proliferation obligations. The agreement underlines the joint Danish and Greenlandic commitment to observe the highest international standards comparing with other uranium supplier states.

The agreement also served as a basis for the new Danish legislation for Greenland on safeguards and export controls, including export of nuclear material from Greenland, being subject to nuclear co-operation agreements to provide assurances that exports are properly protected and used for peaceful purposes. Act. no. 616 on export controls for Greenland and Act no. 621 on safeguards for Greenland was passed on 8 June 2016.

As part of the agreement concerning the special foreign, defence and security policy issues related to the possible future mining and export of uranium in Greenland, the territorial restrictions regarding six nuclear conventions for Greenland are also in the process of being lifted. In 2016, the territorial restrictions for four of these nuclear conventions have been lifted. This includes the International Convention for the Suppression of Acts of Nuclear Terrorism, Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency, Convention on Nuclear Safety and Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

Uranium exploration and development expenditures and drilling effort – domestic

(AUD and Danish krone [DKK])

	2014	2015	2016	2017 (expected)
Industry* exploration expenditures	AUD 6 294 000[1]	AUD 4 500 000[1]	AUD 3 500 000[1]	AUD 4 000 000[1]
Government exploration expenditures	DKK 400 000	NA	NA	NA

* Non-government.

1. Total Industry exploration expenditures; it is not possible to break the expenditures up according to the different elements.

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				102 820
Total				102 820

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				102 820	65
Total				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				102 820	65
Total				102 820	

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

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	65
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	65
Total	0	0	0	125 143	

Finland

Uranium exploration

Historical review

Uranium exploration in Finland was first carried out between 1955 and 1989, 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 and some junior companies. In 2010, Areva closed down its Finnish subsidiary, and its exploration assets in Finland were purchased by Mawson Resources Ltd. Uranium exploration in Finland has slowed down 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. However, uranium is included as a mining mineral in some exploration permits and exploration permit applications of Mawson Resources Ltd. Applications for an exploration permit, including a preliminary assessment of the mining minerals in the area, shall be submitted to the permit authority (Tukes). Mawson Resources is focused on the Rompas-Rajapalot exploration project in the Paleoproterozoic Peräpohja Schist Belt, located a few kilometres south of the Arctic Circle in the municipality of Ylitornio, northern Finland.

Both disseminated and nuggetty high-grade gold has been discovered in the Rompas-Rajapalot area (10 x 10 km). Initial discoveries of the nuggety, high-grade, gold-uraninite-bearing carbonate veins were made at Rompas by Areva Resources Finland Oy in 2008 as part of regional uranium exploration. Mawson acquired the project from Areva in 2010. The initial discovery area, Rompas, is a hydrothermal vein-style system defined over a 6 km strike and 200-250 m width. At Rompas, gold mineralisation is hosted by carbonate and calc-silicate veins in mafic metavolcanic rocks. Gold is intimately associated with uraninite, typically in microfractures of uraninite.

The Palokas prospect at Rajapalot was discovered by Mawson in 2013. Rajapalot, located 8 km to the east of the Rompas vein trend, is currently the primary target area for Mawson. The style of mineralisation at Rajapalot is predominately sulphidic and of a disseminated style, which differs from the nuggety vein-style observed at Rompas.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Finland reports a total of 1 500 tU of reasonably assured conventional resources recoverable at costs of USD 80-130/kgU in the Palmottu and Pahtavuoma U deposits. No inferred conventional resources are reported.

Undiscovered conventional resources (prognosticated and speculative resources)

None reported.

Unconventional resources

Unconventional resources of uranium in the Talvivaara black schist-hosted Ni-Zn-Cu-Co deposit are approximately 16 000 tU in the measured and indicated resources of 970 Mt, and about 24 000 tU in the total mineral resources (measured, indicated and inferred) of 1 458 Mt, calculated from the resource update 2016 by Terrafame Oy.

Another potential target for by-product recovery of uranium is the undeveloped, uraniferous Sokli phosphorus deposit in eastern Lapland. Yara has recently planned to undertake phosphate mining in Sokli. The Sokli phosphorus deposit is hosted by the surface weathered zone (regolith) of carbonatite. There are currently no plans by Yara for recovering uranium as a by-product.

There is also potential for by-product uranium extraction from undeveloped, uraniferous polymetallic Au-Co-U deposits in the Kuusamo Schist Belt, eastern Finland. In recent years, Dragon Mining Ltd has investigated the possibility of developing a gold mining operation in the Kuusamo area with a central processing facility and gold production from the deposits Juomasuo, Hangaslampi, Pohjasvaara, Meurastuksenaho and Sivakkaharju. There were no plans by Dragon Mining for recovering uranium as a by-product from these deposits. In 2016, Dragon Mining's subsidiary (Kuusamo Gold Oy) and exploration assets in Kuusamo were purchased by Nero Projects Australia Pty Ltd.

Uranium production

Historical review

Uranium production in Finland has been confined only to the now restored Paukkajanvaara mine that operated as a pilot-scale mine between 1958 and 1961. A total of 40 000 tonnes of ore was excavated and the concentrates produced amounted to about 30 tU. As reported in the *Red Book Retrospective* (NEA, 2006), the total historical production calculated from the mining register statistics is no more than 41 tU from 1958 to 1961.

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 0.23 wt% Ni, 0.50 wt% Zn, 0.13 wt% Cu, 0.0172 wt% Co, and 0.0017 wt% U.

Production of nickel and zinc from the Talvivaara ore deposit commenced in 2008. The production process includes open-pit mining, crushing, heap leaching, metals recovery and removal of metals having no current value. 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, zinc, nickel and cobalt 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 Harjavalta Nickel Refinery, and reported to the Radiation and Nuclear Safety Authority (STUK). Norilsk Nickel Harjavalta refinery has been licensed by the STUK to extract uranium less than 10 tU/year. As of 31 December 2015, a total amount of natural uranium stored at Norilsk Nickel Harjavalta was 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 March 2012, the Finnish government granted a uranium extraction licence to Talvivaara Sotkamo Oy in accordance with the nuclear energy legislation. In December 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. In November 2014, Talvivaara Sotkamo Oy filed for bankruptcy as a result of financial problems. In August 2015, state-owned company Terrafame Oy acquired the operations and assets of Talvivaara Sotkamo Oy from its bankruptcy estate, and as of 1 November 2017, was carrying on the mining operations in Sotkamo.

On 31 October 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. The mine site currently includes almost fully completed uranium solvent extraction plant from the time of Terrafame's predecessor, Talvivaara Sotkamo Oy. Terrafame expects to start uranium production in Sotkamo in 2020, after completion of licensing processes.

Uranium production centre technical details

(as of 1 January 2017)

	Centre #1
Name of production centre	Terrafame
Production centre classification	Planned
Date of first production	2020
Source of ore:	
Deposit name(s)	Talvivaara (Kuusilampi and Kolmisoppi)
Deposit type(s)	Black schist
Recoverable resources (tU)*	7 200*
Grade (% U)	0.0017
Mining operation:	
Type (OP/UG/ISL)	OP
Size (tonnes ore/day)	50 000
Average mining recovery (%)	50
Processing plant:	
Acid/alkaline	Acid (heap leaching)
Type (IX/SX)	SX
Size (tonnes ore/day)	N/A
Average process recovery (%)	90
Nominal production capacity (tU/year)	250
Plans for expansion	N/A
Other remarks	Heap leaching by-product

* Overall recovery factor of 45% used in the estimate.

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 2015 and 2016.

Regulatory regime

The Mining Act regulates exploration and mining activities in Finland. Tukes is the mining authority and all licences under the Mining Act are decided by 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 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. 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. The granting of a permit for a uranium mine requires that the mining activities are in line with the overall good of society, the municipality in question has given its consent, and safety requirements are fulfilled.

STUK's regulatory control covers 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

Four units (two each at the Olkiluoto and Loviisa NPPs) with a total generating capacity of 2.8 GWe (net) are in operation, providing about 34% of domestic electricity generation. These four reactors require about 450 to 500 tU annually. Olkiluoto units are owned and operated by Teollisuuden Voima Oyj (TVO), Loviisa units by Fortum Power and Heat Oy.

TVO's Olkiluoto 3 European pressurised reactor (EPR; 1.6 GWe net) is under construction. TVO selected EPR technology for Olkiluoto 3 in 2003 and Areva-Siemens Consortium started the construction works in 2005. According to the plant supplier Areva-Siemens Consortium, the start of the regular electricity production of the Olkiluoto 3 nuclear power plant unit will take place in 2019, some ten years later than originally planned.

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 decision in principle made in 2010. The reason was the delay of the start-up of Olkiluoto 3 power plant unit. Consequently, the decision in principle made by the Finnish government and approved by parliament expired at the end of June 2015. TVO will remain prepared to apply for a new decision in principle for OL4. The application is subject to a separate decision.

Fennovoima is a new nuclear power company, established by a group of Finnish companies in 2007. Fennovoima will build a nuclear power plant unit (Hanhikivi 1) in Pyhäjoki, northern Finland. Fennovoima has two main owners: Voimaosakeyhtiö SF Oy (66%) and Rosatom's subsidiary RAOS Voima Oy (34%). Voimaosakeyhtiö SF is owned by Finnish energy and industrial companies.

A construction licence application for Fennovoima's Hanhikivi 1 nuclear power plant unit was submitted to the Finnish government in June 2015. In September 2015, the STUK received a request for statement from the Ministry of Economic Affairs and Employment for assessing the safety of the Hanhikivi 1 unit. The construction licence awarded by the Finnish government can only be issued if Finnish safety requirements are fulfilled. The nuclear power plant unit of Fennovoima (AES-2006; 1.2 GWe net) will be supplied by RAOS Project Oy, which is a part of Rosatom.

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. The majority of the uranium procured by TVO comes from Kazakhstan, Canada, and Australia, and the fuel elements ordered by the company are constructed and assembled in Germany or Sweden.

The fuel assemblies used at the Fortum's Loviisa nuclear power plant are completely of Russian origin. Nuclear fuel is acquired from the Russian TVEL as a turnkey delivery, from the acquisition of the raw uranium to the production 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. In 2016, the uranium used in the Fortum's fuel assemblies originated from the Krasnokamensk, Khiagda and Dalur mines. The quality, environmental, and health and safety management systems of nuclear fuel suppliers and the production of the uranium and fuel assemblies are regularly assessed by Fortum. In summer 2016, Fortum's representatives assessed the operations of Russian fuel supplier's uranium enrichment plant.

Fennovoima will acquire the nuclear fuel as an integrated fuel supply from TVEL. The integrated delivery will cover the procurement of the uranium and the manufacturing of the fuel for the first ten years of Hanhikivi 1 operation. Fuel supply agreement between Fennovoima and TVEL was approved by the Euratom Supply Agency in 2014. Fennovoima has chosen to use reprocessed uranium during the first years of operation.

Uranium policies, uranium stocks and uranium prices

Nuclear energy legislation

The Finnish Nuclear Energy Act requires that the use of nuclear energy must be safe and benefit society as a whole. It must not cause injury to people or damage to property or the environment. 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 Finnish State 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 YVL guides that set out the detailed safety requirements for the use of nuclear energy, and the supervisory practices adopted by the STUK. 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 bedrock of Olkiluoto in Eurajoki. Posiva Oy, owned by TVO and Fortum, is responsible for the final disposal of 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 physical state of the fuel, the disposal canister, the bentonite buffer, the backfilling of the tunnels and the surrounding rock.

In November 2015, the government granted Posiva Oy a licence for the construction of an encapsulation plant and disposal facility for spent nuclear fuel. In November 2016, the STUK decided that Posiva can start the construction of the final disposal facility at Olkiluoto in the municipality of Eurajoki.

Before the actual commencement of final disposal operations for spent nuclear fuel, an operation licence from the government is required for the encapsulation plant and final disposal facility. Posiva plans to submit the operation licence application in 2020. The final disposal is scheduled to start in 2020s. According to current plans, the repository would be sealed up by the 2120s.

An environmental impact assessment (EIA) programme for the final disposal of Fennovoima’s spent nuclear fuel was submitted to the Ministry of Economic Affairs and Employment in June 2016. The alternative final disposal locations in Fennovoima’s EIA programme are Pyhäjoki and Eurajoki. Fennovoima's goal is to achieve long-term co-operation with Posiva and the current companies liable for nuclear waste management (TVO and Fortum). In December 2016, the ministry ruled that Fennovoima should continue co-operation with the current nuclear waste management custodians. The ministry noted that the most desirable solution for Fennovoima’s spent nuclear fuel would be the disposal in Posiva’s final disposal facility in Eurajoki. Fennovoima was obliged to provide a plan for a more detailed timetable of the project by 31 January 2018 as the EIA procedure continues.

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.

Uranium exploration and development expenditures and drilling effort – domestic

(EUR)

	2014	2015**	2016**	2017 (expected)
Industry* exploration expenditures	1 290 000	0	0	N/A
Government exploration expenditures	0	0	0	0
Industry* development expenditures	N/A	0	0	N/A
Government development expenditures	0	0	0	0
Total expenditures	1 290 000	0	0	N/A
Industry* exploration drilling (m)	2 674	0	0	N/A
Industry* exploration holes drilled	N/A	0	0	N/A
Industry* exploration trenches (m)	N/A	N/A	N/A	N/A
Industry* exploration trenches	N/A	N/A	N/A	N/A
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 exploration trenches	0	0	0	0
Industry* development drilling (m)	0	0	0	0
Industry* 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)	2 674	0	0	N/A
Subtotal exploration holes drilled	N/A	0	0	N/A
Subtotal development drilling (m)	0	0	0	0
Subtotal development holes drilled	0	0	0	0
Total drilling (m)	2 674	0	0	N/A
Total number of holes drilled	N/A	0	0	N/A

* Non-government.

** Expenditures of gold exploration are not included although some of the gold exploration permits include uranium as one of the assumed mining minerals in the exploration area.

Reasonably assured conventional resources by deposit type

(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

* In situ resources.

Reasonably assured conventional resources by production method

(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

* In situ resources.

Reasonably assured conventional resources by processing method

(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

* In situ resources.

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2011	2014	2015	2016	Total through end of 2016	2017 (expected)
Sandstone	30	0	0	0	30	0
Total	30	0	0	0	30	0

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2011	2014	2015	2016	Total through end of 2016	2017 (expected)
Open-pit mining[1]	15	0	0	0	15	0
Underground mining[1]	15	0	0	0	15	0
Total	30	0	0	0	30	0

1. 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 2011	2014	2015	2016	Total through end of 2016	2017 (expected)
Conventional	30	0	0	0	30	0
Total	30	0	0	0	30	0

Re-enriched tails production and use

(tonnes natural U-equivalent)

Re-enriched tails	Total through end of 2011	2014	2015	2016	Total through end of 2016	2017 (expected)
Production	0	0	0	0	0	0
Use	843	0	0	0	843	0

Net nuclear electricity generation

	2015	2016
Nuclear electricity generated (TWh net)	22.4	22.3

Installed nuclear generating capacity to 2035

(MWe net)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
2 760	2 760	2 760	2 760	4 380	4 380	5 580	5 740	5 080	5 240	4 580	4 740

Annual reactor-related uranium requirements* to 2035 (excluding MOX)

(tonnes U)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
446	433	436	456	690	750	810	980	700	780	700	780

* 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 mineralisation occurrences discovered during radium exploration. In 1948, exploration led to the discovery of the La Crouzille deposit, formerly 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, arising from eroded granite mountains and 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.

In 2016, Areva (now Orano) Mines have been working outside France focusing on targets aimed at the discovery of exploitable resources in Canada, Gabon, Kazakhstan, Mongolia, Namibia and Niger. In Canada, Kazakhstan, Namibia and Niger, Areva is involved in uranium mining operations and projects. In addition, without being an operator, it holds shares in several mining operations and research projects in different countries.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Areva 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 is 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. Only a few tonnes of uranium per year are recovered from resins during the water cleaning process at the outflow of the former Lodève mine in the south of France. The resins are eluted at the Malvési refinery, where the uranium is recovered.

In France, a total of 244 sites, ranging from exploration sites to mines of various sizes, 8 mills and 17 tailings deposits (containing a total of 52 Mt of tailings) resulted from the production of more than 80 000 tU. All of these sites have been remediated. Monitoring continues at only the most important sites and 14 water treatment plants were installed to clean drainage from the sites. Areva is responsible for the management of 234 of these sites.

The targets of remediation are to:

- ensure public health and safety;
- limit the residual impact of previous activities;
- integrate the industrial sites into landscape;
- maintain a dialogue and consultation with local populations.

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 NPPs (a total of about 120 t/yr, or 960 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. The annual production from Électricité de France (EDF) of spent fuel is around 1 000 tU. Reprocessed uranium was recycled at the EDF nuclear power plant of Cruas. The last fuel assemblies containing reprocessed uranium were loaded in 2013, and EDF is currently studying the possibility of resuming the recycling process.

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).

In order 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*.

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.

After decommissioning, the mining company retains responsibility for the site, including monitoring and maintenance. There has not been a transfer of responsibility for a uranium mine from the mining company to the state because Areva is always present. However, Areva is in discussion with authorities on 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

As of 31 December 2016, France's installed nuclear capacity consisted of 58 pressurised water reactors (34 x 900 MWe units, 20 x 1 300 MWe units and 4 x 1 450 MWe units), with uprates now totalling 63.2 GWe (net), requiring about 8 000 tU/yr.

The Energy Transition Law was voted on 17 August 2015. The Law pursues the following main objectives:

- to reduce greenhouse emissions from 40% between 1990 and 2030, and divide them by four between 1990 and 2050;
- to reduce final energy consumption by 50% in 2050 (ref. 2012);
- to reduce primary energy consumption of fossil fuels by 30% in 2030 (ref. 2012);
- to increase renewable energy share by 23% of final energy consumption in 2020 and by 32% in 2030;
- and to cap the share of nuclear energy at 50% by year 2025.

The French Energy Code, introduced by Energy Transition Law, caps nuclear capacity in France at 63.2 GWe.

Construction of the 1.6 GWe Flamanville 3 EPR began in late 2007. The fuel loading and start-up of the reactor is due at the end of fourth quarter of 2018.

In 2016, major construction steps were achieved:

- most of the equipment of the nuclear section, such as the conventional island, has been delivered and installed on-site;
- completion of the main civil engineering work;
- first start-up of the turbine and the alternator; transfer of the control room to EDF teams that will operate the reactor.

There are currently no short-term plans for additional nuclear generating capacity in France after Flamanville 3 is brought into service.

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 has 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, on schedule as planned. 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 in excess of 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

(EUR millions)

	2014	2015	2016	2017 (expected)
Industry* exploration expenditures	37.5	39	34	35
Government exploration expenditures				
Industry* development expenditures	NA	NA	NA	NA
Government development expenditures				
Total expenditures	37.5	39	34	35

* Non-government.

Historical uranium production by deposit type

(tonnes U in ores)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Sandstone	16 781	0	0	0	16 781	0
Granite-related	63 683	0	0	0	63 683	0
Metamorphite	395	0	0	0		
Volcanic-related	1	0	0	0	1	0
Black shale	3	0	0	0	3	0
Other/unspecified	105	3	2	3	113	2
Total	80 968	3	2	3	80 976	2

Historical uranium production by production method

(tonnes U in ores)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Open-pit mining*	5 427	0	0	0	5 427	0
Underground mining*	1 511	0	0	0	1 511	0
Open-pit and underground**	73 925	0	0	0	73 925	0
Co-product/by-product	105	3	2	3	113	2
Total	80 968	3	3	3	80 976	2

* Pre-2013 totals may include uranium recovered by heap and in-place leaching.

** Not possible to separate in historic records.

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Conventional	80 863	0	0	0	75 890	0
Other methods*	105	3	2	3	113	2
Total	80 968	3	2	3	80 976	2

* Includes mine water treatment and environmental restoration.

Mixed oxide fuel production and use

(tonnes natural U-equivalent)

Mixed oxide (MOX) fuel	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Production	19 712*	1 072	997	992	22 773	1 040
Use	NA	917	961	960	NA	960
Number of commercial reactors using MOX		22	22	22		22

* Includes Cadarache Historical Production and Marcoule production adjustment.

Reprocessed uranium use

(tonnes natural U-equivalent)

Reprocessed uranium	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Production	17 900	1 180	1 170	1 080	21 330	1 120
Use	5 300	0	0	0	5 300	0

Net nuclear electricity generation

	2015	2016
Nuclear electricity generated (TWh net)	416.8	384

Installed nuclear generating capacity to 2035

(MWe net)

2017		2020		2025		2030		2035	
Low	High	Low	High	Low	High	Low	High	Low	High
63 000	63 000	63 000	63 000	NA	NA	NA	NA	NA	NA

Annual reactor-related uranium requirements to 2035 (excluding MOX, including reprocessed uranium)

(tonnes U)

2017		2020		2025		2030		2035	
Low	High	Low	High	Low	High	Low	High	Low	High
8 000	8 000	NA	8 000	NA	8 000	NA	8 000	NA	8 000

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 (see below) in what is today Germany. A summary of the activities is provided below.

Former German Democratic Republic 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 former German Democratic Republic (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 GDR mark 5.6 billion.

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 as remediation activities are completed.

Federal Republic of Germany 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: the partly high-grade hydrothermal deposit near Menzenschwand in the southern Black Forest, the sedimentary Müllenbach deposit in the northern Black Forest and in the Grossschloppen deposit in north-eastern 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.

Recent and ongoing uranium exploration and mine development activities

There have been no exploration activities in Germany since the end of 1990. Several German mining companies 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 above USD 260/kgU.

Unconventional resources and other materials

None reported.

Uranium production

Historical review

Federal Republic of Germany before 1990

In the Federal Republic of Germany, 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 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 Federal Republic of Germany) and 1990 (former GDR). Between 1991 and 2016, uranium recovery from mine water treatment and environmental restoration amounted to a total of 2 645 tU. Since 1992, all uranium production in Germany has been derived from the clean-up operations at the Königstein mine.

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 within the last four years from 1 372 (2012) to 1 043 (2016).

Future production centres

None reported.

Uranium policies, uranium stocks and uranium prices

According to the energy concept 2010, the federal government decided to phase out use of nuclear power for commercial electricity generation on a staggered schedule. With the adoption of the Thirteenth Act amending the Atomic Energy Act (*Dreizehntes Gesetz zur Änderung des Atomgesetzes*), all reactors will be shut down by no later than the end of 2022. The German Bundestag (parliament) passed the amendment on 30 June 2011 and it came into force on 6 August 2011. For the first time in the history of the Federal Republic of Germany, a fixed deadline has been laid down in law for the end of the use of nuclear power in the country. The withdrawal is to be undertaken in stages with specific shutdown dates.

A total of 37 nuclear power plants have been built in Germany and put into commercial operation since 1962. At present, there are eight nuclear power plants still operating in Germany with installed generating capacity of approximately 11 GW. The final shutdown dates for the eight remaining nuclear power plants are determined according to the following schedule: 2017, Gundremmingen B; 2019, Philippsburg 2; 2021, Grohnde, Gundremmingen C and Brokdorf; and 2022, the three youngest nuclear power plants, Isar 2, Emsland and Neckarwestheim 2.

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 (%)
Unspecified				3 000	
Total				3 000	

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 (%)
Unspecified				3 000	
Total				3 000	

Inferred conventional resources by production method

(tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified				4 000	
Total				4 000	

Inferred conventional resources by processing method

(tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Unspecified				4 000	
Total				4 000	

Historical uranium production by processing method

(tonnes U in concentrates)

Processing method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Other methods*	2 567	33	0	45	2 645	40
Total	219 653	33	0	45	219 731	

* Includes mine water treatment and environmental restoration.

Speculative conventional resources
(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
		74 000

Ownership of uranium production in 2016

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
45	100							45	100

Uranium industry employment at existing production centres
(person-years)

	2014	2015	2016	2017 (expected)
Total employment related to existing production centres	1 147	1 062	1 043	1 031
Employment directly related to uranium production	N/A			

Mixed oxide fuel production and use
(tonnes natural U-equivalent)

Mixed oxide (MOX) fuel	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Production	0	N/A	N/A	N/A	N/A	N/A
Use	6 730	N/A	N/A	N/A	N/A	N/A
Number of commercial reactors using MOX		N/A	N/A	N/A		

* Reactors loading fresh MOX.

Re-enriched tails production and use
(tonnes natural U-equivalent)

Re-enriched tails	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Production	N/A	N/A	N/A	N/A	N/A	N/A
Use	N/A	0	0	0	0	0

Reprocessed uranium use

(tonnes natural U-equivalent)

Reprocessed uranium	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Production	N/A	0	0	0	0	0
Use	N/A	N/A	N/A	N/A	N/A	N/A

Net nuclear electricity generation

	2015	2016
Nuclear electricity generated (TWh net)	86.8	80.1

Installed nuclear generating capacity to 2035

(MWe net)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
10 800	10 800		10 800		8 100		0		0		0

Annual reactor-related uranium requirements to 2035 (excluding MOX)

(tonnes U)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
1 620	1 620		1 620		1 200		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	N/A	N/A	N/A	N/A	N/A
Producer	N/A	N/A	N/A	N/A	N/A
Utility	N/A	N/A	N/A	N/A	N/A
Total	N/A	N/A	N/A	N/A	N/A

Hungary

Uranium exploration

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 in 1953 to a geophysical exploration programme (airborne and surface radiometry) 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 placed 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.

Recent and ongoing uranium exploration and mine development activities

In accordance with the expectation of the Hungarian Office for Mining and Geology, the resource estimate was re-evaluated in 2012. In the frame of a non-governmental exploration programme, the sinking of two deep boreholes (1 000 m long each) and related investigations were completed in 2016. As soon as the required permits were obtained, a third borehole (1 000 m deep) was sunk in 2017. Based on the results of this exploration, a database will be developed, followed by the publication of a final report and environmental impact study.

Uranium resources

Hungary's reported uranium resources are limited to those of the Mecsek deposit. The ore occurs in Upper Permian sandstones that may be as thick as 600 m. The sandstones were folded into the Permian-Triassic anticline of the Mecsek Mountains. The ore-bearing sandstone in the upper 200 m of the unit is underlain by a very thick 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)

Following the resource estimate re-evaluation in 2012, 17 946 tU are now reported as in situ high-cost inferred resources, an increase of over 6 000 tU from the previous estimate.

Undiscovered conventional resources (prognosticated and speculative resources)

Prognosticated resources amount to a total of 13 427 tU, the same as reported in the last edition. These resources are tributary to the former Mecsek production centre. Speculative resources are not 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). It began operation in 1956 and was producing ore from a depth of 100-1 100 m until it was definitively shut down in 1997. During operation, it produced about 500 000-600 000 tonnes ore/year 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 t/year.

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 raw ore was 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 closed down at the end of 1997 because changes in market conditions made the operation uneconomical. Throughout its operational history, total production from the Mecsek mine and mill, including heap leaching, amounted to a total of about 21 000 tU.

Status of production capability

Since the closure of the Mecsek mine in late 1997, the only uranium production in Hungary has been recovered as a by-product of water treatment activities, amounting to a total of about 2-6 tU/yr.

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: removing several hundred thousand tonnes of contaminated soil from various areas around the site to an on-site disposal facility; remediation of tailings ponds and waste rock piles through the placement of protective earthen covers; 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 have to continue for some years to come. Because of flooding of the abandoned underground mining openings, in the coming years the enlargement of the water management system and the mine water treatment plant will be crucial; the planning and implementation works began in 2014.

Since July 2016, the long-term aftercare works on the Hungarian uranium mining and ore processing legacy site are under the direct responsibility of the Mining Property Utilization Company in the Public Interest (www.bvh.hu).

The legal successor of the former Mecsek mine (a state-owned company) is also 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 [Hungarian forints])

	Pre-1998	1998 to 2008
Closing of underground spaces	N/A	2 343 050
Reclamation of surficial establishments and areas	N/A	2 008 403
Reclamation of waste rock piles and their environment	N/A	1 002 062
Reclamation of heap leaching piles and their environment	N/A	1 898 967
Reclamation of tailings ponds and their environment	N/A	8 236 914
Water treatment	N/A	1 578 040
Reconstruction of electric network	N/A	125 918
Reconstruction of water and sewage system	N/A	100 043
Other infrastructural service	N/A	518 002
Other activities including monitoring, staff, etc.	N/A	2 245 217
Total	5 406 408	20 056 616

N/A = Not available.

After remediation of the uranium mining and ore processing legacy site, the annual cost of long-term activities amounts to some HUF 600-750 million (about USD 2.2-2.6 million).

Uranium requirements

In accordance with the national energy strategy adopted in 2011, Hungary attributed a major role to nuclear power, and opted for its long-term maintenance in the energy mix. 2016 was a record-breaking year for nuclear power in Hungary; the four units of the MVM Paks Nuclear Power Plant Ltd. generated its all-time-high electricity accounting for 51.3% of inland gross electricity production and 36.5% of domestic electricity consumption. The performance record is dedicated to the changeover from a 12- to a 15-month fuel campaign resulting in 100% load factor for unit 3. 16 053.9 GWh of electric energy was generated by the nuclear power plant in 2016. This amount was generated by four units as follows: unit 1: 4 028.0 GWh; unit 2: 3 576.3 GWh; unit 3: 4 403.8 GWh; unit 4: 4 045.8 GWh.

The lifetime extension of the Paks nuclear power plant from 30 to 50 years is currently ongoing. In 2016, the Hungarian Atomic Energy Authority has given the licence for the lifetime extension programme of unit 3, while the application for a lifetime extension of unit 4 has already been submitted to the national regulatory authority and the decision is expected in 2017.

National policies relating to uranium

Since the shutdown of the Hungarian uranium mining industry in 1997, there are no uranium-related policies. The Energy Mineral Resources Utilisation and Stock Management Action Plan, which is currently under the process of adoption, summarises the Hungarian uranium stocks, but it does not include any policy, measure or action about the utilisation of these assets.

Uranium stocks

The by-product (UO_4 $2H_2O$) of the water treatment activities on the former uranium mining and ore processing site is stored at the mine water treatment facility until export. At the end of 2016, the inventory amounted to 4 403 kg.

Uranium prices

Uranium prices are not available as they are commercially confidential.

Uranium exploration and development expenditures and drilling effort – domestic

(EUR)

	2014	2015	2016	2017 (expected)
Industry* exploration expenditures			N/A	N/A
Government exploration expenditures			N/A	N/A
Industry* development expenditures			N/A	N/A
Government development expenditures			N/A	N/A
Total expenditures			N/A	N/A
Industry* exploration drilling (m)			1 867	1 050
Industry* exploration holes drilled			2	1
Total drilling (m)			1 867	1 050
Total number of holes drilled			2	1

* Non-government.

Inferred conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone				17 946
Total				17 946

* In situ resources.

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)				17 946	
Total				17 946	

* In situ resources.

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 UG				17 946	
Total				17 946	

* In situ resources.

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
		13 427

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Sandstone	21 065	2	4	4	21 075	5
Total	21 065	2	4	4	21 075	21 080

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Underground mining*	21 000					
Co-product/by-product	65	2	4	4	75	5
Total	21 065	2	4	4	21 075	21 080

* 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 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Conventional	20 475					
Heap leaching*	525					
In situ leaching						
Other methods**	65	2	4	4	75	5
Total	21 065	2	4	4	21 075	21 080

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

** Includes mine water treatment and environmental restoration.

Ownership of uranium production in 2016

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
4	100							4	100

Installed nuclear generating capacity to 2035

(MWe net)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
1 890	1 890	1 890	1 890	1 890	2 000	2 000	3 200	3 200	4 400	2 100	3 400

Annual reactor-related uranium requirements to 2035 (excluding MOX)

(tonnes U)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
470	280	394	394	355	355	359	1 027	359	1 001	168	810

Total uranium stocks

(tonnes natural U-equivalent)

Holder	Natural uranium stocks in concentrates	Enriched uranium stocks	Enrichment tails	LWR reprocessed uranium stocks	Total
Government					
Producer	4				4
Utility					
Total	4				4

India

Uranium exploration and mine development

Historical review

The history of uranium exploration in India dates from 1949. Until the mid-1970s, uranium exploration was mainly confined to uranium provinces in the Singhbhum, Jharkhand and Umra-Udaisagar belt in Rajasthan targeting vein-type of mineralisation. This resulted in establishing 14 (after merging of certain deposits) low-grade uranium deposits of varying size in Singhbhum Shear Zone, Jharkhand and one deposit at Umra, Rajasthan. Seven out of the fourteen deposits in Singhbhum are under exploitation. Presently, exploration is being carried out in several sectors of the 160 km long Singhbhum Shear Zone. Subsequently, investigations were expanded to other favourable geological domains, which resulted in establishing a number of small uranium deposits such as Bodal and Bhandaritola, Chhattisgarh in Paleoproterozoic amphibolites; Jajawal, Chhattisgarh in Paleoproterozoic sheared migmatites of Chhotanagpur Granite Gneiss Complex and Walkunji, Karnataka in basal quartz-pebble conglomerates of Dharwar Group.

During the mid-seventies, exploration was initiated in several potential geological sectors targeting sandstone-type uranium deposits. The pursuit for sandstone-type uranium mineralisation resulted in establishing a high-grade, medium-tonnage deposit at Domiasiat (Kylleng-Pyndengsohiong Mawthabah) in the Cretaceous sandstones of Meghalaya. Exploration in the contiguous sectors has established a number of 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 Cuddapah Basin. Since the dolostone ore was not amenable for conventional leaching procedures in vogue at that time, exploration in this sector was discontinued. However, development of an economically viable alkali pressure leaching process rejuvenated the exploration activities in this part of the Cuddapah Basin, especially targeting carbonate-hosted uranium mineralisation in the Vempalle Formation. In recent years, intensive multi-parametric exploration has been carried out in Tummalapalle and adjacent sectors.

Subsequently, during the early 1990s, a near-surface deposit was discovered adjacent to the unconformity contact between basement granites and overlying Proterozoic Srisailam Quartzite at Lambapur in the Nalgonda district, Andhra Pradesh. These occurrences were further investigated and a number of areas had been identified by 1996. Favourable geological criteria and sustained exploration efforts resulted in establishing deposits at Peddagattu and Chitrial. Exploration in the adjacent Palnad sub-basin has established a small deposit at Koppunuru. Exploration is continuing in these sectors.

Sustained exploration in the North Delhi Fold Belt (NDFB), in parts of Rajasthan and Haryana targeting metasomatite type of uranium mineralisation has established the Rohil uranium deposit, Rajasthan. Exploration is being carried out in various sectors of the ~300 km long albitite line in Rajasthan and Haryana.

Recent and ongoing uranium exploration and mine development activities

In recent 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 & Haryana.
- Cretaceous Mahadek basin, Meghalaya.
- Neoproterozoic Bhima Basin, Karnataka.
- Dharmapuri Shear Zone in the Southern Granulite Terrain, Tamil Nadu.
- Proterozoic Kaladgi Basin, Karnataka.
- Palaeozoic – Mesozoic Satpura Gondwana basin, Madhya Pradesh.
- Other potential geological domains such as the Siwaliks, Himachal Pradesh; Chhotanagpur Granite Gneiss Complex, Uttar Pradesh, Madhya Pradesh and Chhattisgarh; Aravalli Fold belt, Rajasthan; Kotri-Dongaragarh belt, Chhattisgarh and Lesser Himalayas, Uttarakhand; are under active exploration.
- Extensive exploration including ground and heliborne geophysical (TDEM, magnetic and radiometric), ground geological with radiometric and geochemical surveys and drilling are planned in the sectors with potential in the country.

Proterozoic Cuddapah Basin, Andhra Pradesh and Telangana

The Cuddapah Basin (Paleo to Neoproterozoic) of 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: a) carbonate-hosted stratabound-type, b) unconformity-related and c) fracture-controlled.

a) Carbonate-hosted stratabound

The southern part of the Cuddapah Basin hosts a unique, low-grade and large-tonnage uranium deposit in dolostone 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 southeast. The vast extent of the deposit, its stratabound nature hosted by dolostone, and point to point correlation with 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 3.0 m, are under active exploration at vertical depths of up to 825 m. Sustained exploration activities over the 16 km segment within the 160 km long belt has added additional uranium resources. In addition, intensive exploration activities in various sectors of the 160 km long belt (e.g. Rachakuntapalle East, Velamvaripalle, Nandimandalam) have substantially increased the uranium resources from this geological domain.

b) Unconformity-related uranium deposits

The north-western margin of Cuddapah Basin comprising Meso to Neoproterozoic Srisailam and Palnad sub-Basins are known for their potential for unconformity-related uranium deposits. Intensive exploration over the past few decades in the northern part of Srisailam sub-Basin had established three low-tonnage, low-grade uranium deposits viz. Lambapur, Peddagattu and Chitrial. Exploration efforts along the northern margin of Palnad sub-Basin has resulted in locating a low-grade and low-tonnage deposit at Koppunuru. Further exploration has under progress in other parts of Srisailam and Palnad sub-Basins having a similar lithostructural setup.

c) Fracture-controlled uranium mineralisation

The Gulcheru quartzite of the Cuddapah Supergroup overlying the basement granitoid in the southern parts of Cuddapah Basin are intensely fractured, faulted and intruded by E-W trending basic dykes. Uranium mineralisation is associated with the quartz-chlorite-breccia occurring along the contact between the Gulcheru quartzite and the basic dykes. Furthermore, the fracture systems within the crystalline basement, proximal to the southern margin of Cuddapah Basin, are known to host uranium mineralisation and are presently under exploration.

Mesoproterozoic Singbhum Shear Zone, Jharkhand

The Singhbhum Shear Zone is a 200 km long, arcuate belt of tectonised rocks fringing the northern boundary of the Singhbhum craton along its contact with the Singhbhum Group of rocks. Exploration efforts since the early fifties have led to the establishment of several low-grade and low- to medium-tonnage uranium deposits, some of which are under active exploitation. The established uranium deposits are mostly located in the central and eastern sector of the shear zone. Intensive exploration in various sectors in the shear zone has added significant resources to the uranium inventory. Notable among them are Bangurdih and Narwapahar, Singridungri and Banadungri-Geradih sectors.

Mesoproterozoic North Delhi Fold Belt of Rajasthan and Haryana

The metasediments of North Delhi Fold Belt comprising Khetri, Alwar and Bayana-Lalsot sub-Basins in the states of Rajasthan and Haryana are host for a number of uranium occurrences. The 170 km long north-northeast to south-southwest trending "albitite line" passes through the Delhi Supergroup and Banded Gneissic Complex and is the site for extensive sodic metasomatism. This zone holds potential to host metasomatite-type uranium mineralisation. An integrated approach with litho-structural, ground geophysical and drilling inputs have resulted in the discovery of a fracture-controlled metasomatite-type uranium deposit near Rohil, Rajasthan and the entire 170 km long zone holds immense potential for additional uranium resources. Vast inputs of ground and airborne geophysical surveys and drilling have been deployed in the contiguous sectors of Rohil. The exploration efforts have resulted in establishing promising new sectors in Gumansingh-Ki-Dhani, Narsinghpuri, Hurra-Ki-Dhani and Jahaj-Maota in the contiguous area of Rohil, which have similar geological settings.

Cretaceous sedimentary basin, Meghalaya

The upper Cretaceous lower Mahadek Formation exposed along the southern fringes of Shillong plateau, Meghalaya, is a potential host for uranium mineralisation. This geological domain has been under exploration since the late seventies. Substantial exploration inputs over the years established seven low- to medium-grade and low- to medium-tonnage uranium deposits at Domiasiat, Wahkyn, Wahkut, Gomaghat, Tyrnai, Umthongkut and Lostain. Exploration efforts are presently being continued in Wahkut and Kulang. The exploration efforts along the southward extensions of the Wahkut deposit have shown positive results.

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 a number of east-west trending faults. A small-sized, medium-grade uranium deposit has been established at Gogi along the Gogi-Kurlagare-Gundahalli fault. Present exploration efforts are concentrated in the Kanchankayi sector along the north-eastern extensions of Gogi uranium deposit.

Neoproterozoic alkaline complexes in Southern Granulite Terrain, Tamil Nadu.

The Dharmapuri Shear Zone of Tamil Nadu is emerging as a potential province for multi-metal deposits including uranium. The north-northeast-south-southwest trending shear zone forms part of the Southern Granulite Terrain and is characterised by Neoproterozoic alkaline intrusives including carbonatites. Exploration for uranium, Nb-Ta and rare earth elements in the northern part of the Shear Zone dates back to mid-1960s, resulting in the discovery of significant uranium anomalies associated with quartz-barite veins at Rasimalai, Sevattur, etc. This was followed by a series of prospecting ventures in the zone during the past two decades, leading to the discovery of a number of uranium anomalies in the alkaline emplacements within the Dharmapuri Shear Zone. The Sevattur alkaline-carbonatite complex has been explored for uranium and rare earth elements (REE) in the past and the alkaline intrusions near Rasimalai and Pakkanadu along the Dharmapuri Shear Zone are under active exploration presently.

Palaeozoic – Mesozoic Satpura Gondwana Basin, Madhya Pradesh

The Gondwana age sedimentary basins of India possess suitable environments for hosting sandstone-type uranium mineralisation. The lower part (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.

Meso-NeoproterozoicKaladgi Basin, Karnataka

The E-W trending Meso-Neoproterozoic Kaladgi Basin is located on the north-western fringe of the western Dharwar Craton. The unmetamorphosed sediments of Kaladgi Supergroup overlie the basement granitoids and Chitradurga schists. The northern and western extensions of the basin are covered by the Deccan Traps. Kaladgi Basin received greater attention for exploration of classical unconformity-type uranium deposit owing to its contrasting basement characteristic when compared with other Proterozoic basins in India. The basement comprises schist belts having 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. Uraninite, pitchblende, coffinite and secondary uranium minerals occur along the fractures and within inter-granular spaces. Subsurface exploration in the western part of Kaladgi Basin led to the emergence of another potential sector in Suldhal-Gujanal-Malarmardi area. Uranium mineralisation hosted by reduced lower conglomerate, basal arenite and basement schist in close proximity to the unconformity has been established.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

India's known conventional uranium resources (reasonably assured resources and inferred) are estimated to be 207 715 tU hosted in the following deposit types:

Carbonate deposits	47.40%
Metamorphite	28.51%
Sandstone-type	9.79%
Unconformity-type	8.70%
Metasomatite	3.69%
Granite-related	1.74%
Quartz-pebble conglomerate	0.17%

As of 1 January 2017, the known conventional in situ resources established so far include 197 249 tU of reasonably assured resources (RAR) and 10 466 tU of inferred resources (IR). This amounts to a substantial increase in RAR and a decrease in IR, compared to what was reported for the 2016 Red Book. 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 in the extension areas of known deposits in the Singhbhum Shear Zone, Mahadek Basin and North Delhi Fold Belt. Furthermore, part of the IR reported in 2015 has been converted to RAR (after detailed exploration and merging of certain deposits).

Undiscovered conventional resources (prognosticated and speculative resources)

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 2017, undiscovered resources increased to 114 480 tU under the prognosticated category and 50 880 tU under the speculative category, both as in situ resources.

The increase in the prognosticated resources category (from 106 000 tU in 2015 to 114 480 tU in 2017) is mainly because of the greater degree of confidence obtained by carrying out multidisciplinary exploration in some of the potential geological domains such as Southern Cuddapah Basin, Andhra Pradesh; Singhbhum Shear Zone, Jharkhand and Bhima Basin, Karnataka; North Delhi Fold Belt, Rajasthan; Mahadek Basin, Meghalaya and Satpura Gondwana Basin, Madhya Pradesh.

Similarly, the increase in the speculative resources category (from 46 640 tU in 2015 to 50 880 tU in 2017) is mainly due to the identification of several potential exploration targets in a number of geological domains, namely Dharmapuri Shear Zone, Tamil Nadu; Lesser Himalaya, Uttarakhand; Shillong Basin, Assam and Meghalaya, Chhotanagpur Granite Gneiss Complex, Uttar Pradesh and Kaladgi Basin, Karnataka.

Uranium production

Historical review

The Uranium Corporation of India Limited (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 Singhbhum East district of Jharkhand State). The ore produced from the mines is processed in two processing plants located at Jaduguda and Turamdih. All these facilities are located in a multi-metal mineralised sector – the Singhbhum Shear Zone in the eastern part of India. 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

The total installed capacity of UCIL's three operating 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 metasediments of Singhbhum Shear Zone. The host rocks are of Proterozoic age. There are two prominent parallel ore lenses – the Footwall lode (FWL) and the Hangingwall 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. De-slimed 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 the 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 has planned for increasing underground productivity of this mine by further mechanising its working methods.
- 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.
- 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 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 sub-level stoping method in specific segments of the orebody is being explored with higher productivity. Trial stoping in one such area has been undertaken.
- 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.

- 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 located 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 located 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 paths. The ore is treated in the plant adjacent to the mine at Tummalapalle. Expansion of the mine and processing plant at Tummalapalle has been 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 is capable of treating 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, resin is used in ion exchange to recover the uranium. After elution, the product is precipitated using hydrogen peroxide to produce uranium peroxide containing about 88% U_3O_8. The final product of the Jaduguda mill is uranium peroxide. The treatment of mine water and reclaiming tailings water has resulted in reduced fresh water 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 mines is being processed in the Turamdih mill. The mill, commissioned in 2009, is capable of treating 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 is under implementation. Expansion of this plant to process 4 500 t/day dry ore has been taken up.
- 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 to process 3 000 t ore/day is under commissioning. Expansion of this plant to process 4 500 t ore/day has also been planned.

Ownership structure of the uranium industry

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 5 000 people are engaged in uranium mining and milling activities.

Uranium production centre technical details
(as of 1 January 2017)

	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	Committed
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)	Vein	Vein	Vein	Vein	Vein	Vein	Vein	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
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 2017)

	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)	Vein	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	

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-hosted uranium deposit in the north-eastern 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 an Environmental Survey Laboratory at Jaduguda and has establishments at all operating facilities.

Regulatory regime

In India all nuclear activities, including mining of uranium or other atomic minerals, falls within the purview of the central government and are governed by the Atomic Energy Act, 1962 (AE Act) and regulations made thereunder. The Department of Atomic Energy (DAE) oversees the development and mining of uranium and other atomic minerals. Accordingly, policies of DAE and provisions of the AE Act and regulations framed thereunder play a key role in the prospecting, exploration and mining of uranium. Relevant provisions of the Mines and Minerals (Development and Regulation) Act, 1957 (MMDR Act) and the Mines Act, 1952 are also applicable in the case of mining of uranium. In addition, all mining activities must comply with environmental regulations. The mining, milling and processing of uranium ore requires a licence under the AE Act. The Atomic Energy (Radiation Protection) Rules (2004) and the Atomic Energy (Working of Mines and Minerals and Handling of Prescribed Substances) Rules (1984) provide procedural details for obtaining a licence and specify conditions required to carry out these activities.

A mining lease for uranium is granted by the state government after the mining plan is approved by the Atomic Minerals Directorate for Exploration and Research as per the provisions of the MMDR Act. The Atomic Energy Regulatory Board (AERB), an independent authority, regulates safety and other regulatory provisions under the AE Act and ensures the safety of workers, the public and the environment. The AERB oversees various aspects of a mining plan that are required to conform to radiological safety, siting of the mill, disposal of tailings and other waste rocks, as well as decommissioning the facility. Opening, operation and decommissioning of uranium mines require compliance with the various provisions under different legislation and regulations.

In India, uranium exploration/prospecting and mining are carried out exclusively by the central government.

Uranium requirements

As of 1 January 2017, 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 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. Total nuclear power generating capacity is expected to grow to about 8 680 MWe by 2019 as projects under construction are progressively completed.

The present plan is to increase nuclear installed capacity to about 10 080 MWe by the year 2022.

Annual uranium requirements in 2015 amounted to about 1 300 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 being opened to India, 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 indigenous 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 the provisions made thereunder.

Imported light water reactors to be built in the future are to 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)

	2014	2015	2016	2017 (expected)
Government exploration expenditures	2 643.40	3 171.00	3 546.61	3 907.90
Total expenditures	2 643.40	3 171.00	3 546.61	3 907.90
Government exploration drilling (m)	176 654	190 585	178 572	215 000
Total drilling (m)	176 654	190 585	178 572	215 000

* Non-government.

Reasonably assured conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	Cost range unassigned
Proterozoic unconformity	N/A	N/A	N/A	18 072
Sandstone	N/A	N/A	N/A	17 444
Granite-related	N/A	N/A	N/A	3 618
Metamorphite	N/A	N/A	N/A	52 665
Metasomatite	N/A	N/A	N/A	7 005
Carbonate	N/A	N/A	N/A	98 445
Total				197 249

* In situ resources.

Reasonably assured conventional resources by production method

(tonnes U*)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	Cost range unassigned
Underground mining (UG)	N/A	N/A	N/A	175 175
Open-pit mining (OP)	N/A	N/A	N/A	22 074
Total				197 249

* In situ resources.

Reasonably assured conventional resources by processing method

(tonnes U*)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	Cost range unassigned
Conventional from UG	N/A	N/A	N/A	175 175
Conventional from OP	N/A	N/A	N/A	22 074
Total				197 249

* In situ resources.

Inferred conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	Cost range unassigned
Sandstone	N/A	N/A	N/A	2 890
Paleo-quartz-pebble conglomerate	N/A	N/A	N/A	352
Metamorphite	N/A	N/A	N/A	6 558
Metasomatite	N/A	N/A	N/A	666
Total	N/A	N/A	N/A	10 466

Inferred conventional resources by production method

(tonnes U*)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	Cost range unassigned
Underground mining (UG)	N/A	N/A	N/A	8 372
Open-pit mining (OP)	N/A	N/A	N/A	2 094
Total	N/A	N/A	N/A	10 466

* In situ resources

Inferred conventional resources by processing method

(tonnes U*)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	Cost range unassigned
Conventional from UG	N/A	N/A	N/A	8 372
Conventional from OP	N/A	N/A	N/A	2 094
Total	N/A	N/A	N/A	10 466

* In situ resources.

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	Cost range unassigned
N/A	N/A	114 480

Speculative conventional resources

(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
N/A	N/A	50 880

Ownership of uranium production in 2017

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
N/A	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100

Uranium industry employment at existing production centres

(person-years)

	2014	2015	2016	2017 (expected)
Total employment related to existing production centres	4 689	4 725	4 741	5 000
Employment directly related to uranium production				

Short-term production capability

(tonnes U/year)

2013				2015				2020			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
N/A				N/A				N/A			

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
N/A				N/A				N/A			

Net nuclear electricity generation

	2015	2016
Nuclear electricity generated (TWh net)	38.36	38.78

Installed nuclear generating capacity to 2035

(MWe gross)

2014	2016	2019		2022		2030		2035	
		Low	High	Low	High	Low	High	Low	High
5 680	6 780	6 780	NA	N/A	10 080	N/A	N/A	N/A	N/A

Annual reactor-related uranium requirements to 2035 (excluding MOX)

(tonnes U)

2015	2017		2019		2022		2030		2035	
	Low	High	Low	High	Low	High	Low	High	Low	High
1 300	NA	1 100	NA	1 350	N/A	1 600	N/A	N/A	N/A	N/A

Indonesia

Uranium exploration and mine development

Historical review

Uranium exploration by the Centre for Development of Nuclear Ore and Geology of the National Nuclear Energy Agency of Indonesia (BATAN) started in the 1960s. Up to 1996, reconnaissance surveys had covered 79% of a total of 533 000 km^2 identified for survey on the basis of 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 in order 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 2007 at Semut (174 m). In 2008, no exploration drilling was undertaken.

In 2009, exploration drilling was continued in the Kalan sector and detailed, systematic prospection in the Kawat area and its surroundings was carried out. General prospection in Bangka Belitung Province was also undertaken. Plans to extend exploration in Kalimantan and Sumatera by prospecting from general reconnaissance to systematic stages in order to discover new uranium deposits have been adopted. In 2010, efforts were devoted to evaluating drilling data from the Kawat sector to re-evaluate estimates of speculative resources.

Recent and ongoing uranium exploration and mine development activities

Uranium and thorium exploration in 2015 continued in the Mamuju area, West Sulawesi Province 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 metapelite schistose and metatuff.

In 2016, a regional geophysical survey, which included ground geomagnetic and gravity measurements was conducted in the Mamuju area. Systematic exploration was conducted in the eastern part of the Hulu Mamuju sector, which included geological and radiometric mapping, soil geochemistry, radon gas measurements, and trenching. In other parts of the the Mamuju area, systematic radiometric mapping was conducted in the Orobatu sector.

In 2017, exploration focused on the Mamuju and Kalan areas. Exploration activities in the the Mamuju area includes geophysical resistivity and induced polarisation surveys in the Ahu sector, stream sediment geochemistry in the southern part of the Mamuju area, and reconnaissance drilling to a depth of 350 m in the Ahu sector. Meanwhile, in Kalan activities have included building the exploration database, and studying the grade relations between well logging radiometric and chemical analysis.

No mining activity is currently under consideration.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Geological prospection followed by exploration drilling during 2015 to 2016 resulted in an additional 458 tU in inferred resources category from the Ella Ilir area, 556 tU from the Lembah Hitam sector as measured resources, and 2 562 tU from the Takandeang sector in the prognosticated category.

A resources re-evaluation in the Eko-Remaja sector within Kalan area, along with additional measured resources of 556 tU from the Lembah Hitam Sector, provides a total of 2 029 tU. The 2 029 tU measured resources is reported in the RAR classification in the <USD 80/kgU category, whereas the RAR <USD 130/kgU category (7 123 tU) includes the measured and indicated resources (2 029 and 5 094 tU).

Lembah Hitam Sector, Kalan Area, West Kalimantan

Uranium mineralisation occurs within fractures in tectonic breccias, associated with pyrite, pyrrhotite, magnetite, molybdenite, tourmaline and quartz in the host rock of schistose metasiltstone and metapelites. The uranium grade of the veins ranges from 0.0076-0.95% eU_3O_8, with a thickness of 0.1-4.5 m. The uranium resource estimation for 26 ores bodies using a 25 m searching radius resulted in 556 tU.

Ella Ilir Area, West Kalimantan

Uranium mineralisation is trending NW-SE with 1-30 cm of thickness with a radiometric anomaly ranging from 250-15 000 cps hosted in metapelite schistose and metatuff rocks. The mineralisation present as boudinage vein with uraninite as the radioactive mineral, associated with quartz tourmaline, feldspar, pyrite, iron oxide and hematite. Resource estimation results of 458 tU as inferred category of resources. The total of inferred resources by addition of Ella Ilir is 2 998 tU.

Undiscovered conventional resources (prognosticated and speculative resources)

Mamuju area

Since 2013, the Mamuju area, West Sulawesi has been intensively explored to identify uranium mineralisation and its resource potential based on highly radiometric anomalies in the area. In 2015, drilling activities were carried out in the Botteng, Takandeang, and Taan Sectors. A total of 21 boreholes were drilled for a total of 1 600 m. Resource estimation of the Salumati sub-sector, which is part of the Takandeang sector resulted in 2 562 tU in the prognosticated category. The total prognosticated resources with the addition of the Mamuju resources is 30 179 tU.

Unconventional resources and other materials

Singkep, Riau Archipelago Province

Uranium potential in Singkep is associated with a placer ore deposit. Monazite is a uranium/thorium phosphate mineral, which has been deposited in the alluvium and mostly accumulated as tailings as a by-product material of tin mining. The resources estimated are 1 100 tU in the prognosticated category and the total unconventional resources of uranium in the placer including Singkep, have been calculated to be as much as 26 960 tU.

Uranium exploration and development expenditures and drilling effort – domestic

(Indonesian rupiah [IDR])

	2014	2015	2016	2017 (expected)
Government exploration expenditures	1 209 137 000	6 171 437 000	2 559 661 000	2 420 000 000
Total expenditures	1 209 137 000	6 171 437 000	2 559 661 000	2 420 000 000
Government exploration drilling (m)	375	2 000	-	350
Government exploration holes drilled	2	25	-	4
Subtotal exploration drilling (m)	375	2 000	-	350
Subtotal exploration holes drilled	2	25	-	4
Total drilling (m)	375	2 000	-	350
Total number of holes drilled	2	25	-	4

* Non-government.

Reasonably assured conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Metamorphite	0	2 029	7 123	7 123
Total	0	2 029	7 123	7 123

* In situ resources.

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	2 029	7 123	7 123	75
Total	0	2 029	7 123	7 123	75

* In situ resources.

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	2 029	7 123	7 123	75
Total	0	2 029	7 123	7 123	75

* In situ resources.

Inferred conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Metamorphite	0	0	2 998	2 998
Total	0	0	2 998	2 998

* In situ resources.

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	0	2 998	2 998	75
Total	0	0	2 998	2 998	75

* In situ resources.

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 UG	0	0	2 998	2 998	75
Total	0	0	2 998	2 998	75

* In situ resources.

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	0	30 179

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) in order to evaluate the uranium mineralisation potential.

Systematic uranium exploration in Iran began in the early 1970s in order 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 terrain clearance airborne geophysical surveys. Many surficial uranium anomalies were identified and follow-up field surveys have continued to the present. The airborne coverage is mainly over the central, south-eastern, eastern and north-western 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 south-eastern Iran and Dechan, Mianeh and Guvarchin in Azarbaijan. Outside of the airborne geophysics coverage area, uranium mineralisation at Talmesi, Meskani, Kelardasht and the salt plugs of south Iran are also worthy of mention.

Mine development

In Saghand uranium mine (1 and 2), feasibility studies and basic engineering designs (1994-1995) and mining preparation reports (1996) led to 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 underground development of the Saghand mine began in 2003. Khoshumi area is composed of 47 anomalies that are mainly related to metamorphite-type deposits. Orefield number 6 of this area was considered for feasibility studies. Five anomalies in Narigan turned out to be ore fields of hydrothermal and metasomatite-type uranium deposits. Mineral deposit number 3 in Narigan area was a candidate for feasibility studies.

Recent and ongoing uranium exploration and mine development activities

Uranium exploration activities

According to comprehensive planning, exploration activities within recognised favourable areas are being performed in different phases (i.e. reconnaissance to detailed phase). The reconnaissance and prospecting phases are being accomplished in: central, southern, eastern, north-eastern and north-western provinces of the country. As a result, uranium mineralisation with positive indications has been found in various geological environments. Uranium exploration activities are being conducted in a variety of deposit types, such as: granite-related, metasomatite, volcanogenic, intrusive and sedimentary types. Currently, most of the prospecting and general exploration is being undertaken in different parts of the country for the aforementioned deposit types.

Mine development activities

At present, the development of mines No. 1 and 2 is being carried out in the Saghand ore field. In mine No. 1, based on the basic and detailed design, open-pit method is being used to access orebodies to a specified level, through overburden stripping. Ore at mine No. 2 is being extracted by an underground method. For this purpose two shafts (main and ventilation shafts) have been sunk and the adits are being drilled. Also some stopes are being developed at different levels for ore production. The extracted uranium ores are transported to the uranium production centre.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Based on exploration activities completed during 2015 and 2016, and considering overall changes since the last report, total RAR is 1 407 tU. The resources are related to metasomatite, granite-related and metamorphite types of deposit. Changes in inferred resources have occurred as a result of new discoveries, most of which are metasomatite-type mineralisation. Some inferred resources were moved to the RAR category because of additional studies. The total inferred resources as of 1 January 2017 is 6 750 tU.

Undiscovered conventional resources (prognosticated and speculative resources)

Kerman-Sistan mineralisation trend

The uranium mineralisation potential in this trend is of volcanic-related, metasomatic and granite-related type and at present, exploration studies are being conducted on favourable areas. Considering the potential of these areas, some of them are expected to be selected for further exploration.

Naiin-Jandagh mineralisation trend

The uranium mineralisation potential is of granite-related and volcanic-related type and is polymetallic. The surficial studies are being undertaken on favourable areas. If results are positive, further exploration will be performed on subsurface.

Birjand-Kashmar mineralisation trend

The uranium mineralisation potential is of sedimentary, granite-related and volcanic-related type. The surficial studies are being conducted on favourable areas. If favourable results are obtained, further exploration, including borehole drilling and logging will be undertaken.

Hamedan-Marand metallogenic trend

There is uranium mineralisation potential in granite-related, volcanogenic, intrusive and sedimentary-type environments. Surficial exploration has identified favourable areas for further subsurface exploration.

Unconventional resources

Recent studies have identified favourable areas of the country for investigation of the potential for unconventional resources. This includes phosphate rocks, non-ferrous ores, ferrous ores, carbonatite and black shales. Speculative resources, with an unassigned cost category amount to approximately 53 000 tU.

Uranium production

Historical review

Uranium ore recovered by open-pit mining of the Gachin salt plug has been processed at Bandar Abbas uranium plant since 2006.

Status of production facilities, production capability, recent and ongoing activities and other issues

Iran's only operating production centre (Bandar Abbas uranium plant) began operating in 2006 with a nominal annual production capacity of 21 tU. The second production facility near Ardakan, with a nominal annual production capacity of 50 tU, is in the commissioning phase and is expected to begin operations in the middle of 2017. It will be supplied with ore from the Saghand uranium mine.

Ownership structure of the uranium industry

The owner of uranium industry is the government of Iran and the operator is the Atomic Energy Organisation of Iran (AEOI).

Uranium production centre technical details

(as of 1 January 2017)

	Centre #1	Centre #2
Name of production centre	Gachin	Ardakan
Production centre classification	Existing	Committed
Date of first production	2006	2017
Source of ore:		
Deposit name(s)	Gachin	Saghand
Deposit type(s)	Salt plug	Metasomatite
Recoverable resources (tU)	84	500
Grade (% U)	0.068	0.0385
Mining operation:		
Type (OP/UG/ISL)	OP	30% OP, 70% UG
Size (tonnes ore/day)	70	400
Average mining recovery (%)	80	80
Processing plant:		
Acid/alkaline	Acid	Acid
Type (IX/SX)	SX	IX
Size (tonnes ore/day)	70	280
Average process recovery (%)	73	80
Nominal production capacity (tU/year)	21	50
Plans for expansion	Yes	Yes

Uranium exploration and development expenditures and drilling effort – domestic

(IRR millions [Iranian rial])

	2014	2015	2016	2017 (expected)
Government exploration expenditures	608 056	107 500	319 791	620 000
Government development expenditures	670 500	75 500	210 012	400 000
Total expenditures	1 278 556	183 000	529 803	1 020 000
Government exploration drilling (m)	29 906	4 119	7 216	13 987
Government exploration holes drilled	410	62	28	78
Government exploration trenches (m)	406	500	1 931	9 680
Government exploration trenches	18	12	26	169
Government development drilling (m)	0	1 529	1 680	3 000
Government development holes drilled	0	15	278	500
Total drilling (m)	29 906	5 648	8 896	16 987
Total number of holes drilled	410	77	306	578

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	0	653	653
Metamorphite	0	0	136	136
Metasomatite	0	0	618	618
Total	0	0	1 407	1 407

* In situ resources.

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	491	491	80-90
Open-pit mining (OP)	0	0	136	136	80-90
Unspecified	0	0	780	780	NA
Total	0	0	1 407	1 407	NA

* In situ resources.

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	491	491	80-90
Heap leaching** from OP	0	0	136	136	40-50
Unspecified	0	0	780	780	NA
Total	0	0	1 407	1 407	NA

* In situ resources.

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

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	479	479
Metamorphite	0	0	25	25
Volcanic-related	0	0	128	128
Metasomatite	0	0	6 118	6 118
Total	0	0	6 750	6 750

* In situ resources.

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	0	876	876	80-90
Unspecified	0	0	5 874	5 874	NA
Total	0	0	6 750	6 750	NA

* In situ resources.

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 UG	0	0	876	876	80-90
Unspecified	0	0	5 874	5 874	NA
Total	0	0	6 750	6 750	NA

* In situ resources.

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	12 450	12 450

Speculative conventional resources

(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	0	33 200

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Metasomatite	0	0.0	0.0	0.0	0.0	20
Surficial	55	11.3	9.7	8.1	84.1	0
Total	55	11.3	9.7	8.1	84.1	20

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Open-pit mining[1]	55	11.3	9.7	8.1	84.1	0
Underground mining[1]	0	0.0	0.0	0.0	0.0	16
Total	55	11.3	9.7	8.1	84.1	20

1. 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 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Conventional	55	11.3	9.7	8.1	84.1	20
Total	55	11.3	9.7	8.1	84.1	20

Ownership of uranium production in 2016

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
8.1	100	0	0	0	0	0	0	8.1	100

Uranium industry employment at existing production centres

(person-years)

	2014	2015	2016	2017 (expected)
Total employment related to existing production centres	500	350	340	290
Employment directly related to uranium production	135	110	112	95

Net nuclear electricity generation

	2015	2016
Nuclear electricity generated (TWh net)	3.2	5.9

Short-term production capability

(tonnes U/year)

2017				2020			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	0	20	20	N/A	N/A	50	80

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
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Installed nuclear generating capacity to 2035

(MWe net)

2013	2014	2015		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
915	915	915	915	915	915	2 815	5 075	6 975	7 925	N/A	N/A

Annual reactor-related uranium requirements to 2035 (excluding MOX)

(tonnes U)

2013	2014	2015		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
160	160	160	160	160	160	490	910	1 230	1 390	N/A	N/A

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 Niger, the People's Republic of China, the United States and Zimbabwe.

In October 1998, 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 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 JNC.

In April 2007, the Japanese government decided to resume overseas uranium exploration activities with financial support provided by Japanese companies through Japan Oil, Gas and Metals National Corporation (JOGMEC). JOGMEC is carrying out exploration activities in Australia, Canada, Namibia, Uzbekistan and other countries.

Recent and ongoing uranium exploration and mine development activities

Japan-Canada Uranium Co. Ltd (JCU), which took over JNC's Canadian mining interests, is continuing exploration activities in Canada while JOGMEC continues exploration activities in Australia, Canada, Namibia, Uzbekistan and elsewhere. Japanese private companies hold shares in companies developing uranium mines and also with those operating mines in Australia, Canada, Kazakhstan and Niger.

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

A test pilot plant with a capacity of 50 t ore/day was established at the Ningyo-toge mine in 1969 by PNC. The operation was 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 operation in 1966. As of December 2014, approximately 2 tonnes of MOX fuel had been fabricated in the PFDF.

The PFFF had two MOX fuel fabrication lines, one for the experimental Jōyō fast breeder reactor (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 FBR, 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 December 2014, 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 Energy, Trade and Industry. 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. JAEA is working on countermeasures against tsunami, station black-out and severe accidents on the basis of the severe Fukushima Daiichi accident. The Ministry of Education, Culture, Sports, Science and Technology (MEXT) established the Monju research plan in September 2013. JAEA has also been preparing for the new safety standards that have been determined by the Nuclear Regulation Authority (NRA) in July 2013.

The government formally decided on 21 December 2016 to decommission the Monju prototype fast breeder nuclear reactor in Fukui Prefecture.

The government estimates that decommissioning Monju will cost at least JPY 375 billion. It plans to remove the spent nuclear fuel by 2022 and finish dismantling the facility in 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.

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 NPP in March 2011, all operational reactors in Japan that normally provide about 30% of electricity production have been progressively taken out of service during scheduled refuelling and maintenance outages. As of 31 March 2017, the five reactors have been restarted under the new regulatory regime of the Nuclear Regulation Authority (JCN): Kyushu Electric Power Company's Sendai 1 and 2 reactors in August and October 2015, Kansai Electric Power Company's Takahama 3 and 4 reactors in January and March 2016, and Shikoku Electric Power Company's Ikata 3 reactor in August 2016. Until the number of reactors to be restarted is better defined, Japanese uranium requirements remain uncertain. However, the finalisation in 2015 of a new long-term energy policy of the government envisions nuclear power representing 20-22% of total domestic energy supply in 2030.

Uranium exploration and development expenditures – non-domestic

(JPY million [Japanese yen])

	2014	2015	2016	2017 (expected)
Industry* exploration expenditures	N/A	N/A	N/A	N/A
Government exploration expenditures	555	486	522	265
Industry* development expenditures	N/A	N/A	N/A	N/A
Government development expenditures	0	0	0	0
Total expenditures	N/A	N/A	N/A	N/A

* Non-government.

Reasonably assured conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	6 600	6 600
Total	0	0	6 600	6 600

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	6 600	6 600	85
Total	0	0	6 600	6 600	85

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	6 600	6 600	85
Total	0	0	6 600	6 600	85

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Sandstone	84	0	0	0	84	0
Total	84	0	0	0	84	0

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Open-pit mining[1]	39	0	0	0	39	0
Underground mining[1]	45	0	0	0	45	0
Total	84	0	0	0	84	0

1. Pre-2012 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 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Conventional	45	0	0	0	45	0
Heap leaching*	39	0	0	0	39	0
Total	84	0	0	0	84	0

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

Mixed oxide fuel production and use

(tonnes natural U-equivalent)

Mixed oxide (MOX) fuel	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Production	684	0	0	0	684	0
Use	912	0	72	18	1 002	0
Number of commercial reactors using MOX		0	1	3		-

Reprocessed uranium use

(tonnes natural U-equivalent)

Reprocessed uranium	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Production	645	0	0	0	645	N/A
Use	217	0	0	0	217	N/A

Net nuclear electricity generation*

	2015	2016
Nuclear electricity generated (TWh net)	4.3	17.5

* Data from the 2016 and 2017 editions of *NEA Nuclear Energy Data*.

Installed nuclear generating capacity to 2035

(MWe net)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
40 343	39 805	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

In 1980, an airborne spectrometric survey covering the entire country was undertaken and by 1988 ground-based radiometric surveys of anomalies identified in the airborne survey were completed. From 1988 to 1990, Precambrian basement and Ordovician sandstone target areas were evaluated using geological, geochemical and radiometric mapping and/or surveys.

During the 1990s, reconnaissance and exploration studies revealed surficial uranium deposits distributed in several areas of the country, as described below:

- Central Jordan: exploration, including 1 700 trenches and over 2 000 samples were analysed for uranium using a fluorometer, which revealed the occurrence of uranium deposits 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. Results of channel sampling in three areas indicated uranium contents ranging from 140 to 2 200 ppm U_3O_8 (0.014% to 0.22% U_3O_8) over an average thickness of about 1.3 m, with overburden of about 0.5 m.
- Three uranium anomalous areas (Mafraq, Wadi Al-Bahiyyah and Wadi-SahabAlabyad) with potential for hosting uranium deposits were also covered by the reconnaissance studies.

In 2008, the Jordan Atomic Energy Commission (JAEC) was established, in accordance with the Nuclear Energy Law (Law No. 42) of 2007 and amendments of 2008. The JAEC is the official entity entrusted with the development and execution of the Jordanian nuclear power programme. The exploration, extraction and mining of all nuclear materials; including uranium, thorium, zirconium and vanadium is under the authority of 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, JAEC created Jordan Energy Resources Inc. as its commercial arm.

In September 2008, JAEC signed an exploration agreement with Areva 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 of developing resources in the Central Jordan Area. In January 2009, 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 2009-2010, JFUMC started the first phase of the exploration programme in the northern part of the central Jordan licence area that included geological mapping, a carborne radiometric survey, drilling, trenching, sampling, chemical analyses, development of an environmental impact assessment and a hydrogeological study and building a database inventory.

Recent and ongoing uranium exploration and mine development activities

During 2015-2016 the exploration programme carried out in the Central Jordan Area (CJA) included trenching, channel sampling (QA/QC), chemical analyses and JORC compliant resource estimation. In April 2016, the second JORC compliant report was prepared.

The estimated tonnages and average grade values at 80 ppm U cut-off grade in CJA were as follows: 11 620 tU at 0.0156% U in the surficial layer (0-5 m deep); 21 800 tU at 0.0127% eU in the deep layer (more than 5 m deep). The total estimated tonnage in CJA is about 33 420 tU.

Plans for 2017 include a trenching programme on a 100 x 100 m and 50 x 50 m grid in the selected mining areas to upgrade the resource category leading to pre-feasibility studies. Research on the heap leaching process to develop optimised extraction parameters will also continue.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Central Jordan Area

JORC compliant resource estimation includes 26 500 tU as inferred resource and 6 900 tU as (RAR) resource (in situ).

Hasa-Qatrana Area

In 2012, a preliminary resource estimation was carried out in this area, covering seven mineralised zones with a total in situ inferred resource of about 28 700 tU.

Undiscovered conventional resources (prognosticated and speculative resources)

No change (about 50 000 tU as speculative resources).

Unconventional resources and other materials

No change (about 100 000 tU in the phosphate deposits).

Uranium production

Historical review

Jordan does not currently produce uranium. 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; the company was 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 performed a technological and economic feasibility study for the recovery of uranium from the phosphoric acid produced at the Aqaba Fertilizer Complex. This study was performed jointly with Prayon Technologies SA. The profitability was evaluated to be 6.8% for the internal rate of return.

JAEC is currently conducting research to develop optimised extraction parameters including:

- research on dynamic alkaline leaching of central Jordan ore provided promising results of more than 80% recovery;
- planning for small alkaline heap demonstration project (few tons of ore);
- a pilot-scale, 6 m high, 0.5 m diameter, 6 column extraction facility was installed at the camp site. Experimental heap leaching process is being undertaken.

Status of production capability

Jordan does not have firm plans in place to produce uranium.

Uranium requirements

In 2010, Jordan announced plans to pursue the development of civil nuclear power, stating its intention to have four units in operation by 2040. Nuclear co-operation agreements have been signed with a number of countries, including Canada, China, France, Japan, Korea, Russia and the United Kingdom. In 2011, it was reported that Jordan would be receiving bids from nuclear power plant vendors. Currently, the kingdom imports over 95% of its energy needs and disruptions in natural gas supply from Egypt have reportedly cost Jordanians more than USD 1 million a day.

Despite the need to generate electricity by other means, the accident at the Fukushima Daiichi nuclear power plant has created some local resistance to the plan to have one 700-1 200 MWe reactor operating by 2020 and a second unit of similar size by 2025. This has created some issues in site selection for the planned reactor construction.

Applying exclusion and discretionary criteria, a country-wide survey was carried out and a proposed site (2.5 km^2) was selected for the construction of the NPP. Currently, detailed studies are being carried out to evaluate and characterise the selected site, as well as other studies related to the construction and operation of the NPP.

National policies related to uranium

With Jordan’s intention to develop a peaceful atomic energy programme for generating electricity and water desalination, JAEC reactivated uranium exploration in the country with the goal of achieving some energy self-sufficiency.

Uranium exploration and development expenditures and drilling effort – domestic

(JOD [Jordanian dinars])

	2014	2015	2016	2017 (expected)
Government exploration expenditures	2 704 800	2 617 500	2 043 200	2 500 000
Total expenditures	2 704 800	2 617 500	2 043 200	2 500 000
Government exploration trenches (m)	10 008	4 964	4 856	5 600
Government trenches	2 502	1 241	1 214	1 400

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 (%)
Open-pit mining (OP)			6 900	6 900	
Total			6 900	6 900	

* In situ resources.

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 (%)
Heap leaching** from OP			6 900	6 900	
Total			6 900	6 900	

* In situ resources.

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

Reasonably assured conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Surficial			6 900	6 900
Total			6 900	6 900

* In situ resources.

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)			55 200	55 200	NA
Total			55 200	55 200	

* In situ resources.

Inferred conventional resources by processing method

(tonnes U*)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Heap leaching** from OP			26 500	26 500	NA
Unspecified			28 700	28 700	NA
Total			55 200	55 200	

* In situ resources.

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

Inferred conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Surficial			55 200	55 200
Total			55 200	55 200

Speculative conventional resources

(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	50 000	N/A

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 deposits suitable for uranium mining by in situ leaching (ISL), such as Inkai, Mynkuduk, Moinkum, Kanzhugan and North and South Karamurun, were discovered.

Recent and ongoing uranium exploration and mine development activities

During 2015 and 2016, exploration was undertaken at Uvanas, Moinkum, Inkai, Budenovskoye in the Shu-Sarysu Uranium Province and in the Northern Kharasan and Zarechnoye deposits in the Syrdaria Uranium Province.

JV Katco has completed ISL pilot mining at the southern part of site No. 2 (Tortkuduk) of the Moinkum deposit and the uranium resources will be presented for review to the State Resource Committee of Kazakhstan.

The Akbastau JSC completed the exploration and ISL pilot production at site No. 4 of the Budenovskoye deposit in 2015 and have proceeded to commercial production.

The Karatau LLP completed additional exploration, which resulted in a transfer of inferred resources to reasonably assured resources at site No. 2 of the Budenovskoye deposit in 2015

JV Inkai has completed the exploration and ISL pilot production at site No. 3 of the Inkai deposit and will begin additional exploration at site No. 2 of the Inkai deposit.

During 2015 and 2016, NAC Kazatomprom JSC explored and re-evaluated resources at the Uvanas deposit and at site No. 3 of the Moinkum deposit by the Kazatomprom-SaUran LLP, which merged Taukent Mining Chemical Plant LLP and Stepnoye Mining Group LLP.

The Kyzylkum LLP and the Baiken-U LLP have exploration activities at the Northern Kharasan deposit.

The Zarechnoye JSC are undertaking additional exploration and re-evaluation resources at the Zarechnoye deposit.

NAC Kazatomprom JSC has restarted exploration and ISL pilot production at the Zhalpak deposit in 2017.

In October 2015, NAC Kazatomprom JSC obtained the contract for the exploration on the new part of the Budenovskoye deposit, sites No. 6 and No. 7. Prognosticated resources are about 70 000 tU. Since 2017, a new enterprise the Bydenovskoye LLP started prospection and exploration of these sites.

The Volkovgeology JSC renewed geological prospecting of sandstone-type deposits amenable for ISL mining in new perspective areas of the Shu-Sarysu uranium provinces with funding from the NAC Kazatomprom JSC budget.

Identified uranium resources increased by 12 769 tU as a result of geological exploration in sandstone deposits from 2015-2016. However, this is offset by depletion during the same period resulting in an overall decrease in identified resources of 41 602 tU. The total increase of 117 784 tU reported for reasonably assured resources is a result of additional resources being added through exploration and transfer of inferred resources to the reasonably assured resources classification. A depletion of 37 330 tU during the same time period results in a net increase of 80 454 tU for RAR during this reporting period. A decrease of inferred resources by 105 015 tU is reported as a result of resources being reclassified from inferred to reasonably assured resources and depletion of 17 041 tU in the inferred resources category resulted in an overall decrease of 122 056 tU for inferred resources reported as of 1 January 2017.

The resource increases occurred at the Budenovskoye (sites No. 2 and No. 4), Inkai (sites No. 3), Moinkun (site No. 3) and Northern Kharasan (site Kharasan-1) deposits.

No uranium exploration and development was performed by Kazakh enterprises outside of Kazakhstan.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2017, identified uranium resources recoverable at a cost <USD 260/kgU amounted to 1 031 331 tU, including 718 284 tU of resources amenable for ISL recovery. The resource estimates are "net" and depletion is taken into consideration.

In the two-year period from 2015-2016, a total of 48 495 tU was produced by ISL. Considering losses during mining (6 853 tU or 12.6%), 54 371 tU of resources were depleted (37 330 tU – reasonably assured and 17 041 tU – inferred).

Underground mining at the Vostok and Zvezdnoye deposits was stopped.

Identified uranium resources increased by 12 769 tU as a result of geological exploration in sandstone deposits from 2015-2016. An increase of 117 784 tU is reported for reasonably assured resources while a decrease of inferred resources by 105 015 tU was reported because of resources reclassified from inferred to reasonably assured resources.

There were significant changes in cost categories owing to devaluation of the national currency – tenge. Thus, the amount of resources recoverable at <USD 40/kg U increased from 109 523 tU (as of 1 January 2015) to 540 504 tU (as of 1 January 2017).

In Kazakhstan, 95% of all identified uranium resources (RAR plus IR) recoverable at <USD 40/kgU are associated with existing and committed production centres, whereas 94% recoverable at <USD 80/kgU are in existing and committed production centres, 71% recoverable at <USD 130/kgU are in existing and committed production centres and 66% recoverable at <USD 260/kgU are in existing and committed production centres.

Undiscovered conventional resources (prognosticated and speculative resources)

Re-evaluation of prognosticated and speculative resources was completed in the reporting period.

The majority (229 053 tU) of the total of 230 583 tU of prognosticated resources are related to sandstone deposits, while the remaining 2 000 tU are metasomatite deposits. Of the 300 000 tU of speculative resources, 90% are related to sandstone deposits and 10% to unconformity-related or metasomatite deposits.

Prognosticated resources assessment methodology of uranium sandstone deposits for ISL production is based on a linear productivity (amount of uranium per unit length of the border zone of formation pinching out in the oxidation zone) and considering reduction factors that consider the variability of linear productivity, including intermittency and variability of the mineralisation width of the ore zone.

Unconventional resources and other materials

Estimates are not made of Kazakhstan's unconventional uranium resources and other materials.

Uranium production

Historical review

The growth of uranium production in Kazakhstan is connected with the discovery of sandstone-type deposits of uranium, suitable for ISL mining, which is one of the cheapest methods of uranium mining and has a minimal impact on the environment.

Production capability and recent and ongoing activities

Over the two-year period from 2015-2016, uranium production was 48 495 tU.

Uranium was mined at the Kanzhugan, Moinkum, Akdala, Uvanas, Mynkuduk, Inkai, Budenovskoye, North and South Karamurun, Irkol, Zarechnoye, Semizbay, Northern Kharasan deposits. All uranium deposits were mined by in situ leaching acid technique.

Shu-Sarysu uranium province

The Uvanas, Mynkuduk (Eastern and Central sites), Kanzhugan, Moinkum (the southern part of site No. 1 and site No. 3) deposits are operated by NAC Kazatomprom JSC through the Ortalyk LLP and Kazatomprom-SaUran LLP (uniting Stepnoye Mining Group LLP and Taukent Mining Chemical Plant LLP) enterprises. NAC Kazatomprom JSC starts ISL pilot production at the Zhalpak deposit in 2017.

JV Katco LLP took part in the operation of the Moinkum deposit (northern part of sites No. 1 [Southern] and site No. 2 [Tortkuduk]).

JV Inkai LLP operates the Inkai deposit (sites No. 1 and 2) and since 2018 commercial production started at sites No. 3 of the Inkai deposit.

Appak LLP is developing the western site of the Mynkuduk deposit.

JV Akbastau JSC operates the deposit Budennovskoye (sites No. 1, No. 3 and No. 4), Karatau LLP develops the Budenovskoye deposit (site No. 2), and processes the solutions extracted from the sites No. 1 and No. 3 of Budennovskoye deposit.

JV South Mining Chemical Company LLP operated the Akdala and Inkai (site No. 4) deposits.

Syrdarya uranium province

NAC Kazatomprom JSC through the Mining Group-6 LLP operated the North and South Karamurun deposits.

The Irkol deposit was developed by Semizbay-U LLP and Baiken-U LLP carries out uranium production at the Northern Kharasan (site Kharasan-2) deposit.

Khorasan-U LLP operated the Northern Kharasan (site Kharasan-1) deposit, and processing is carried out by Kyzylkum LLP.

JV Zarechnoye JSC developed Zarechnoye deposit, the licence for the South Zarechnoye deposit ceased operation in November 2013 because of a lack of commercial viability.

The company Balausa LLP is developing the uranium-vanadium Bala-Sauskandykskoye deposit by open-pit mining. By-product uranium from mining, amounting to about 0.7 tU (2015-2016) is not processed.

Northern Kazakhstan uranium province

Stepnogorsk Mining Chemical Complex LLP stopped production at the Vostok and Zvezdnoe deposits and the mine was closed.

Semizbay-U LLP operates the Semizbay deposit utilising the in situ leach acid method.

As of 1 January 2017, the total capacity of uranium production centres in Kazakhstan was 25 000 tU/yr.

Uranium production at ISL mines in Kazakhstan is carried out using sulphuric acid to produce pregnant uraniferous solutions. Further processing of pregnant solutions using ion-exchange sorption-elution technologies produces a uranyl salts precipitate that, with further extraction refining, results in the production of natural uranium concentrate.

A number of mining enterprises (Appak LLP, Karatau LLP, JV South Mining Chemical Company LLP, Inkai LLP, Baiken-U LLP) obtain natural uranium concentrate by sedimentation of uranium using hydrogen peroxide and further calcination without an extraction stage.

Ownership structure of the uranium industry

In 2016, the state share of uranium production in Kazakhstan was 53% (13 175 tU), including 33% from NAC Kazatomprom owing to its partnership in joint ventures and 20% – from its own production by NAC Kazatomprom, a 100% state-owned company, through the Samruk-Kazyna JSC national wealth fund.

The NAC Kazatomprom JSC includes the following production centres: Kazatomprom-SaUran LLP, Mining Group-6 LLP, and Ortalyk LLP, all of which produce uranium by ISL.

In April 2015, the production centres Taukent Mining and Chemical Plant LLP and Stepnoye Mining Group LLP merged into Kazatomprom-SaUran LLP.

In 2016, NAC Kazatomprom had shares in 12 joint ventures with private companies from Canada, Japan and Kyrgyzstan (JV Inkai LLP, Appak LLP, Kyzylkum LLP, Khorasan-U LLP, Baiken-U LLP, JV Zarechnoe JSC, JV Budennovskoye LLP), and with foreign state companies from China, Russia and France (Semizbai-U LLP, JV Katco LLP, YuGHK LLP, JV Akbastau JSC, Karatau LLP, JV Zarechnoe JSC, Kyzylkum LLP, Khorasan-U LLP).

The company Balausa LLP belongs to a foreign private company.

In 2016, the production share of private foreign companies in Kazakhstan amounted to 17%, while the share of state foreign companies in Kazakhstan amounted to 30% of total production.

Employment in the uranium industry

For the purpose of obtaining qualified personnel of required specialties, NAC Kazatomprom JSC co-operates with 25 universities and 11 colleges of the Republic of Kazakhstan and neighbouring countries. This co-operation includes engagement of two local training centres in Shieli village, Kyzylordinskaya oblast, and Taukent village, South-Kazakhstan oblast for training and retraining of local employees. The specialist universities have opened departments in new areas unique for the Republic of Kazakhstan including fuel assemblies and refineries. New professions have also been introduced such as fuel assembly plant operator and refinery plant operator.

Uranium production centre technical details

(as of 1 January 2017)

	Centre #1	Centre #2	Centre #3	Centre #4	Centre #5	Centre #6	Centre #7	Centre #8
Name of production centre	Kazatomprom-SaURan LLP Taukent Mining Chemical Plant	Kazatomprom-SaURan LLP Stepnoye Mining Group	Mining Group-6 LLP	South Mining Chemical Company LLP	JV Katco LLP	JV Inkai LLP	JV Zarechnoe JSC	Karatau LLP
Production centre classification	Existing	Existing	Existing	Existing	Existing	Existing	Existing	Existing
Start-up date	1982	1978	1985	2001	2004	2004	2007	2007
Source of ore:								
Deposit name(s)	Kanzhugan, Moinkum (sites 1, 3)	Mynkuduk (Eastern site), Uvanas	North & South Karamurun	Akdala, Inkai (site 4)	Moinkum (sites 1, 2)	Inkai (sites 1, 2, 3)	Zarechnoye	Budenovskoe (site 2)
Deposit type(s)	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone
Recoverable resources (tU)	30 606	9 249	19 784	44 968	26 487	272 620	11 569	51 755
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/AL)	IX, SX	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	3 000
Plans for expansion	Yes	No	No	No	No	Yes	No	Yes
Other remarks								

Uranium production centre technical details *(cont'd)*

(as of 1 January 2017)

	Centre #9	Centre #10	Centre #11	Centre #12	Centre #13	Centre #14	Centre #15	Centre #16
Name of production centre	Ortalyk LLP	Appak LLP	Khorasan-U LLP	Bayken-U LLP	Akbastau JV JSC	Semyzbai-U LLP	NAC Kazatomprom JSC	Budenovskoe LLP
Production centre classification	Existing	Existing	Existing	Existing	Existing	Existing	Committed	Prospective
Start-up date	2007	2008	2008	2009	2009	2007	2022	2022
Source of ore:								
Deposit name(s)	Mynkuduk (Central site)	Mynkuduk (Western site)	North Kharasan (site 1)	North Kharasan (site 2)	Budenovskoe (sites 1, 3, 4)	Semyzbai, Irkol	Zhalpak	Budenovskoe (sites 6, 7)
Deposit type(s)	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone
Recoverable resources (tU)	31 675	20 685	27 923	22 621	46 990	36 467	14 525	0
Grade (% U)	0.047	0.027	0.204	0.117	0.089	0.050	0.033	0
Mining operation:								
Type (OP/UG/ISL)	ISL	ISL	ISL	ISL	ISL	ISL	ISL	ISL
Size (tonnes ore/day)								
Average mining recovery (%)	90	90	90	90	90	87	90	N/A
Processing plant:								
Acid/alkaline	Acid	Acid	Acid	Acid	Acid	Acid	Acid	Acid
Type (IX/SX/AL)	IX	IX	IX	IX	N/A	IX	IX	IX
Size (kilolitre/day)	70 000	60 000	50 000	60 000	20 000	85 000	0	0
Average process recovery (%)	98.5	98.9	98.5	98.5	98.9	98.6	N/A	N/A
Nominal production capacity (tU/year)	2 000	1 000	1 400	2 000	600	1 200	0	0
Plans for expansion	No	No	Yes	No	Yes	No	Yes	Yes
Other remarks								

To train personnel for the nuclear industry, the International Scientific and Training Center has been established for specialists to obtain bachelor and master degrees. As part of the personnel qualification upgrade commitments, various mandatory trainings as required by law of the Republic Kazakhstan are ongoing, including other types of professional training. Such trainings are provided by the Corporate University based on the company's branch, and by external training providers.

The Subsoil Use Contract requires that annual expenditures for personnel training and retraining be 1% of annual exploration cost for the exploration period, and 1% of annual operating cost during the uranium mining period.

Future production centres

In April 2015, a new production centre Kazatomprom-SaUran LLP was established in NAC Kazatomprom JSC, which united the production centres Taukent Mining and Chemical Plant LLP and Stepnoye Mining Group LLP.

In October 2016, a new enterprise was formed, JV Budenovskoe LLP, the founders of the enterprise were NAC Kazatomprom JSC and Stepnogorsk Mining Chemical Complex LLP. JV Budenovskoe LLP will explore and develop the uranium deposit Budenovskoe (sites No. 6 and No. 7). NAC Kazatomprom JSC transfers the Subsoil Use Contract to JV Budenovskoe LLP in 2017.

Once prospecting of promising areas of Shu-Sarysu and Syrdaria Uranium Provinces is completed, new ISL production centres may be established.

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 liquidation fund to eliminate the effects of operations on subsoil use in Kazakhstan. Contributions to the liquidation 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 2015-2016, liquidation work in the uranium mines in Kazakhstan was not carried out.

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.

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 2015-2016

(KZT million)

	2015	2016	Total
Environmental impact assessments	92.0	78.8	170.8
Monitoring	256.4	278.9	535.3
Tailings impoundment	202.1	359.0	561.1
Waste rock management	172.4	198.7	371.1
Effluent management	46.0	79.1	125.1
Site rehabilitation	0.0	0.0	0.0
Regulatory activities	51.0	60.0	111.0
Social and/or cultural issues	3 590.0	4 230.00	7 820.0

Uranium demand

Internal demand for natural and enriched uranium is not expected in Kazakhstan until 2020. Construction of an NPP is under consideration.

Supply and procurement strategy

At present the entire volume of uranium produced in Kazakhstan is exported to the world market.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Since 2014, Kazakhstan has been working on the development of the Subsoil Use Code, as well as the implementation of standards of international reporting system on Mineral Resources CRIRSCO (Committee for Mineral Reserves International Reporting Standards).

Adoption of the Code allows the transformation of the sphere of subsoil use, bringing it to a qualitatively new level, raising efficiency and providing a comprehensive regulation, which is systemic in nature, thus creating the conditions for long-term growth.

In 2015, a formal ceremony was held for the launching of the International Bank of low-enriched uranium in Kazakhstan with the IAEA signing of the Agreement on the establishment of the Bank. The event was held with the participation of the IAEA, including the Director-General, Yukiya Amano, and representatives from China, France, Germany, Russia, the United Kingdom and the United States.

Uranium exploration and development expenditures and drilling effort – domestic

(KZT million)

	2014	2015	2016	2017 (expected)
Industry* exploration expenditures	4 724	10 738	6 920	4 890
Government exploration expenditures	0	0	0	0
Industry* development expenditures	1 639	608	1 194	1 284
Government development expenditures	0	0	0	0
Total expenditures	6 363	11 346	8 114	6 174
Industry* exploration drilling (m)	222 600	802 943	497 955	281 430
Industry* exploration holes drilled	395	1 942	1 035	476
Industry exploration trenches (m)	0	0	0	0
Industry trenches	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	0	0	0	0
Industry* development drilling (m)	129 360	150 214	193 859	226 301
Industry* development holes drilled	408	477	551	613
Government development drilling (m)	0	0	0	0
Government development holes drilled	0	0	0	0
Subtotal exploration drilling (m)	222 600	802 943	497 955	281 430
Subtotal exploration holes drilled	395	1 942	1 035	476
Subtotal development drilling (m)	129 360	150 214	193 859	226 301
Subtotal development holes drilled	408	477	551	613
Total drilling (m)	351 960	953 157	691 814	547 731
Total number of holes drilled	803	2 419	1 586	1 089

* Non-government.

Reasonably assured conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	256 031	338 131	351 481	351 481
Metasomatite	0	4 179	61 097	75 471
Phosphate deposits	0	0	29 184	38 455
Lignite-coal	0	0	29 433	29 433
Total	256 031	342 310	471 195	494 840

* In situ resources reported.

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	4 179	85 827	109 472	83
Open-pit mining (OP)	0	0	47 237	47 237	91
In situ leaching acid	256 031	338 131	338 131	338 131	89
In situ leaching alkaline	0	0	0	0	0
Co-product and by-product	0	0	0	0	0
Unspecified	0	0	0	0	0
Total	256 031	342 310	471 195	494 840	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	85 827	109 472	83
Conventional from OP	0	0	47 237	47 237	91
In situ leaching acid	256 031	338 131	338 131	338 131	89
In situ leaching alkaline	0	0	0	0	0
In-place leaching**	0	N/A	N/A	N/A	N/A
Heap leaching*** from UG	0	N/A	N/A	N/A	N/A
Heap leaching*** from OP	0	0	N/A	N/A	N/A
Unspecified	N/A	N/A	N/A	N/A	N/A
Total	256 031	342 310	471 195	494 840	88

* In situ resources reported with recovery factors provided.

** 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

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	284 474	371 855	394 617	394 617
Metasomatite	0	4 896	80 226	126 814
Phosphate	0	0	0	4 857
Lignite-coal	0	0	10 203	10 203
Total	284 474	376 751	485 046	536 491

* 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	84 549	135 994	83
Open-pit mining (OP)	0	0	18 471	18 471	91
In situ leaching acid	284 474	369 982	380 153	380 153	89
Co-product and by-product	0	1 873	1 873	1 873	91
Total	284 474	376 751	485 046	536 491	88

* In situ resources reported with recovery factors provided.

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 UG	0	4 896	84 549	135 994	83
Conventional from OP	0	1 873	20 344	20 344	91
In situ leaching acid	284 474	369 982	380 153	380 153	89
Total	284 474	376 751	485 046	536 491	88

* In situ resources reported with recovery factors provided.

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
194 108	229 053	230 583

Speculative conventional resources

(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
266 900	300 000	N/A

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Proterozoic unconformity	0	0	0	0	0	0
Sandstone	157 759	22 781	23 806	24 689	229 035	22 300
Metasomatite	42 549	0	0	0	42 549	0
Phosphate	21 618	0	0	0	21 618	0
Total	221 926	22 781	23 806	24 689	293 202	22 300

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Open-pit mining[1]	21 618	0	0	0	21 618	0
Underground mining[1]	42 549	0	0	0	42 549	0
In situ leaching	157 759	22 781	23 806	24 689	229 035	22 300
Co-product/by-product	0	0	0	0	0	0
Total	221 926	22 781	23 806	24 689	293 202	22 300

1. 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 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Conventional	42 109	0	0	0	42 109	0
In-place leaching*	0	0	0	0	0	0
Heap leaching**	440	0	0	0	440	0
In situ leaching	157 759	22 781	23 806	24 689	229 035	22 300
U recovered from phosphate rocks	21 618	0	0	0	21 618	0
Other methods***	0	0	0	0	0	0
Total	221 926	22 781	23 806	24 689	293 202	22 300

* Also known as stope leaching or block leaching.

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

*** Includes mine water treatment and environmental restoration.

Ownership of uranium production in 2014

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
13 175	53	0	0	7 310	30	4 204	17	24 689	100

Uranium industry employment at existing production centres

(person-years)

	2014	2015	2016	2017 (expected)
Total employment related to existing production centres	7 728	8 042	8 222	8 213
Employment directly related to uranium production	6 915	7 179	7 394	7 399

Short-term production capability

(tonnes U/year)

2017				2020				2025			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
25 000	25 000	26 000	26 000	26 000	27 000	27 000	28 000	25 000	26 000	27 000	28 000

2030				2035			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
20 000	22 000	22 000	24 000	12 000	14 000	14 000	16 000

Mali

Uranium exploration and mine development

Historical review

Exploration for uranium in Mali was done along the border with Senegal between 1954 and 1956, by the French Atomic Energy Commission in the Adrar des Iforas region. 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 this area but only the younger granites showed anomalous radioactivity, probably because of the presence of monazite as an accessory mineral.

Under an agreement with the government of Mali, Krupp carried out a reconnaissance survey in the eastern part of Mali in 1970 with no positive results. In 1971, the 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 emanometry and very low frequency electromagnetics over an area of 14 km^2, and then ended its activities in the second quarter of 1985. From 2007-2008, several 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 north-eastern part of Mali. Exploration covered a large crystalline geological province known as the Adrar des Iforas that is considered prospective for palaeo-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, substantial uranium and copper values were first discovered by COGEMA in the late 1970s, but the project has not advanced because of the prevailing low commodity prices. Exploration conducted since 2008 by Rockgate and Delta had focused on defining and expanding these initial results.

The mineralisation at the Faléa Project occurs within the Neoproterozic 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.

The first event related to ore genesis is believed to have deposited copper (mostly in the form of chalcopyrite) and silver mineralisation. The copper mineralisation occurs as disseminations primarily within the Kania Sandstones, as halos around the uranium minerals, and thus it acts as a trap for uranium mineralisation, which occurs mostly as pitchblende and coffinite.

The uranium mineralisation is believed to be a sandstone-type, possibly roll-front type deposit. With a few exceptions, mineralisation has been confined to the flat-lying Kania Sandstones unit, as well as within the units immediately above and below it. The distance from surface to the mineralised horizon varies between 31.5 m to more than 350 m below surface.

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 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 on the North Zone, and expanded north into the Bodi Zone. An additional 44 diamond drill holes were completed at the East Zone and 19 more at the Central Zone as part of an expanded resource definition programme.

In October and November 2012, a total of 15 936 m was completed in 66 diamond drill holes located in the Bodi and North Zone areas. Almost all work to date has been completed on the Falea Permit.

Recent and ongoing uranium exploration and mine development activities

In January 2014, Denison concluded the purchase of Rockgate and commenced work on the project including a detailed project review and re-interpretation of existing exploration data and 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.

As of 1 January 2015, seven uranium exploration permits had been granted to five exploration companies. However, because of the rebellion in the north-eastern part of the country, exploration activities are only being undertaken in the western part of the country.

Exploration permits

Eastern part of Mali

Arafat	1 750 km^2	Earthshore Resources Mali Ltd
Diarindi	150 km^2	Merrea Gold
Dombia	254 km^2	Tropical Gold of Mali Sarl
Kidal	3 980 km^2	Oklo Uranium Ltd Mali Sarl
Tessalit	4 000 km^2	Oklo Uranium Ltd Mali Sarl

Western part of Mali

Bala	125 km^2	Delta Exploration Mali Sarl
Madini	67 km^2	Delta Exploration Mali Sarl
Faléa	75 km^2	Delta Exploration Mali Sarl

Uranium resources

Identified conventional resources

An updated NI43-101 compliant resource estimate was reported for the Falea project in October 2015 using a cut-off grade of 0.03% U_3O_8 (0.025% U) resulting in a total indicated resource of 6.88 Mt at an average grade of 0.098% U and an inferred resource of 8.78 Mt at an average grade of 0.059% U. Total in situ identified resources amount to 11 846 tU, which includes 6 692 tU indicated and 5 154 tU inferred.

Recent metallurgical test work and engineering have confirmed recoveries of uranium, silver and copper on a consistent basis, and hence the contribution of all these metals that may be expected from mining. A pre-feasibility study has begun based upon 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 Capital Corp. announced that it had commissioned Golder Associates to conduct environmental and social baseline studies on the Faléa Project. In January 2014, Denison Mines of Canada took over Rockgate Capital Corp.

Reasonably assured conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	6 692	6 692
Total	0	0	6 692	6 692

* In situ resources.

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 (%)
Unspecified	0	0	6 692	6 692	N/A
Total	0	0	6 692	6 692	N/A

* In situ resources.

Inferred conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	5 154	5 154
Total	0	0	5 154	5 154

* In situ resources.

Inferred conventional resources by production method

(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	N/A
Total	0	0	5 154	5 154	N/A

* In situ resources.

Uranium exploration and development expenditures and drilling effort – domestic

(USD)

	2014	2015	2016	2017 (expected)
Industry exploration expenditures	1 516 362	773 514	386 942	1 032 668
Total expenditures	1 516 362	773 514	386 942	1 032 668

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, are 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.

Recent and ongoing uranium exploration and mine development activities

In 2009, the Mexican Geological Survey (SGM) reactivated radioactive exploration in Mexico, in order to validate and re-evaluate the resources reported by URAMEX according to international standards. This involves 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.

In order to have 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 have continued through drilling programmes.

During the period 2013-2016, a total of 16 442 m were drilled in 144 holes. All drill holes were logged using caliper, long and short resistivity, spontaneous potential and gamma ray and also performed with a sonic sonde and spectral gamma ray equipment.

Other areas under study were Buenavista, Chapote, La Diana, Peñoles, La Presita, Trancas, Dos Estados and Santa Fe in Nuevo León State with geological and radiometric prospection works, in order to have a base map to locate the drillings made by URAMEX in the 1980s and to assess the uranium mineralisation and geometry of the ore bodies.

In Durango State, the main exploration works have focused on Santiago Papasquiaro where anomalies and evidence of surface and underground uranium minerals were defined.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Past evaluation of these projects by URAMEX did not fulfil the international standards of evaluation. Potential was demonstrated, however, and the Mexican Geological Survey began a programme to evaluate resources following international standards. The first results of this programme are presented here.

Projects	Tonnes U (in situ)
Las Margaritas, Chihuahua State	597
El Puerto III, Chihuahua State	180
El Nopal I, Chihuahua State	422
Los Amoles, Sonora State	399
La Coma, Nuevo León State	852
Buenavista, Nuevo León State	1 455
El Chapote, Nuevo León State	1 104
La Diana, Nuevo León State	940
Peñoles, Nuevo León State	191
La Presita, Nuevo León State	185
Trancas, Nuevo León State	130
Dos Estados, Nuevo León State	169
Santa Fe, Nuevo León State	90

Undiscovered conventional resources (prognosticated and speculative resources)

There are 53 uranium occurrences in Mexico that will be evaluated by the Mexican Geological Survey.

Unconventional resources and other materials

The San Juan de la Costa phosphorite deposit is estimated to contain significant uranium resources.

Uranium production

Historical review

From 1969 to 1971, the Mining Development Commission operated a plant in Villa Aldama, Chihuahua. 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 2017, two boiling water reactors with a total installed capacity of 1.4 GW net were in operation at the Laguna Verde NPP. These two units have been in operation since 1990 and 1995. The two units supply about 4-5% 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, which will allow their operation for 30 more years. The unit 1 licence expires on July 2020 and the unit 2 licence expires on May 2025.

Supply and procurement strategy

Uranium purchase open bid is under study for six reloads (2018-2022).

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 in force on 5 February 1985. It specifies that the exploration, exploitation and the benefit of radioactive minerals are the exclusive domain of the government of Mexico. Exploration activities are exclusively delegated to the Mexican Geological Survey.

Uranium stocks

Uranium stocks are maintained at minimum levels in order to reduce costs.

Uranium exploration and development expenditures and drilling effort – domestic

(USD)

	2014	2015	2016	2017 (preliminary)
Industry* exploration expenditures				
Government exploration expenditures	1 383 248	1 451 841	1 236 842	1 200 000
Industry* development expenditures				
Government development expenditures				
Total expenditures	1 383 248	1 451 841	1 236 842	1 200 000

Reasonably assured conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	852	852
Volcanic-related	0	0	1 598	1 598
Total	0	0	2 450	2 450

* In situ resources.

Inferred conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	2 559	4 264
Volcanic-related	0	0	0	0
Total	0	0	2 559	4 264

* In situ resources.

Net nuclear electricity generation*

	2015	2016
Nuclear electricity generated (TWh net)	11.6	10.3

* Data based on NEA Nuclear Energy Data reports.

Installed nuclear generating capacity to 2035*

(MWe net)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
1 510	1 608	1 608	1 634	1 608	1 634	1 608	1 634	1 634	4 329	1 634	5 689

* Data based on NEA Nuclear Energy Data reports.

Annual reactor-related uranium requirements* to 2035 (excluding MOX)**

(tonnes U)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
188	402			408		205		203		396	

* Refers to natural uranium acquisitions, not necessarily consumption during the calendar year.

** Data based on NEA Nuclear Energy Data reports.

Mongolia

Uranium exploration and mine development

Historical review

Uranium exploration in Mongolia 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.

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. Full airborne gamma-spectrometric surveys at a scale of 1:25 000 and 1:50 000 were conducted over 420 000 km^2, about 27% of Mongolian territory; at a scale of 1:200 000 over 450 000 km^2, or 28% of the territory; and at a scale of 1:1 000 000 over 224 000 km^2, or 14% of the Mongolian Altai, Khangai mountains and Gobi Desert region. The territory along the border with the People's Republic of China and the central Mongolian mountain area, about 30% of the country, were not included in these surveys.

Metallogenic investigation at the scale of 1:500 000 over a 500 000 km^2 area and more detailed geological exploration at the scale of 1:200 000-1:50 000 over 50 000 km^2 area territory of 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.

Based on these surveys, the territory of Mongolia was classified into four uranium-bearing metallogenic provinces: Mongol-Priargun, Gobi-Tamsag, Khentei-Daur and Northern Mongolian. Each of these provinces has different geology and hosts different deposit types. Mineral associations and ages of mineralisation also vary. Within these provinces, 12 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 tracing along the extension over some 1 200 km, from the Mongolian Altai to the Lower-Priargun. This territory includes mainly deposits and occurrences of 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, Ulaan (incidental), 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 60-180 km wide in southern Mongolia. It is characterised by numerous uranium occurrences in grey and motley coloured terrigenous sediments related to stratum oxidation and restoration. The district units include a perspective uranium deposit in the south, near the Dulaanuul and Nars deposits and numerous occurrences, as well as perspective uranium-bearing basins, such as Tamsag, Sainshand, Zuunbayan Basins and 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 light-coloured granite fragments 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. This north-western part of Mongolia is a comparatively old geological province characterised by a variety of minerals such as uranium, thorium and rare earth elements related to alkaline mineralisation; uranium and thorium in metasomatites, pegmatite, magmatic and quartz schist uranium host rock.

Recent and ongoing uranium exploration and mine development activities

At present ten national and foreign investment companies are carrying out intensive exploration activities across the country.

There are two types of uranium exploration activities in Mongolia – prospecting aimed at new deposit discovery and exploration of previously discovered deposits with a view to increasing resource endowments.

In 2015-2016, the majority of the uranium prospecting was performed in south Mongolian basins, with the objective of identifying sandstone-type uranium mineralisation for ISL mining.

Uranium exploration expenditures were MNT 15 209 million in 2015 (Mongolian tugrug), and in 2016 exploration expenditures were MNT 13 058 million. Uranium prospecting and exploration drilling totalled 12 128 m in 2016, compared with 2 624 m reported in 2015.

Identified recoverable conventional resources (reasonably assured and inferred resources) as of 1 January 2017 amounted to 113 357 tU. Compared to 1 January 2015, this represents a decrease of 27 987 tU. This decrease is due to a re-evaluation of the ore deposits data, which also resulted in transfers of the resources from the reasonably assured resources category to the inferred category. However, it should be noted that there has been an increase of around 22 000 tU (in situ) identified resources for the Zooch Ovo deposit.

Undiscovered conventional resources (prognosticated and speculative resources)

As of 1 January 2017, prognosticated resources amounted to 21 000 tU and speculative resources totalled 1 390 000 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. Assuming an ore grade of 0.12%, this equalled a mining production capability of 2 400 tU/year. Mongolia has no processing facilities. The ores mined in the Mardai-gol district were transported by rail 484 km to Priargunsky mining and processing combinate in Krasnokamensk, Russia, for processing. Because of political and economic changes both 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, a number of mines are in the planning stage of development.

Uranium production centre technical details

(as of 1 January 2017)

	Centre #1	Centre #2				Centre #3	
Name of production centre	Emeelt mines	Gurvansaihan				Orano mines	
Production centre classification	Planned	Planned				Planned	
Date of first production (year)	2021	2021				2022	
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
Recoverable resources (tU)	7 731	7 950	7 386	3 187	1 958	4 695	55 234
Grade (% U)	0.162	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 plant:							
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

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)

Currently, no uranium has been produced in Mongolia.

Ownership structure of the uranium industry

According to the Nuclear Energy Law of Mongolia ownership structure is described below:

- Article 5: Ownership of radioactive minerals and state participation in exploitation of radioactive minerals:
  - 5.1: Radioactive minerals occurring in subsoil of land Mongolia shall be the property of the state.
  - 5.2: Provided the radioactive mineral deposit, which exploration and reserves determination were conducted by the state budget financing, 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 special licence for exploitation of the radioactive mineral deposit, 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 would positively influence and improve the national economy. As a result the government has developed a special programme on uranium and is committed to implementing this programme.

The programme covers the following policies and guidelines:

- Geological exploration and the mining of uranium deposits, processing and marketing of uranium ores on the territory of 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 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 to introduce 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
(MNT million)

	2014	2015	2016	2017 (expected)
Industry* exploration expenditures	27 940	15 209	13 058	23 395
Government development expenditures	100	0	0	0
Total expenditures	27 940	15 209	13 058	23 395
Industry* exploration drilling (m)	24 685	2 624	12 128	15 960
Subtotal exploration drilling (m)	24 685	2 624	12 128	15 960
Total drilling (m)	24 685	2 624	12 128	15 960

* Non-government.

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)		23 711	23 711	23 711	75
In situ leaching acid		26 066	26 066	26 066	80
Total		49 777	49 777	49 777	

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		23 711	23 711	23 711	75
In situ leaching acid		26 066	26 066	26 066	80
Total		49 777	49 777	49 777	

Reasonably assured conventional resources by deposit type
(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone		26 066	26 066	26 066
Volcanic-related		23 711	23 711	23 711
Total		49 777	49 777	49 777

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)		4 051	4 051	4 051	75
In situ leaching acid		59 706	59 706	59 706	80
Total		63 757	63 757	63 757	

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 UG		4 051	4 051	4 051	75
In situ leaching acid		55 974	55 974	55 974	80
Total		63 757	63 757	63 757	

Inferred conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone		55 974	55 974	55 974
Volcanic-related		4 051	4 051	4 051
Total		63 757	63 757	63 757

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
21 000	21 000	21 000

Speculative conventional resources

(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
1 390 000	1 390 000	0

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Open-pit mining	535	0	0	0	535	0
Total	535	0	0	0	535	0

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Volcanic-related	535	0	0	0	535	0
Total	535	0	0	0	535	0

Short-term production capability (tonnes U/year)

2017				2020				2025			
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

2030				2035			
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.

Namibia*

Uranium exploration and mine development

Historical review

Uranium was first discovered in the Namib Desert in 1928 by Captain G. Peter Louw in the vicinity of the Rössing Mountains. Over many years he tried to promote the prospect, but it was not until the late 1950s that the Anglo American Corporation of South Africa prospected the area by drilling and limited underground exploration. As a result of erratic uranium prices and limited economic prospects for uranium, Anglo American abandoned its work.

As a result of an upswing in the uranium market demand and prices, extensive uranium exploration started in Namibia in the late 1960s. Several airborne radiometric surveys were conducted by the national geological survey and numerous uranium anomalies were identified. In 1966, after discovering a number of uranium occurrences, Rio Tinto acquired the rights to the low-grade Rössing deposit, 65 km inland from Swakopmund. During the same exploration period, Trekkopje, a near-surface calcrete deposit, was discovered just north of Rössing and Langer Heinrich, another calcrete deposit, was discovered in 1973 by Gencor, 50 km south-east of Rössing.

Mining commenced in 1976 at Rössing and exploration intensified as uranium prices increased sharply. However, in the early 1980s the combined effects of political uncertainty and the decline of uranium prices caused the rapid curtailment of exploration and development work. This was unfortunate as the refinement of exploration techniques, which had proved to be successful in the Namib Desert, appeared poised to potentially locate a number of new deposits.

The upward trend in uranium prices that began in 2003 once again stimulated extensive exploration activity, mainly in the Namib Desert. Based on earlier successes, two major types of deposits were targeted; the intrusive-type associated with alaskite, as at Rössing, and the surficial, calcrete-type, as at Langer Heinrich. In 2002 Paladin Energy bought the Langer Heinrich tenement and following the completion of a bankable feasibility study in 2005 started the construction of the mine with the mine officially opening in March 2007. In 2007, French state controlled Areva purchased the Trekkopje Uranium Project from Canadian mining company UraMin, and started construction of the alkaline heap leach Trekkopje Mine in 2008. This included the construction of a seawater desalination plant. The mine was initially expected to start production in early 2010, with an initial output of 3 000 tU per year. In February 2011, however, Areva announced that the mine was not expected to reach full capacity until 2013. The decreased uranium demand as well as correspondingly lower prices after the Fukushima Daiichi accident in Japan, led Areva to slow down development of the Trekkopje project and it was placed on care and maintenance in mid-2013 following completion of the phase 2 pilot tests. Other uranium projects that were issued mining licences, but have not commenced construction are the Norasa Uranium Project and the Zhonge Uranium Project.

* Report prepared by the NEA/IAEA, based on previous Red Books, government data and company reports.

During the same time, Extract Resources discovered the Husab uranium deposit (initially known as Rössing South), the third largest uranium–only deposit in the world. In March 2012, China Guandong Nuclear Power Corporation acquired the project in a takeover bid of USD 2.4 billion. Construction of the Husab mine started in April 2013 and the first uranium oxide was drummed in December 2016.

Exploration activities continue, but declining uranium prices since 2011, partly as a result of the Fukushima Daiichi accident, have slowed activities to a certain extent. Despite this recent slowdown, substantial growth in uranium exploration already took place in the Erongo area of west-central Namibia, focusing mainly on previously known deposits with considerable historical data. Bannerman Mining Resources (Namibia) (Pty) Ltd for example has progressed the Etango Uranium Project from the initial scoping study (2007) and pre-feasibility study (2009) to the definitive feasibility study (DFS) (2012) phase, and subsequently also built a heap leach demonstration plant (2015) where the metallurgical heap process could be tested and the metallurgical assumptions of the DFS demonstrated. Over 300 000 m of exploration drilling has been completed in the Etango Uranium Project area. Other uranium exploration companies that have continued exploration include Reptile Mineral Resources and Exploration and Marenica Energy. Over 60 exploration licences were issued up 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 for uranium mining.

Recent and ongoing uranium exploration and mine development activities

Rössing Uranium Limited

A positive evaluation of the possibility of extending the mine life to 2016 and later to 2023 led to efforts to expand the existing pit to expose more of the steeply dipping SJ orebody. Between 2007 and 2010, exploration at Rössing focused on extensions of the main SJ ore body, as well as the adjacent SK and SH deposits. However, the SK deposit contains largely refractory mineralisation (betafite) for which the existing process plant is not suitable.

Since 2010, the main exploration focus has been on the southernmost Z20 deposit that extends across the lease boundary into the adjacent lease held by Swakop Uranium Limited. A total of 24 000 m of drilling was completed on Z20 to declare an inferred resource by the end of 2012. The third phase of drilling on the Z20 ore body was completed during 2013. Data from the drilling indicated a significant uranium resource in Z20. In 2013, in situ resources for the Z20 orebody amounted to 46 012 tU at higher grades (0.023% U) than the main orebody.

A recent revision of the pricing outlook has resulted in the removal of the Z20 mineralised zone from RUL's resource declaration. This decision was taken as a result of a financial analysis, which demonstrated that, with the down-revised pricing outlook, the Z20 deposit would not contribute any additional value to the existing SJ Pit operations. The resources contained within the phase 4 pushback, as well as the inferred resources within the phase 2 and 3 pushbacks, continue to demonstrate value.

Having returned to a four-panel shift roster and a seven-day operations schedule at the end of 2015, 2016 witnessed an increase in production of rock mined.

In 2016, Rössing mined a total of 24.4 million tonnes of rock, of which 8.0 million tonnes were uranium-bearing ore from the open pit and 16.5 million tonnes were waste rock. In addition, 1.2 million tonnes of uranium-bearing ore was fed from the stockpiles to achieve a waste-to-ore strip ratio of 1.97 and a ratio of 0.56 in respect of ore milled to waste rock removed.

The north-west area of the open pit, referred to as Phase 2 of the SJ Pit, was the main source of uranium-bearing ore in 2016. Considerable success was also achieved in removing bottlenecks and improving milling efficiencies. The goal was to reach 38 000 tonnes crushed per day consistently. After analysing the downtime trend and removing bottlenecks, the frequency with which more than 2 000 tonnes per hour crushed was achieved, improved from an average of 11% achieved during the six months prior to the project to 15% during the three months of the project. It is expected that when this improvement continues to increase, it will contribute significantly to the achievement of 38 000 tonnes crushed per day. A post-implementation review is scheduled for October 2017 to assess the effectiveness of these improvements in addressing the bottlenecks to consistent throughput.

These efforts, combined with having returned to a 24-7 production, resulted in increased mill throughput and a 48% rise in production from 1 055 tU produced in 2015 to 1 569 tU in 2016.

Langer Heinrich

Langer Heinrich is a surficial, calcrete-type uranium deposit located in the Namib Desert, 80 km from the major seaport of Walvis Bay. The ore occurs over 15 km in a paleochannel system; some 50 m deep is covered by mining licence ML 140. An exploration prospecting licence, EPL 3500, covers the western extension of the mineralised Langer Heinrich paleochannel. In 2015, this prospecting licence was converted to a mining licence, ML 172. The Langer Heinrich identified in situ resources amounted to 49 179 tU at an average grade of 0.040% U.

There has been no recent exploration activity due to the continued depressed uranium prices. Instead the focus has been on the improvement of operating efficiencies to improve production and reduce costs. In 2015 the mine produced 1 937 tU and in 2016 a total of 1 832 tU. Towards the end of 2016, a mining curtailment programme was initiated in order to further cut costs, and stockpile material only will be processed until 2019.

Trekkopje

The Trekkopje Uranium Project is located approximately 65 km north-east of the coastal town of Swakopmund. The project area contains the Klein Trekkopje resource, a broad, surficial uranium deposit (80% of mineralisation is contained in the top 15 m) hosted in calcium carbonate cemented (calcrete) conglomerates of Cenozoic age, which lie on a peneplane of Precambrian/Cambrian age meta-sedimentary rocks and intrusive granite. The basal channels in the Trekkopje area follow the north-east trending structural grain of the underlying basement rocks.

In 1974, an airborne radiometric survey, commissioned by Rio Tinto, identified a uranium anomaly in the south-west of the property over what is now known as the Klein Trekkopje deposit. Sporadic exploration was undertaken by different companies between 1974 and 1999. In December 1999, UraMin Inc., the parent company of UraMin Namibia, was granted licences over the project area. In 2006, UraMin initiated a programme of exploration drilling and in November that year announced resources for the Klein Trekkopje and Trekkopje deposits. In July 2007, UraMin Inc. was purchased by Orano (formerly Areva) with its 100%-owned subsidiary, Orano Mining Namibia (formerly Areva Resources Namibia), responsible for exploration and development activities.

Exploitation at Trekkopje has been a technical challenge due to its very low uranium content and the use of alkaline heap leaching. The mine was developed in three phases. Phase one, also known as “Mini”, was designed to validate the chemistry of the heap leach process and was successfully completed in 2009. Phase two (“Midi”) treated 3 million tons of ore to prove the commercial process before scaling up to full production. Phase three (“Maxi”) represents the full production stage of the mine, which was expected to produce about 3 000 tU per annum. However, due to the depressed uranium market, the mine was put on care and maintenance in 2012. As at 1 January 2013, the resource inventory for Klein Trekkopje equated to 26 000 tU (250 Mt at 105 ppm U).

The care and maintenance phase has been an opportunity to thoroughly research the alkaline heap leach process and make improvements to the uranium recovery methods. The company explored ways to preconcentrate ore by discarding most of the waste material. They also investigated options such as finer crushing, scrubbing and flotation, which were found to be technically feasible. An optimised process was developed that enhances the permeability of the heap by adding cement at the agglomeration stage and recovers a substantial part of the reagents through membrane technology.

The desalination plant associated with the mine continued to supply sufficient water to meet the demand of the uranium mines and other users in the coastal area. Production capacity was boosted to one million cubic metres per month to cater for increased demand as the Husab mine commenced with production.

Husab

The main part of the Husab Project is the Husab (previously known as the Rössing South) orebody, about 5 km south of the Rössing mine. The Husab area was targeted as an exploration area of interest in 2006-2007. The geological reasoning behind this was that similar rock formations (alaskites) to those hosting the Rössing mine to the north were interpreted to be concealed beneath the desert plain in the northern part of Swakop Uranium's EPL area. Data from the Geological Survey of Namibia's airborne geophysics project supported this interpretation. The discovery holes were drilled in late 2007; the chemical assay results for the three discovery holes were returned from the laboratory in early 2008 and released to the market in February 2008. Cementing its place as one of the largest resource drilling projects globally, Swakop Uranium has completed over 800 000 m of combined reverse circulation and diamond core drilling from April 2006, when the drilling programme started.

The 8-km long uranium mineralisation has been confirmed as the highest-grade granite-hosted uranium deposit in Namibia and one of the world's most significant discoveries in decades. The deposit lies under a shallow alluvial sand cover. Waste stripping commenced in May 2014. A 1 500 t/day sulphuric acid plant was commissioned at the end of 2015. Additional acid may be imported. First uranium production was achieved in December 2016.

Estimated resources for all deposits currently licensed to Swakop Uranium, reported by the Mineral Resource Department are summarised in the following table.

Resources reported by Swakop Uranium*

	Measured resources			Indicated resources			Inferred resources		
	Ore (Mt)	Grade (ppm U)	U (tU)	Ore (Mt)	Grade (ppm U)	U (tU)	Ore (Mt)	Grade (ppm U)	U (tU)
Husab Zone 1	35.49	340	12 050	166.12	344	57 506	70.63	318	22 476
Husab Zone 2	43.09	513	22 098	112.12	466	52 262	49.30	358	17 654
Total Husab	78.58	435	34 148	278.24	394	109 590	119.04	337	40 130
Husab Zone 3							46.10	204	9 270
Husab Zone 4							19.80	475	9 424
Husab Zone 5							44.58	239	10 663
Salem							36.16	131	4 742
Middel Dome							25.90	334	8 654
Total Husab Ext							172.54	248	42 753

Resources reported by Swakop Uranium* *(cont'd)*

	Measured resources			Indicated resources			Inferred resources		
	Ore (Mt)	Grade (ppm U)	U (tU)	Ore (Mt)	Grade (ppm U)	U (tU)	Ore (Mt)	Grade (ppm U)	U (tU)
Garnet Valley							83.70	165	13 847
Ida east				2.10	199	423	5.20	144	754
Holland's Dome							4.00	132	538
Total Ida Dome				2.10	199	423	92.90	163	15 139
Total Swakop	78.58	435	34 148	280.10	393	110 013	384.48	255	98 022

* The resources for Husab mine were estimated by MRM (Resource DEPT) at a cut-off grade of 100 ppm U_3O_8, and are supported by competent person's reports (2014).

Etango

The Etango Uranium Project is located in the Erongo uranium province, which lies to the south-west of Rio Tinto's Rössing Uranium mine and CGNPC's Husab Project, and to the west of Paladin Energy's Langer Heinrich mine. The Etango mine consists of three prospects named Anomaly A, Oshiveli and Onkelo. These prospects contain uraniferous sheeted leucogranite bodies or alaskites, which have intruded into metasediments of the Nosib (Khan and Etusis Formations) and Swakop Groups (Chuos Formation) of the Damara Sequence. The alaskite ore is very similar to that at Rössing, and although extensions continue to 400 m below the surface, two-thirds of the resource base is located less than 200 m from the surface.

The Etango mineral resource estimate (in situ resources) was first prepared for Bannerman in accordance with the AusIMM JORC Code 2004 by Coffey Mining Pty Ltd ("Coffey") in 2010. The resource estimate incorporates all new drilling to September 2010 and was announced in October 2010. It was updated in 2015 in accordance with the JORC Code 2012 and the Canadian National Instrument 43-101 by Optiro Mining Consultants ("Optiro") incorporating all new drilling to November 2015.

Uranium mineralisation has been defined inside grade envelopes by categorical indicator kriging using a lower cut-off grade of 50 ppm U_3O_8 and lithological constraints.

Relevant operational aspects associated with open-pit uranium mining, most notably the established practice of radiometric haul truck scanning as a means of discriminating between ore and waste material at the haul truck payload level, have been considered. This practice, which is unique to uranium mining due to the ability to measure the gamma radiation associated with the mineralisation, has been very effectively implemented at the Rössing and Langer Heinrich uranium mines.

In order to model this high selectivity, a uniform conditioning estimation approach has been adopted.

This is a recoverable resource estimation technique based upon ordinary kriging into large blocks (panels), which seeks to predict the resource available at the time of mining using the assumption of selective mining unit (SMU) related to the production rate and equipment. The uniform conditioning approach effectively determines a tonnage-grade curve of smaller volumes (SMU scale) within the larger mining panel curve consistent with the mining method and the use of a radiometric truck scanner. In the context of the Etango project this approach stimulates the range of the grades that would be presented to the truck scanner for each larger mining block. The cut-off grade for the Etango mineral resource was reduced to 55 ppm to be consistent with the ore reserves cut-off grade.

The mineral resources have been classified into measured, indicated and inferred categories on the basis of geological and grade continuity, drill hole spacing and estimation quality. The measured category was applied to blocks, which were informed either in pass one or two, where the drill spacing was 25 m x 25 m or 25 m x 50 m, and where the slope of regression statistic was generally greater than 0.9. The indicated category was applied to blocks estimated in the first or second pass, where the drill spacing was nominally 50 m x 50 m x 100 m, where the grade tenor was moderately consistent, and where the slope of regression was between 0.3 and 0.9. Any material that did not meet the criteria for measured or indicated was allocated to the inferred category, apart from extrapolated or laterally – extensive mineralisation, which was set to potential using a number of "unclassified" solids.

Total in situ resources for Etango (as of November 2015)

	Measured resources			Indicated resources			Inferred resources		
	Tonnes (Mt)	Grade (ppm U)	Uranium (tU)	Tonnes (Mt)	Grade (ppm U)	Uranium (tU)	Tonnes (Mt)	Grade (ppm U)	Uranium (tU)
Etango	33.7	165	5 500	362.0	159	57 500	144.5	166	24 000

Bannerman is also investigating potential satellite pit opportunities at Ondjamba and Hyena. These resources (in situ) have been included in the following table:

	Inferred resources		
	Tonnes (Mt)	Grade (ppmU)	Uranium (tU)
Ondjamba	85.1	141	12 000
Hyena	33.6	141	4 700
Total	118.7	141	16 700

Bannerman Mining Resources (Namibia), a subsidiary of Bannerman Resources, is the operator of the mining project. Bannerman holds 95% of the Etango project, with the remaining 5% owned by the One Economy Foundation, a Namibian not-for-profit organisation that concerns itself with the dual economy in Namibia. One economy is a loan carried for all future project expenditure including pre-construction and development expenditure, with the loan capital and accrued interest repayable from future dividends.

Reptile Mineral Resources & Exploration (RMRE)

RMRE holds three EPLs for nuclear fuel south of the Husab mine covering areas of high-grade Rössing-type alaskite (Omahola Project) and surficial Langer Heinrich-type mineralisation in the Tubas Sand and Tubas/Tumas paleochannel and Aussinanis calcrete scree deposits.

The Omahola Project consists of three deposits, the Ongolo, the MS7 alaskite deposits and the Inca uraniferous magnetite skarn deposit. The Tubas Sand Project consists primarily of low-grade secondary uranium mineralisation (carnotite) in well-sorted aeolian sediments. The Tubas/Tumas Paleochannel system is extending over an area >100 km. It contains significant secondary uranium mineralisation (carnotite) in fluviatile grits, calcrete and gravel sequences in a complex palaeochannel system.

The Aussinanis deposit forms a more shallow palaeochannel system, also with carnotite-rich calcrete. Aussinanis was transferred into Yellow Dune Uranium Resources Ltd. in 2013. The Namibian Government Mining Company, Epangelo acquired a 5% stake and an option to earn up to 70% if they fund further test work and a bankable feasibility

Omahola

The Omahola Project consists of three deposits, the Ongolo and MS7 alaskite deposits and the Inca uraniferous magnetite deposit. Ongolo mineralisation is primarily uraninite type. MS7 is a mineralised zone of about 600 m along strike and up to 400 m wide about 2 km west of Ongolo, while Inca hosts unique high-grade uranium, magnetite and pyrite mineralisation. It is envisaged that the project would consist of a processing plant located close to the Ongolo Alaskite deposit, treating a blend of primary ore from these three deposits.

Following the first discovery hole at Ongolo South in late 2010, the extent of the deposit was confirmed in follow-up drilling late in 2012. Further infill and extension drilling at Ongolo was included in an updated mineral resource estimate. The JORC mineral resource of the Ongolo deposit is 11 366 tonnes U_3O_8 (9 638 tU) at a 250 ppm cut-off.

Omahola's JORC Mineral Resource base, the majority of which will be mineable by open-pit methods, currently amounts to 17 370 tU at a 250 ppm cut-off. The 2013 exploration programmes at Ongolo focused on infill drilling and resource extension at Ongolo South.

RMRE is a wholly owned subsidiary of Australia's Deep Yellow Ltd, an Australian Securities Exchange-listed entity that also has a listing on the Namibian Stock Exchange. To date, RMRE's Omahola Project was predicated on open-pit mining and conventional tank acid leach extraction. However, recent test work indicated that a heap leach option may also be viable. Recent preliminary economic assessments and trade-off studies indicate that the project is more economically viable as a heap leach process.

Work commenced on the evaluation of all calcrete-associated uranium mineralisation in Tumas 1, 2 and 3 areas including the Tubas zones. The objective is to improve the geological characterisation of these prospective channels through the creation of 3D palaeo-geographic models.

Revised mineral resource status

In October 2016, a clarifying announcement was made on the company's previous release regarding the revised mineral resource estimate ("MRE") for its Tumas Project.

Comparisons of revised and previous MRE are shown in the table below indicating a shift of 3 138 tU into the measured resource category leaving 1 866 tU remaining in the indicated resource category, together totalling just over 5 000 tU.

	Revised Tumas JORC 2012 MRE					Previous JORC 2004 Tumas					
MRE category	Cut-off (ppm)	Tonnes (M)	eU (ppm)	U (t)	U (Mlb)	Category	Cut-off (ppm U)	Tonnes (M)	eU (ppm)	U (t)	U (Mlb)
Measured	170	9.7	327	3 138	6.9	Measured	-	-	-	-	-
Indicated	170	6.5	285	1 866	4.1	Indicated	170	14.4	310	4 494	9.9
Inferred	170	0.4	298	127	0.28	Inferred	170	0.4	305	85	0.2
Total	170	16.6	310	5 131	11.3	Total	170	14.8	310	4 579	10.1

Overall mineral resource estimates

The company still has some mineral resource estimates classified under JORC 2004 and has committed to progressively bringing all resources up to JORC 2012 standard.

Nova Energy Namibia holds two EPLs for nuclear fuel, base and rare metal exploration adjacent to RMREs Omahola Project and close to the Kuiseb River. Both EPLs are considered prospective for primary Rössing-type mineralisation and surficial Langer Heinrich-type mineralisation.

RMRE is the operator and holds a 65% interest. NOVA recently secured a Joint Venture with Japan Oil, Gas and Metals National Corporation (JOGMEC).

Satellite imagery with 1.5 m spatial resolution covering the total JV area has been acquired to prepare an initial geological photointerpretation of both tenements. Initial results of the interpretation indicate that field checking in 2017 could lead to substantial changes in geological understanding with the expectation that targets could be delineated for follow-up drilling.

Total in situ resources for Omahola Project

	Measured resources			Indicated resources			Inferred resources		
	Ore (Mt)	Grade (ppmU)	U (tU)	Ore (Mt)	Grade (ppm U)	U (tU)	Ore (Mt)	Grade (ppm U)	U (tU)
Inca				7.0	399	2 800	5.4	441	2 400
Ongolo	7.7	374	2 500	9.5	315	3 000	12.4	328	4 100
MS7	4.4	349	1 700	1.0	367	370	1.3	381	500
Total Omahola	12.1	347	4 200	17.5	353	6 170	19.1	366	7 000

The Tubas Sand Project

Formerly referred to as the Tubas Red Sands Project, it was originally discovered and explored in the 1970s and 1980s. The Tubas Sand Project consists primarily of low-grade secondary uranium mineralisation (carnotite) in well-sorted aeolian sediments. Since 2006, RMRE has conducted two infill drilling campaigns, which lead to an update of the MRE in early 2014. This MRE comprises approximately 1/3 of the area explored previously and is a subset of the entire deposit. The updated 2012 JORC compliant MRE totals 34.0 Mt at an average grade of 170 ppm U_3O_8 for 5 800 tonnes U_3O_8 (4 900 tU) at a 100 ppm cut-off.

	Indicated resources			Inferred resources		
	Ore (Mt)	Grade (ppmU)	U (tU)	Ore (Mt)	Grade (ppm U)	U (tU)
Tubas Sand	10.0	160	1 600	24.0	137	3 300

Preliminary economic analysis and trade-off studies show that the project is not viable as a standalone yellow cake producing facility. A physically beneficiated concentrate could be transported and successfully treated at a nearby processing facility within a 100 km radius. Efforts are continuing to secure an off-taker for the concentrate or a toll-treat arrangement at a nearby processing plant.

Aussinanis

The Aussinanis Project is a palaeochannel deposit, located near the coast. Uranium mineralisation is present from the surface to an average depth of 6 m as carnotite hosted in sediments and calcrete. It has 6 900 tU indicated and inferred resources at about 0.02% U. In January 2013, Deep Yellow agreed with Epangelo to transfer its Aussinanis and Ripnes projects into a new company, Yellow Dune Uranium Resources Ltd. Epangelo acquired a 5% stake in Yellow Dune to fund test work and confirm that the Aussinanis deposit can be upgraded by beneficiation. Reptile holds 85% and Oponona Investments 10%. If the test work at Aussinanis is successful, Epangelo will become the operator of the joint venture and would earn up to 70% in Yellow Dune by funding the project through to a bankable feasibility study. Reptile's holding would reduce to 20%.

Total in situ resources at Aussinanis Project

	Indicated resources			Inferred resources		
	Ore (Mt)	Grade (ppm U)	U (tU)	Ore (Mt)	Grade (ppm U)	U (tU)
Aussinanis	5.6	179	1 000	29.0	203	5 900

Marenica

Marenica is situated in a paleochannel approximately 40 km north of Trekkopje. Carnotite uranium mineralisation occurs in both the paleochannel and weathered basement rock. The regional geology of this area consists of basin and dome tectonic features, where massive marbles of the Karibib Formation form three prominent domal structures, while steeply dipping biotite schists (Kuiseb Formation) form the basins similar to that of the Rössing mine. Potential to find a hard rock deposit is therefore encouraging. The recent discovery of uraninite-bearing alaskites on the Marenica Project further enhances the hard rock potential of the area. In November 2011, Marenica Energy Ltd reported a resource estimate, based on historical and new data, totalling 23 578 tU at an average grade of 0.008% U.

As the deposit is a relatively well-known, large, low-grade resource, and the market is depressed, Marenica Energy suspended all drilling activities, focusing on metallurgical testing and on an upgrade process to increase the grade of mined material prior to leaching. The upgrade process has proven successful and has reduced the leach feed to about 1% of the plant feed because of a rejection of the major gangue mineral calcite. 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 and operating costs.

During 2015 and 2016, Marenica continued to do test work with various types of ores using this by now called U-PgradeTM process, for which patent applications have been lodged. In December 2016 the Namibian Ministry of Mines and Energy granted a Mineral Deposit Retention Licence covering the previous EPL 3287 area.

Marenica Energy has a 75% interest in the project, while the other partners are Xanthos Mining Limited (20%) and Millennium Minerals (5%).

	Indicated resources			Inferred resources			Total		
	Ore (Mt)	Grade (ppmU)	U (tU)	Ore (Mt)	Grade (ppm U)	U (tU)	Ore (Mt)	Grade (ppm U)	U (tU)
Marenica	26.5	93	2 462	250	78	19 577	276.1	80	22 039
MA7				22.8	69	1 539			

Happy Valley/Zhonghe Resources

EPL3602, located in the so-called Happy Valley area in Namibia some 110 km north-east of Swakopmund and east of Rössing Uranium, was granted to Zhonghe Resources on 1 August 2006. Zhonghe Resources (Namibia) Development P/L is a Namibian registered company founded in 2008 by China Uranium Corporation Ltd (SinoU) (58%), a wholly owned subsidiary of China National Nuclear Corporation (CNNC), and a private company, Namibia-China Mineral Resources Investment and Development P/L (Nam-China) (42%).

Exploration work, including geological mapping, radiometric surveying, geochemical surveying, drilling, and trenching was started in the area by Zhonghe Resources in 2007, with a total of 372 drill holes and 89 512 m drilled as of end of 2012. ML 177 was subsequently granted in 2012 and is valid until 2031. However, at current prices the deposit is not economical.

Total in situ resources for Happy Valley (as of 2012)

Indicated resources				Inferred resources			
Tonnes (Mt)	Grade (ppm U)	Uranium (tU)	U_3O_8 (mlbs)	Tonnes (Mt)	Grade (ppm U)	Uranium (tU)	U_3O_8 (mlbs)
54.3	190	8 730	22.7	205	184	32 000	83.3

The Zhonghe Resources uranium project mineral resource estimate is reported in accordance with the standards and guidelines in the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (the JORC Code 2012) and the China national reserve calculation standard. Uranium mineralisation has been defined inside grade envelopes by categorical indicator kriging using a lower cut-off grade of 100 ppm U_3O_8 and lithological constraints.

A feasibility study for mine development of the No. 18 deposit was undertaken from 2011 to 2012. In 2015 and 2016, Zhonghe Resources continued to focus on potential resource evaluation and economic reassessment for mining development on their mining licence. The company is also looking to conclude partnerships with other Namibian uranium mining companies.

Metals Australia Ltd/Mile 72

Metals Australia Ltd owns 100% of the Mile 72 uranium project, located near Henties Bay on the west coast of Namibia. The project is considered prospective for calcrete and gypcrete hosted uranium as well as alaskite hosted uranium. High-resolution airborne geophysical survey, radon cup, surface trenching and drilling exploration activities have been conducted. Activity during 2015 and 2016 was restricted to geological and economic assessments.

Engo Valley

The Engo Valley Project comprises a series of uranium anomalies exposed in and adjacent to Karoo sedimentary rocks. The project is located 600 km north of Swakopmund, on the Skeleton Coast of northern Namibia. The licence was relinquished in 2014 following a review of the prospectivity and remoteness of the project.

Identified conventional resources (reasonably assured and inferred resources)

Identified, recoverable conventional resources in Namibia amounted to 541 346 tU as of end 2016. Deposits in Namibia are typically large and low grade. In 2016, about 82% of the recoverable identified uranium resources were classified in the <USD 130/kgU cost category with the remainder reported in the <USD 260 kg/U category.

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 Ida. As of 1 January 2017, prognosticated resources amounted to 57 000 tU and speculative resources totalled 110 700 tU (unchanged from 1 January 2015).

Uranium production

Historical review

Rössing Uranium Limited was formed in 1970 to develop the Rössing deposit. RTZ was the leading shareholder with 51.3% of the equity at the time of the formation of the company (69% in 2013). Mine development commenced in 1974 and commissioning of the processing plant and initial production took place in July 1976. In 1977, a full design capacity of 5 000 short tons of U_3O_8/year (3 845 tU/year) was established, but because of the highly abrasive nature of the ore, an aspect not identified during the pilot plant testing stage, the production target was not reached until 1979 following plant design changes. From the date of first production in July 1976 to end 2016, the Rössing mine produced a cumulative total of over 110 000 tU.

Full-scale development of the Langer Heinrich mine proceeded after licensing and commissioning began in late 2006. A bankable feasibility study had confirmed that a large body of uranium mineralisation could be mined by open pit with a minimum mine life of 11 years and a process plant life of 15 years. The study showed 1 000 tU/yr could be produced for the first 11 years at a head feed grade of 0.074% U and that an additional 340 tU could be produced over an additional 4 years using the accumulated low-grade (0.027% U) stockpile. Commercial production began at Langer Heinrich in 2007 and as outlined above, the Langer Heinrich project has been expanded three times in recent years to achieve a production capacity of just over 2 000 tU/yr.

Status of production facilities, production capability, recent and ongoing activities and other issues

Total uranium production in Namibia declined from 3 246 tU in 2014 to about 2 992 tU in 2015, but increased to 3 593 tU in 2016.

Rössing Uranium Ltd

Production at Rössing Uranium fluctuated in recent years (1 309 tU in 2014, 1 055 tU in 2015 and 1 569 tU in 2016) as a result of planned maintenance shutdowns, but also because of low ore grades and challenges with recovery. As the cut-back in the open pit has progressed substantially, the ore grades are starting to improve. Various efforts are also ongoing to improve the recovery rates.

Since 2010, the main exploration focus has been on the southernmost Z20 deposit that extends across the lease boundary into the adjacent lease held by Swakop Uranium Limited. A total of 24 000 m of drilling was completed on Z20 to declare an inferred resource by the end of 2012. The third phase of drilling on the Z20 ore body was completed during 2013. Data from the drilling indicated a significant uranium resource in Z20. In 2013, in situ resources for the Z20 orebody amounted to 46 983 tU at higher grades (0.027% U) than the main orebody. The objective in 2014 was to establish the development pathway for the economical extraction of ore from the Z20 deposit. This included establishing a new pit and overland conveyor for transporting ore for processing through a modified plant at the mine. Although this major investment was discussed with potential funding partners, because of the poor uranium price, it did not come to fruition.

In 2014, Rössing Uranium initiated a study to develop a desalination plant that would supply fresh water to the mine, considering the current constraints on the supply of aquifer water, as well as the high costs associated with alternative desalination supplies. Consulting teams were appointed to conduct detailed engineering, costing and environmental impact assessments of such a plant. The last quarter of 2014 saw the environmental impact assessment process completed. The envisaged location will be approximately 6 km north of Swakopmund, at the existing Swakopmund Salt Works. In June 2016, the environmental clearance certificate was received from the Environmental Commissioner's office of the Ministry of Environment and Tourism. To meet prerequisites for receipt of the certificate, Rössing Uranium applied for the water permits required by the Directorate Water Resources Management of the Ministry of Agriculture, Water and Forestry in September 2016. No reply from the directorate had been received by the end of 2016. The current cost of water is high and the mine remains open to implementing alternative measures to reduce the cost of desalinated water.

Output from the Rössing Uranium mine increased from 1 055 tonnes in 2015 to 1 569 tU tonnes in 2016. Grades recovery was in line with the new production plan, while milling output was below target due to challenges in throughput and equipment reliability. The Rössing Uranium mine at current mine plans foresee a cessation of production at the end of 2025.

Langer Heinrich

At Langer Heinrich, the initial planned production level of 1 040 tU/yr was achieved in 2008-2009. 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. A Stage 4 expansion feasibility study and environmental impact assessment were submitted to government, but subsequently the project was put on hold because of low uranium prices. The Stage 4 expansion plan is aimed at achieving a production level of 3 850 tU/yr.

After an increase of the production in 2014, production performance was affected by lower grades and recoveries (1 938 tU in 2014, 1 937 tU in 2015 and 1 832 tU in 2016). In April 2014, new plant investment was put on hold, for at least two years.

In January 2014, China National Nuclear Corporation's subsidiary CNNC Overseas Uranium Holding Limited bought a 25% joint venture equity stake in the Langer Heinrich mine for USD 190 million, entitling it to that share of output.

Trekkopje

In October 2007, Areva commenced phase 1 trial mining (250 000 t of ore) and processing operations at Klein Trekkopje. The phase 2 pilot test commenced in October 2009 and resulted in an additional 3 Mt of ore being mined and stacked on a heap leach pad. The trials involved the extraction of uranium using a sodium carbonate/bicarbonate heap leach process and represent the first commercial-scale application of alkaline heap leach technology in the world.

Also in 2009, a geotechnical site investigation and the engineering design were completed for a new 30 million tonne, on-off uranium heap leach pad covering 2.5 km^2. Construction of the main production pad began in 2010. A final production level of 3 000 t U_3O_8/yr (2 545 tU) was envisaged. However, in 2012, as a direct consequence of the low uranium price, a decision was taken by Orano to place the project on care and maintenance in mid-2013 following completion of the phase 2 pilot tests on extraction.

Production in 2012 and 2013 was limited to 251 tU and 186 tU, respectively, demonstrating the feasibility of the technical solutions adopted and confirming the production cost targets.

Since 2010, the operation has been supplied with water from a coastal desalination plant set up by Orano with about 55 000 m^3/day (20 million m^3/year) output. Water from the desalination plant now also supplies all other mines

Husab

Swakop Uranium has developed and constructed a world-class uranium mine, called the Husab mine, in the Erongo region in western-central Namibia. The Husab orebody is located 5 km south of the Rössing mine and 45 km north-east of Walvis Bay port. The project received environmental clearance from the Namibian Ministry of Environment and Tourism in January 2011. By the end of 2011, it had obtained a mining licence from the Ministry of Mines and Energy.

Based on the positive results of a definitive feasibility study, Husab was developed as a conventional, large-scale open-pit mine, feeding ore to a conventional agitated acid leach process plant. The process is estimated to recover approximately 88% of the uranium. With the Husab Project seen as one of the most important uranium discoveries of recent years, Swakop Uranium has developed and constructed what could potentially be the third largest uranium mine in the world with the potential to produce 15 million pounds uranium oxide per annum (5 700 tU). This is more than the current total uranium production of Namibia and will potentially elevate Namibia past Niger, Australia and Canada to the second place among the world's leaders of uranium producers. The forecast ore grade at Husab Zones 1 and 2 is 0.0518% U. The feasibility study showed a production cost of USD 32/lb U_3O_8 including royalties, marketing and transport, with a capital cost of USD 1.66 billion. The study envisages mining of 15 million tonnes of ore per year from two separate open pits to feed a processing plant producing 5 700 tU per year. Water supply and labour agreements were signed in April 2014. Construction began in February 2013 and first uranium production occurred at the end of 2016, with a 24-month ramp up to full production capacity of 5 700 tU/yr planned for completion by the end of 2018. The project created more than 6 000 temporary jobs during construction and about 2 000 permanent operational job opportunities.

Until April 2012, Swakop Uranium was a 100% subsidiary of Extract Resources, an Australian company listed on the Australian, Canadian and Namibian stock exchanges. During April 2012, Taurus Minerals Limited of Hong Kong became the new owners following a successful takeover of Extract Resources. Extract Resources has subsequently been delisted. Taurus is an entity owned by CGNPC Uranium Resources Co., Ltd and the China-Africa Development Fund. In November 2012, the Namibian state-owned mining company, Epangelo, and Swakop Uranium finalised an agreement for the subscription of a 10% stake in Swakop Uranium.

Future production centres

Etango

Bannerman Resources have received environmental approvals to proceed with development of the Etango mine. A scoping study for the mine's development was completed in September 2007, followed by a preliminary feasibility study (PFS). Results of the PFS were announced in December 2009. A DFS was completed by Amec in April 2012. The DFS confirmed the viability of the project with a long-term uranium price of about USD 61/lb U_3O_8 (USD 159/kgU) with pre-production capital costs estimated to amount to USD 870 million. In 2015 Bannerman concluded a DFS Optimisation Study together with the consulting group Amec Foster Wheeler, which resulted in the project having a break-even cost of USD 52/lb U_3O_8 (135/kgU). The pre-production capital cost estimate was reduced to USD 793 million. As currently planned, the Etango project has a projected life of 16 years at a production rate of 2 770 tU/yr. The Etango mine will be developed as a conventional open-pit mine. Tests conducted on the ore samples recovered from the mine revealed that the ore is free from clay and acid consuming carbonates. In addition, the majority of the mineralisation is available at coarse crush size. These results led to the conclusion that heap leaching is the most suitable method for optimal recovery.

Production at 3 500 tU/yr is now envisaged over the first five years, then decreasing to 2 500 tU/yr for the remaining mine life. In September 2014, the company awarded contracts to construct and operate a heap leach demonstration plant, which was commissioned in March 2015.

During 2015 and 2016 Bannerman Resources focused on metallurgical test work at its heap leach demonstration plant. A six-phase metallurgical test work programme was executed during this time. The six-phase Heap Leach Demonstration Plant Program demonstrated the strong potential to achieve and exceed the DFS metallurgical parameters. The key objectives achieved were:

- valuable process knowledge generated over the two-year programme duration;
- Etango Uranium Project DFS assumptions confirmed as robust; de-risking of key processing aspects;
- test work demonstrated exceptional leaching dynamics (93% extraction in 22 days) and lower acid consumption (14.4 kg/tonne), confirming Etango's low technical risk;
- no observed impurities and potential for further reagent optimisation;
- phase 6 defined optimal particle size, enabling completion of the test programme.

Bannerman Resources also did a DFS Optimisation Study with particular focus on the mining aspect of the envisaged Etango Uranium Project and completed this work at the end of 2015 with the key results being:

- project net present value (NPV 8%) of USD 419 M (previously USD 69 M);
- post-tax internal rate of return ("IRR") of 15% (previously 9%);
- average annual production of 7.2 Mlbs U_3O_8 over an initial 15.7 year open-pit mine life:
  - 9.2 Mlbs U_3O_8 per annum over the first five full production years (previously 7.9 Mlbs).
- average life-of-mine cash operating costs of USD 38/lb U_3O_8 (reduced 17%):
  - USD 33/lb U_3O_8 over the first five full production years (reduced 20%).
- pre-production capital of USD 793 million including mining fleet (reduced 9%);
- rapid payback from first production (4.4 years) and initial mine life to payback ratio of 3.6 times;
- total operating cash flow of USD 3.7 billion before capital and tax, and free cash flow of USD 1.6 billion after capital and tax. From production commencement, average annual operating cash flow of USD 236 million and free cash flow of USD 150 million. Peak annual free cash flow of USD 392 million;
- potential upside from heap leach demonstration plant results and other identified opportunities still to be incorporated via additional optimisation work.

Bannerman continued its demonstration plant test work and following the excellent results obtained from the Ion-exchange and Nano-filtration, a processing Optimisation Study was concluded, which resulted in the flow sheet changing from a heap leach/ solvent extraction process to a heap leach/ion-exchange/Nano-filtration processes. This further reduced the pre-production capital cost estimate to USD 720 million.

Norasa Project

The Norasa Project is a proposed development involving both deposits, Valencia and Namibplaas. A March 2015 feasibility study estimates annual production of about 2 000 tU over a 15-year mine life. Costs are estimated at USD 32.96 per lb U_3O_8 over the first five years of production, and USD 34.72 per lb U_3O_8 over the mine life. Test work has improved uranium recovery from 85% to 91% by using hydrogen peroxide rather than pyrolusite (MnO_2) as the leach oxidant. 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). Uranium production is planned to start once the uranium price has recovered. Indicated resources are 44 230 tU and inferred resources are 4 230 tU at a cut-off grade of 119 ppm U (140 ppm U_3O_8).

Uranium production centre technical details

(as of 1 January 2017)

	Centre #1	Centre #2	Centre #3	Centre #4	Centre #5	Centre #6
Name of production centre	Rössing	Langer Heinrich	Husab	Trekkopje	Norasa	Etango
Production centre classification	Existing	Existing	Existing	Care and maintenance	Prospective	Prospective
Date of first production (year)	1976	2006	2016	2013	N/A	N/A
Source of ore:						
Deposit name(s)	SJ, SK, SH	Langer Heinrich	Zones 1 and 2	Trekkopje, Klein Trekkopje	Valencia and Namibplaas	Etango
Deposit type(s)	Intrusive	Calcrete	Intrusive	Calcrete	Intrusive	Intrusive
Recoverable resources (tU)	77 956	37 623	187 546	18 720	37 417	68 043
Grade (% U)	0.025	0.045	0.033	0.012	0.017	0.016
Mining operation:						
Type (OP/UG/ISL)	OP	OP	OP	OP	OP	OP
Size (tonnes ore/day)	40 000	20 000	42 000	30 800	33 000	55 000
Average mining recovery (%)	85	90	88	90	77	90
Processing plant:						
Acid/alkaline	Acid	Alkaline	Acid	Alkaline	Acid	Acid
Type (IX/SX)	IX/SX	IX	IX/SX	HL/IX	IX/SX	HL/IX/NF
Size (tonnes ore/day)	40 000	15 000	40 000	100 000	30 000	55 000
Average process recovery (%)	85	85	88	80	89	87
Nominal production capacity (tU/year)	4 000	2 030	5 700	3 000	2 000	2 770
Plans for expansion (yes/no)	No	No	Yes	No	No	No
Other remarks						

Employment in the uranium industry

At Rössing employment increased from 850 employees in 2014 to 949 employees at the end of 2016. The average number of contractors at the mine for the reporting period was 773.

At Langer Heinrich, the number of employees decreased from 318 in 2014 to 309 in 2016.

After the construction of Husab was completed in 2016 the 4 000 construction workers left the mine and by the end of 2016 a total of 1 488 permanent employees were working at the mine.

At Trekkopje, 20 people are employed for care and maintenance operations.

Environmental activities and socio-cultural issues

Namibia's "Vision 2030", is a document that clearly spells out the country's development programmes and strategies to achieve its national objectives. Vision 2030 focuses on eight themes to realise the country's long-term vision. Namibia's National Development Plans (NDPs).

Uranium mine and exploration companies actively support the government initiatives.

The Namibian Uranium Association

The Namibian Uranium Association (NUA) is the advocacy body that represents the uranium industry exclusively. The association enables senior executives in the Namibian uranium sector to shape the context in which their industry operates. It supports policies that will let uranium compete on its merits as an energy source appropriate for our modern society and the need for a low-carbon footprint through research, factual information and advocacy. Members of NUA include 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, the general public and anybody interested in the position and policies of the Namibian uranium industry. NUA promotes industry's adherence to strong sustainable development performance, product stewardship and compliance with 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 has 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 uranium 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 work together to improve safety and health performance through the identification of world-class leading best practices and their implementation. As such, NUI is working closely with the Namibian government and state agencies, and also has close ties with the Namibian University of Science and Technology.

Environmental Management Act, Act No. 7 of 2007

Namibia committed itself to sound environmental management and this is reflected in the Environmental Management Act, Act No. 7 of 2007 and Regulations, gazetted on 6 February 2012. The object of the act is prevention and mitigation, on the basis of the principles of environmental management that:

- ensure that the significant effects of activities on the environment are considered in time and carefully;
- 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 taken into account before any decision is made with respect to the activities.

The Strategic Environmental Assessment and the Strategic Environmental Management Act

The Erongo Region is characterised by its aridity, vast desert landscapes, scenic beauty, high biodiversity and endemism and heritage resources. It has the second-largest economy of the Namibian regions, and mining plays an important part in this economy. Walvis Bay and Swakopmund are among Namibia's five largest towns, but at the same time, large parts of the Erongo Region, especially along the coast, are under active conservation in the form of national parks.

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 the associated developments are vital for the growth of the Namibian economy, and the country must therefore reconcile development objectives and mineral exploitation with environmental protection for its long-term socio-economic growth and stability. Clearly, 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 by industry at an early stage when the high uranium prices of 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), and such an assessment was subsequently carried out by the Geological Survey of Namibia, Ministry of Mines and Energy. The Uranium-SEA, as it has become known, dealt with a variety of aspects, such as water, energy, air quality, radiation, health, transport, tourism, biodiversity, heritage, economics, education and governance. It was independently assessed by the International Institute for Environment and Development, and received the highest recommendations. As a result of the SEA, a Strategic Environmental Management Plan (SEMP) was drawn up, and is implemented by the Ministry of Mines and Energy. The Namibian uranium industry has at all times 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, skills development and infrastructure development. A number of constraints to development were also identified, such as possible water shortages, lack of skills, capacity of physical infrastructure and environmental protection. The SEA noted that a uranium rush could have a number of negative impacts in the areas of 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 (socio-economic development, employment, infrastructure, water, air quality and radiation, health, effect on tourism, ecological integrity, education, governance, heritage and future, closure and land use) that are to be continuously monitored as a collective proxy for measuring the extent to which uranium mine development activities are moving the Erongo Region towards a desired future state. An SEMP office has been established to administer the programme.

One of the key aspects of the SEMP is water supply. Since 2010, water has been supplied to Trekkopje from a coastal desalination plant built by Areva in the Erongo region. This plant can supply 20 million m^3/year, requiring 16 MWe from the grid. Desalinated water is also supplied via the Namibian Water Corporation to Rössing, Langer Heinrich and Husab. The desalination plant is owned by Orano (formerly Areva Namibia Pty Ltd.). The SEMP report notes that uranium mining, mine development and exploration have not compromised community access to water supplies of acceptable quality.

Rössing Uranium had an environmental impact assessment done on a second proposed desalination plant close to Swakopmund. An environmental clearance certificate was received from the Environmental Commissioner's office of the Ministry of Environment and Tourism. To meet prerequisites for receipt of the certificate, Rössing Uranium applied for the water permits required by the Directorate Water Resources Management of the Ministry of Agriculture, Water and Forestry in September 2016.

Individual monitoring

The uranium mining operations in co-operation with the Environmental Affairs Department of the Ministry of Environment and Tourism continued to actively monitor environmental issues of concern in the sector and learnt from best practices and shared experiences by encouraging the industry to undertake participatory environmental planning and management to promote effective waste management in an environmentally sound manner. In addition to the SEMP, the members of the Namibian Uranium Association carry out their own environmental monitoring and programmes to assure that their footprint is as small as possible. Stringent water-saving measures, air quality monitoring, biodiversity monitoring, mitigation measures for adverse impacts and environmental training of staff are only a few examples.

Rössing focused continuously on improving environmental management programmes to maximise benefits and to minimise negative impacts. Key environmental management programmes included energy efficiency and greenhouse gas emissions, air quality control (including emissions of dust, other impurities and noise and vibration), water usage, waste management (both mineral and non-mineral waste), chemical substance management, land use management (including biodiversity, rehabilitation and closure).

The mineral waste generated at Rössing Uranium during 2016 amounted to a total of million tonnes including 9.2 million tonnes of tailings and 16.5 million tonnes of waste rock. Tailings were deposited on the existing tailings storage facility, mainly in the re-activated deposition areas that had been prepared during 2015. The tailings footprint extended by 4.65 ha or 0.6% into a partly disturbed area to the immediate north of the facility.

Waste rock generated was deposited on the 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 40 years now consists of 1.36 billion tonnes covering a total footprint of 1 377 ha.

Since 1980, Rössing has been recycling 60 to 70% of its water, which is indicative of an effective water management strategy. All spillages in the processing plant are captured and channelled to a large recycle sump for reuse. Effluents from the workshops are treated to remove oils, and sewage is treated in the on-site sewage plant. These purified effluents are used in the open pit for dust control purposes. The Rössing operating plan of 2016 set a target for desalinated freshwater usage of 2.9 million cubic metres (m^3) supplied by NamWater. The actual consumption of fresh water was 2.1 million m^3 in 2016.

Rössing Uranium resumed its abstraction of saline groundwater from the Khan aquifer following the encouraging rainy season of 2011. The groundwater is sprayed on the haul roads in the open pit to suppress dust. Such abstraction continued under the permit issued by the Directorate Water Resources Management. The mine will apply for an extension of the permit early in 2017.

Biannual environmental reports and annual reports on project-specific issues, such as water, are submitted to government by Paladin Energy, owner and operator of the Langer Heinrich production facility. An environmental database was established to better evaluate and assess accumulating monitoring data (including a comprehensive surface and groundwater monitoring) in order to detect any potential issues that may arise as early as possible. The reuse and recycling of water is maximised as much as possible using water returned from the tailings storage facility and recovery boreholes and trenches, as well as treated effluent from the sewage treatment plant.

Swakop Uranium's environmental activities included expanding the bio-physical monitoring network to detect early pollution for air quality and groundwater aspects along with additions to the biodiversity monitoring network. Since Swakop Uranium operates within the Namib Naukluft National Park, it is responsible for minimising impacts on this fragile ecosystem and along infrastructure routes to site. Water requirements have been met with the supply of desalinated water through an agreement between Swakop Uranium, NamWater and Orano.

Projects have been initiated to address some of the research needs of Swakop Uranium's Environmental Management Plan. Groundwater monitoring in both the Khan and Swakop rivers has been undertaken to collect baseline water-level and water quality data. Groundwater monitoring wells are established around the locations of the open pits, waste rock dump and the tailings storage facility to measure the effect that pit groundwater drawdown has on the area. Water quality in drawdown wells is used as additional baseline data and monitoring throughout the life of the mine will provide an early warning system of potential impacts. As early as 2009, Swakop Uranium began assessing the amount of particulate matter (dust in the air) to contribute to baseline environmental data collection. A dust suppressant is used at Husab on the pit and dump haul roads and other gravel roads. This reduces the dust produced to acceptable levels, as well as saving up to 90% of the water that would be required to achieve the same level of control if no suppressant is used.

Site rehabilitation

All Namibian uranium operators subscribe to the Mine Closure Framework of the Chamber of Mines of Namibia. The purpose of this Mine Closure Framework is to provide guidance for the Namibian mining industry in how to develop relevant, practical and cost-effective closure plans and to lay down minimum requirements for the members of the Chamber of Mines of Namibia bound by the Chamber's Code of Conduct and Ethics.

The framework addresses the need to:

- conform to current legislative requirements;
- consult with a variety of stakeholders to derive a widely acceptable social, economic and environmental closure outcome;
- develop an optimal closure strategy based on envisaged and agreed final post-mining social and environmental conditions;
- develop a plan of practical closure actions, incorporating the optimal strategy;
- provide all the necessary financial, knowledge and skills resources at implementation of the closure plan;
- have a formal relinquishment process in place releasing the mining company from future obligations when closure outcomes have been accepted and achieved.

The establishment of the Rössing Environmental Rehabilitation Fund, which provides for the mine's closure expenditure, complies with statutory obligations and stipulated requirements of both the Ministry of Mines and Energy and the Ministry of Environment and Tourism. Accordingly, the Fund Agreement states that each year the mining company will pay a contribution to the fund to provide for the eventual closure of the mine.

At the end of December 2016, the fund had a cash balance of NAD 600 million. In 2016 the total cost of closure excluding retrenchment costs was estimated at NAD 1.5 billion. The mine will make additional payments to the fund each year to provide for the eventual total cost of closure by 2025.

Corporate social responsibility

Members of the NUA have undertaken corporate social responsibility projects for more than three decades. Members also fully support the Harambee Prosperity Plan (HPP) initiative, and work with government in this important venture to eliminate the inequalities sadly still prevailing in Namibian society.

The Namibian uranium industry currently has a total of 28 Corporate Social Responsibility projects. Out of these, 18 support the HPP pillar of Social Progression, and a majority of 13 projects concentrate on education and training. Four projects address hunger and poverty, while sanitation is also dealt with by one.

Nine projects contribute to the HPP pillar of Economic Advancement, of which seven deal with economic transformation through Small and medium-sized enterprise development and micro loan schemes, and one with youth enterprise development. One company addresses economic competitiveness by developing a process supporting employment and revenue generation through upgrading Namibian uranium deposits. A project under the HPP pillar of infrastructure development has contributed to the supply of water to communities. Projects of NUA's affiliated members from the service providing sector add to the ones listed.

The Erongo Development Foundation is an important partner for NUA in realising the effective selection of projects. Active participation NUA on the board of the Erongo Development Foundation ensures that industry is keeping abreast with issues and needs of the communities in order to support them as best as possible.

Rössing Uranium's community and social investments are channelled directly through the Rössing Foundation towards these programmes, but the mine also supported various community-investment initiatives directly. Rössing particularly promotes healthy, safe and environmentally-responsible lifestyles among neighbouring communities, and makes direct contributions to initiatives targeting biodiversity protection, conservation, health and safety (including HIV/Aids) and waste management.

Despite facing various production and market challenges during 2016, Rössing remained steadfast in honouring corporate social responsibilities. This goal was accomplished through continued and generous investment supporting sustainability of neighbouring communities. The community and social investment focus is aligned with the requirements of Namibia's Mining Charter. The charter, overseen by the Chamber of Mines of Namibia, is aimed at positively and proactively addressing sustainable and broad-based economic and social transformation in the Namibian mining sector and is grounded in key government policies such as Vision 2030, the National Development Plan 4 (NDP4) and the Harambee Prosperity Plan.

Throughout 2016, Rössing ensured accountability by tracking compliance against the charter's targets. This is over and above the direct and indirect economic benefits the company created through local employment and the procurement of goods and services from local businesses.

A three-year safety awareness initiative, designated as the Project Safety W.I.S.E., which Rössing implemented in partnership with Areva Resources Namibia and the Directorate of Education, Arts and Culture of the Erongo Regional Council in 2015, continued throughout 2016. This initiative supports the creation of a culture of safety among primary education learners in Arandis, Swakopmund and Walvis Bay. The initiative is built on the belief that if learners are exposed to safety awareness in small but progressively increasing amounts throughout their education, safety consciousness will become an integral part of their lives.

The Langer Heinrich mine implemented a Social Performance Management Plan, which is consistent with the ISO 14001 and 26000 and follows the ISO 26000 systems plan.

Swakop Uranium, also a contributing member of the Namibian Uranium Association, has committed itself to social aspects such as local procurement, recruitment and employment, involvement in social responsibility programmes, training, education and sound environmental management practices. The Swakop Uranium Foundation was established to support the Erongo region and Namibia.

Orano has engaged with stakeholders at local, regional and national level in the areas of economic development, education, culture and sport, and fully supports the Harambee Prosperity Plan.

Another example is Bannerman Resources who even at an early stage of development focuses on education and tourism as part of their social programme. The company is an active member of the Erongo Development Foundation and its managing the foundation's artisan development programme. Bannerman has to date also supported over 2 000 disadvantaged primary school children within the Erongo Region and recently expanded this programme to other regions within Namibia. Bannerman's work within the tourism industry focuses primarily on skills development for conservancy members working at lodges throughout Namibia.

Depressed uranium prices currently present a major challenge to the uranium exploration and mining companies, and the contributions therefore speak for themselves when it comes to the unwavering commitment of the industry to the improvement of living standards for all Namibians, even in economically challenging times.

Atomic Energy and Radiation Protection Act, Act No 5 of 2005

The Atomic Energy and Radiation Protection Act, 2005 (Act No.5 of 2005) was gazetted on 16 January 2012. It is administered by the National Radiation Protection Authority and provides for the regulation of all activities associated with radiation sources, radioactive or nuclear material.

The primary purpose of the act is 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;
- guarantee that Namibia meets its obligations within the context of international legal instruments in the sector of radiation or nuclear technologies.

Regulatory regime

Namibia has been mining uranium for more than 40 years and is covered by a range of comprehensive legislation that governs uranium exploration and mining. First and foremost, the Namibian Constitution provides for the protection of the environment and the welfare of humankind.

Furthermore, the Minerals (Prospecting and Mining) Act 1992 (No. 33) requires every licence holder to conduct environmental impact assessments before the start of exploration. The Minerals (Prospecting and Mining) Act 33 of 1992 is the principle legislation for the granting mining exploration and mining licences. Section 102 of the Act prohibits the processing, import, export or possession of source material without the Minister's approval.

Namibia's Environmental Management Act of 2007 (Act No. 7 of 2007) came into effect in 2012 and underlines the importance of consultation with interested and affected parties. The act promotes the sustainable management of the environment and the use of natural resources by establishing principles for decision-making on matters affecting the environment and provides environmental impact assessment regulations.

Uranium mining is regulated under both, the Minerals (Prospecting and Mining) Act No. 33 of 1992 and Environmental Management Act of No. 7 of 2007.

Government had imposed a moratorium on applications for exclusive prospecting licences (EPLs) for nuclear fuel minerals in 2007, which was terminated on 15 December 2016, providing an opportunity for further exploration within the country.

Namibia is party to the Nuclear Non-Proliferation Treaty and has a comprehensive safeguards agreement in force since 1998, and in 2000 signed and ratified the Additional Protocol. During 2016 a national legislative review mission was undertaken by the International Atomic Energy Agency to provide advice on the revision of the Atomic Energy and Radiation Protection Act and discussed steps to enhance the national legal framework and to boost adherence to the relevant international legal instruments.

Epangelo Mining Company was established in July 2008 to participate in the mining sector as per the provisions of the Minerals (Prospecting and Mining) Act, and acquire mining rights and equity by concluding joint ventures with existing companies. The Namibian government is the sole shareholder. Namibia has identified uranium as a strategic mineral and potential source of energy production within the nuclear fuel cycle. The government has expressed its desire to increase beneficiation to enhance economic development and is considering nuclear power to augment its energy needs.

Uranium requirements

At present, Namibia has no nuclear power generating facilities. More than half of Namibia's electricity supply of some 4 400 GWh per year is supplied from neighbouring states South Africa, Zimbabwe and Zambia.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

The government has designated its uranium resources as strategic and controlled minerals that must be treated differently from other minerals, among other reasons, because of the risk of proliferation, its characteristic as material for production of nuclear weapons, its use as fuel for energy production and its associated radiological risks.

In consideration of the special nature of uranium ore and its products, and the radiological and fissile properties of uranium, the government is prompted to develop a responsive regulatory framework, which will address health, safety, research and development applicable to the nuclear fuel cycle. In addition, Namibia is considering the development of commercial nuclear power to promote energy security and meet its increasing energy needs while reducing greenhouse gas emissions in accordance with international climate change obligations. The country has therefore developed a Nuclear Fuel Cycle Policy.

Uranium exploration and development expenditures and drilling effort – domestic

(NAD – Namibian dollars)

	2012	2013	2014	2015	2016	2017 (expected)
Industry* exploration expenditures	458 690 351	123 062 784	51 542 657	40 400 000	40 399 837	43 280 649
Industry* development expenditures	185 714 370	66 318 296	11 060 556 911	81 138 309	84 465 924	21 607 602
Total expenditures	644 404 721	189 381 080	11 112 099 568	121 538 309	124 865 761	64 888 251
Industry* exploration drilling (m)	169 499	18 023	5 428	9 845	8 390	21 926
Industry* exploration holes drilled	1 187	320	186	377	40	553
Industry* development drilling (m)	205 493	282 701	241 098	378 497	47 777	17 362
Industry* development holes drilled	4 334			380	108	202
Subtotal exploration drilling (m)	169 499	18 023	5 428	9 845	8 390	21 926
Subtotal exploration holes drilled	1 187	320	186	377	40	553
Subtotal development drilling (m)	205 493	282 701	241 098	378 497	47 777	17 362
Subtotal development holes drilled	4 334			380	108	202
Total drilling (m)	374 992	300 724	246 526	388 342	56 167	39 288
Total number of holes drilled	5 521			757	148	755

* Non-governmental expenditure.

Reasonably assured conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Intrusive			252 057	285 227
Surficial			83 262	83 262
Total			335 319	368 489

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 (%)
Open-pit mining (OP)			335 319	368 489	80
Total			335 319	368 489	80

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 OP			291 994	325 164	80
Heap leaching* from OP			41 005	41 005	80
Unspecified			2 320	2 320	80
Total			335 319	368 489	80

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

Inferred conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Intrusive			88 741	129 405
Surficial			18 012	43 452
Total			106 753	172 857

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)			106 753	172 857	80
Total			106 753	172 857	80

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			99 073	124 057	80
Heap leaching* from OP			0	36 840	80
Unspecified			7 680	12 320	80
Total			106 753	172 857	

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

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD80/kgU	<USD 130/kgU	<USD 260/kgU
0	0	57 000

Speculative conventional resources

(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	0	110 7000

Historical uranium production by deposit type

(tonnes U in concentrate)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (preliminary)
Intrusive	108 117	1 308	1 055	1 761	112 241	2 639
Surficial	9 055	1 938	1 937	1 832	14 762	1 308
Total	117 172	3 246	2 992	3 593	127 003	3 947

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (preliminary)
Open-pit mining[1]	117 172	3 246	2 992	3 593	127 003	3 947
Total	117 172	3 246	2 992	3 593	127 003	3 947

1. 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 2013	2014	2015	2016	Total through end of 2016	2017 (preliminary)
Conventional	116 735	3 246	2 992	3 593	126 566	3 947
Heap leaching	437	0	0	0	437	0
Total	117 173				127 003	3 947

Ownership of uranium production in 2016

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
43	1.20	0	0	362	10.07	3 188	88.73	3 593	100

Uranium industry employment at existing production centres

(Person-years)

	2014	2015	2016	2017 (preliminary)
Employment directly related to uranium production	5 101	8 107	4 331	4 881

Short-term production capability

(tonnes U/year)

2017				2020			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	0	4 000	4 000	0	0	5 500	5 500

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
0	0	7 200	7 200	0	0	7 200	7 200	0	0	7 200	9 800

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 per year, for a total of 5 900 tU over this 17-year period. The uranium recovery rate achieved was low at 50% or less and from 1988 to 2009 more than 10 Mt of low-grade ore (0.08% U average grade) has 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 Somaïr mine. In 2017, due to tough condition of the uranium market, Somaïr entered into a plan of production reduction (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 (Orano) was awarded a mining licence and a joint venture agreement was signed to develop Imouraren, but it was shelved 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.

* Report prepared by the NEA/IAEA, based on company reports and government data.

All uranium deposits in Niger are located within the Tim Mersoï Basin, a sub-basin of the Illemmenden Basin. Tim Mersoï Basin is in close proximity 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) on 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.

Recent and ongoing uranium exploration and mine development activities

Uranium exploration in Niger was revitalised in 2007. A total of 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 have been 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 (currently Orano) agreed to increase royalty payments to the government by 50%; the development of the Imouraren deposit about 80 km south of Arlit and 160 km north of Agadez was confirmed in January 2008. In January 2009, Areva (Orano) 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%.

The Imouraren project is a EUR 1.9 billion investment, and Orano has agreed to spend EUR 6 million per year on health, education, training, transport and access to water and energy for local people. Production is expected to be 5 000 tU/yr for 35 years. The deposit covers 8 km by 2.5 km and Orano reports 213 722 tonnes of uranium reserves at 0.072% U, plus 62 584 tU indicated 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, with current uranium prices not sufficient to allow profitable mining of the deposit, the government and Areva agreed to set up a joint strategic committee that will determine when mining should start.

GoviEx Uranium in 2008 held exploration properties of 2 300 km^2 near the Arlit mine, including the Madaouela deposit, as well as 2 000 km^2 near Agadez. Trendfield (25%) and UK-based GoviEx Uranium Inc formed the GoviEx Niger JV in 2007 to explore the Madaouela and Anou Melle deposits, but Trendfield then exchanged this equity for a 10% share of GoviEx. GoviEx was founded by one of its major shareholder Govind Friedland. In August 2008, Cameco bought an 11% share in the company for USD 28 million, with option to increase to 48%. The Niger government holds 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, after the permission to start field works in the vicinity of the Madaouela Army Base was obtained. The GoviEx work programme was based on three objectives: i) Resource definition drilling of 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 14 January 2010 for Marianne-Marilyn and 15 February 2010 for Madaouela South, a project wide total of 584 000 m have been drilled by GoviEx, including outlying exploration holes and water well testing holes. In January 2016, GoviEx obtained two new exploration licences, Eralral and Agaliouk in close proximity to the five other licences Madaouela (I, II, III IV) and Anou Melle.

GoviEx has developed an NI 43-101 Integrated Development Plan for five deposits (Marianne, Marilyn, Miriam, MSNE and Maryvonne). The Integrated Development Plan is based on detailed pre-feasibility geological studies, metallurgical testing and processing options, mine design, infrastructure, rock mechanics, tailings and heap leach, hydrogeological and environmental impact. In November 2017, NI 43-101 compliant resources of the Madaouela Uranium Project were 42 615 tU measured and indicated resources and 10 654 tU inferred resources. An open-pit mine on at least part of the deposit, 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 is expected to begin by 2022. The environmental and social impact assessment for the project was filed with the Nigerien government in March 2015, and the company obtained a mining licence in January 2016.

Global Atomic Fuels Corp., a private Canadian company, had 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. The Dasa deposit occurs at the intersection between the Adrar Emoles flexure and the east-northeast trending Azouza Fault. The Azouza Fault comprises several steep east-northeast faults characterised by significant vertical displacement and forming a regional graben structure. The Dasa deposit can be described as a roll-front style deposit that formed in a meandering stream depositional environment with basal sands and basal conglomerates with secondary remobilisation possibly being due to a later methane event, a hydrothermal event or a groundwater event.

From 2010 to 2014, Global Atomics Fuels Corp had drilled 969 holes (867 rotary drill holes and 102 diamond drill holes), for a total of > 120 000 m in carboniferous sediments. In January 2014, SRK Exploration Services released an initial resource estimation, which totalled 43 850 tU grading 540 ppm U, using an 85 ppm U cut-off. The Dasa inferred resource occurs within a 500 m wide corridor along a 1.2 km long trend. In June 2014, Global Atomic announced an internal update. Resource estimates range from 64 600 tU at 490 ppm U (85 ppm U cut-off), to 29 600 tU grading 0.29% U (0.127% U cut-off). The base case appears to be the 36 500 tU grading at 0.222% U (0.085% U cut-off).

In 2017, Global Atomic Fuels Corp changed its name to Global Atomic Corporation (GAC) and released a new NI 43-101 compliant report by CSA Global Pty. Ltd listing the indicated resources as 60 million pounds of U_3O_8 with an average grade of 4 552 ppm U_3O_8 using a cut-off of 1 200 ppm U_3O_8. The inferred resources were given as 48.1 million pounds at 2 651 ppm U_3O_8 again using the 1 200 ppm U_3O_8 cut-off. GAC also signed a Memorandum of Understanding with Orano (ex Areva) on ore sales and joint co-operation. A 37 000 metre drilling programme to further extend the resources started in late January 2018 on Dasa.

In addition to Dasa, two other deposits are located on the Adrar Emoles permits, Dajy and Isakanan. The Dajy deposit is located along the same major NE-SW trending Azouza Fault, which hosts the Azelik and Dasa deposits, 30 km SE of Imouraren. Whereas Dasa can be traced to 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 Tarat sandstone, the Guezouman sandstone and the Madouela sandstone. The Dajy deposit hosts 6 400 tU grading 584 ppm U (inferred resources). The Isakanan deposit is located 15 km south of the Dasa and Dajy deposits. It hosts 13 000 tU grading 760 ppm U. The Tin Negouran Permits 1-4 host the Tagadamat deposit. This deposit strikes for 3 km. The mineralisation occurs within surface paleochannels with potential for open-pit, heap leach mineralisation. The Tagadamat deposit hosts 3 500 tU grading 150 ppm U. An environmental baseline study was completed in 2009, but the project is today on hold.

URU Metals Limited reported a SAMREC (South African Mineral Resource Committee) compliant inferred resource of 1 654 tU on their 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 and 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 follow-up drilling campaign. However, this was put on hold because of security concerns. All fieldwork has ceased and *Force Majeure* has been 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. On March 2017, the company submitted a pre-feasibility study through which it declares according to the JORC code the following resources:

- tabular mineralisation with 29 630 t of uranium metal at a grade of 157 ppm;
- a roll-front deposit containing 17 000 t of uranium metal with a grade varying from 400 to 600 ppm;
- and a surface deposit containing 823 7 t of uranium metal at a grade of 252 ppm.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

The total recoverable identified conventional resources for Niger, as of the end of 2017, amounted to 425 577 tU, compared to 411 387 tU as of the end of 2014. All uranium deposits in Niger are sandstone-hosted, with average grades of 0.07 to 0.40% U.

Undiscovered conventional resources (prognosticated and speculative resources)

Total speculative and prognosticated resources in Niger, as of 1 January 2017, amounted to 64 900 tU (unchanged from 2014).

Uranium production

Historical review

Uranium has been produced from sandstone deposits in Niger since 1971 by Somaïr and 1978 by Cominak.

The Société des Mines d'Azelik SA (SOMINA) was established in 2007 to mine the Azelik/Teguidda deposits. Azelik has been developed by the CNNC and came into production at the end of 2010, with the aim to ramp up to 700 tU/yr. It is an open-pit and underground operation using alkaline leach.

Uranium production in Niger has been increasing in recent years as efficiencies have been introduced. In 2015, production recorded for Niger amounted to 4 116 tU, then decreased to 3 477 tU in 2016, and remained almost the same in 2017 (3 485 tU), due mainly to depressed uranium prices.

Uranium production centre technical details
(as of 1 January 2017)

	Centre #1		Centre #2	Centre #3	Centre #4	Centre #5	Centre #6
Name of production centre	Arlit (Somaïr)		Akouta (Cominak)	Azelik (Somina)	Imouraren	Madaouela	Dasa
Production centre classification	Existing		Existing	Care and maintenance	Planned	Planned	Prospective
Date of first production	1971	2009	1978	2010	N/A	N/A	N/A
Deposit name(s)	Tamou-Artois-Tamgak-Taza-Tamou	Low-grade stockpiles	Akouta-Akola-Ebba Ebene	Azelik-Teguidda-Abokurum	Imouraren	Miriam-Marianne-Marilyn -MSNE-Maryvonne	Dasa
Deposit type(s)	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone	Sandstone
Recoverable resources (tU)	43 770	N/A	8 978	13 770	227 555	43 680	31 385
Grade (‰ U)	0.196	0.08	0.314	0.142	0.72	0.08	0.22
Mining operation:							
Type (OP/UG/HL)	OP	HL	UG	OP/UG	OP/HL	OP/UG	OP
Size (tonnes ore/day)		1 800 kt/yr					
Average mining recovery (%)							
Processing plant:							
Acid/alkaline	Acid	Acid	Acid	Alkaline	Acid	Acid	
Type (IX/SX)	SX	SX	SX			SX	
Size (tonnes ore/day)							
Average process recovery (%)	78	up to 85	93	85	82	82	80
Nominal production capacity (tU/year)	1 700		1 800	700	5 000	1 030	770
Plans for expansion						Yes up to 5 000	Yes, 1 130) (up to 1 900)
Other remarks							

Status of production facilities, production capability, recent and ongoing activities and other issues

Somaïr and Cominak were licensed to the end of 2013, and in mid-December 2013 both were shut down for maintenance, pending resolution of negotiation on licence renewal. 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. The royalty rate will increase potentially to 12% of market value, but this increase depends on profitability.

In August 2014, CNNC announced that Azelik has 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 on care and maintenance because of "tight cash flow".

In the autumn of 2017, Areva (Orano) decided to reduce the capacity of production at Somaïr due to current weak uranium market conditions.

Ownership structure of the uranium industry

The ownership structure of Niger's four uranium production companies are set out in the table below:

Somaïr	Cominak	Somina	Imouraren
36.6% Sopamin (Niger)	31% Sopamin (Niger)	33% Sopamin (Niger)	33.35% Sopamin (Niger)
63.4% Areva NC	34% Areva NC (France)	37.2% CNUC (China)	57.65% Areva
	25% OURD (Japan)	24.8% ZXJOY invest (China)	9% KEPCO
	10% ENUSA (Spain)	5% Trend Field Holdings SA	

Employment in the uranium industry

As of 1 January 2018, 898 workers were employed at the Somaïr mine and 776 at the Cominak mine. It is reported that 99% of the workers at these two mines are Nigerien. About 680 workers were employed at the Azelik mine, but due to the cessation of mining operations, only 25 workers have been retained. The Imouraren project employed about 300 during the development stage and is expected to create about 1 400 permanent and up to 3 000 indirect jobs when the facility is in full production.

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 up to full production capacity, production of 5 000 tU/yr for 35 years is expected. Production, originally scheduled to start mid-2015, was delayed owing to poor market conditions.

GoviEx has completed a preliminary feasibility study and proposed an open-pit/underground mine development at the Madaouela project, which could go into production around 2022 with a capacity to produce 1 040 tU/yr at the beginning and plans to reach 5 000 tU/yr when fully operational.

Global Atomic Fuels plans to construct its first mine at Dasa. It is targeting a 770 tU annual capacity with potential to ramp up to 1 900 tU production per year. Global Atomic has spent approximately CAD 50 million on exploration and development to date on its Niger projects and expects to apply for its mining licence for the Dasa project.

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). Areva 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. Areva has initiated ways to conserve and reduce water consumption and reports that over the past 15 years the annual consumption of water at the mines has been reduced by 35% while uranium production at Somaïr has doubled in the past 10 years.

In April 2010, 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 initiated an ambitious societal policy and committed EUR 6 million per year for the next five years to implement it. Mining activity has resulted in the construction of housing and a modern network of water distribution and contributes to the funding of public services and the construction of educational facilities (schools, libraries, lunch rooms, etc.).

Uranium requirements

There are currently no uranium requirements in Niger. However, it has been reported that Niger has started consultations with the IAEA and are considering 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.

In May 2014, the government and Orano (formerly 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. The royalty rate will increase potentially to 12% of market value, but this increase depends on profitability. The deal stipulates for the first time that the firms' boards will include Nigerien managing directors – appointed in 2014 for Somaïr, and in 2016 for Cominak. Also, Orano will provide EUR 90 million (USD 122 million) to support constructing a road from Tahoua to Arlit, near the uranium developments, as well as a further EUR 17 million (USD 23.1 million) for development in the surrounding Irhazer Valley. Orano will also build a new headquarters building (Maison de l'uranium) for its operating companies in the capital Niamey at a cost of EUR 10 million (USD 13.6 million). The government expects more than USD 39 million in additional tax revenues annually from the new agreement (Strategic Partnership Agreement). In October 2014, the government formally approved the agreement.

Production of each year 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 prevailing spot price.

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 in the course of the year, it is retroactively applicable to already made deliveries.

Reasonably assured conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone			237 449	336 358
Total			237 449	336 358

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)			22 296	53 073	89
Open-pit mining (OP)			215 153	281 539	82
Unspecified				1 746	80
Total			237 449	336 358	

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			22 296	53 073	89
Conventional from OP			40 957	56 331	82
Heap leaching from OP			174 196	225 208	82
Unspecified				1 746	80
Total			237 449	336 358	

Inferred conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone				89 219
Total			42 561	89 219

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)			877	10 241	76
Open-pit mining (OP)			41 684	61 329	79
Unspecified				17 649	76
Total			42 561	89 219	

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 UG			877	10 241	76
Conventional from OP			39 337	58 982	79
Heap leaching from OP			2 347	2 347	82
Unspecified				17 649	76
Total			42 561	89 219	

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
	13 600	13 600

Speculative conventional resources

(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	51 300	

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2013	2014	2015	2016	2017	Total through end of 2017
Sandstone	127 960	4 223	4 116	3 477	3 485	143 261
Total	127 960	4 223	4 116	3 477	3 485	143 261

Historical uranium production by production method
(tonnes U in concentrates)

Production method	Total through end of 2013	2014**	2015	2016	2017	Total through end of 2017
Open-pit mining*	61 552	2 652	2 509	2 164	2 154	71 031
Underground mining*	66 408	1 571	1 607	1 313	1 331	72 230
Total	127 960	4 223	4 116	3 477	3 485	143 261

* Pre-2014 totals include uranium recovered by heap and in-place leaching.

** Numbers have been revised since the last report.

Historical uranium production by processing method
(tonnes U in concentrates)

Processing method	Total through end of 2013	2014**	2015	2016	2017	Total through end of 2017
Conventional	N/A	N/A	N/A	N/A	N/A	N/A
Heap leaching*	N/A	N/A	N/A	N/A	N/A	N/A
Total	127 960	4 223	4 116	3 477	3 485	143 261

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

** Numbers have been revised since the last report

Ownership of uranium production in 2016

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)			(tU)	(%)	(tU)	(%)
1 196	34.4	0	0			2 281	65.6	3 477	100

Uranium industry employment at existing production centres
(person-years)

	2016	2017	2018 (expected)
Total employment related to existing production centres	3 935	3 843	3 011
Employment directly related to uranium production	1 800	1 745	1 478

Short-term production capability
(tonnes U/year)

2017				2020			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
		3 500	3 500			3 500	3 500

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
N/A		3 500	3 500			5 000	5 000			5 000	6 800

Paraguay

Historical review

Uranium exploration and mining development

Exploration for uranium in south-eastern Paraguay was started in 1976 by the Anschutz Corporation (Anschutz) of Denver, Colorado, after signing 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, a number of reports by Anschutz consultants A.F. Renfro, D.G. Bryant and G.E. Thomas, 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, Renfro concluded that the Anschutz concession contained areas with good potential for uranium mineralisation. The regional correlation of stratigraphic horizons favourable for uranium mineralisation is mentioned.

The initial uranium exploration by Anschutz in 1976 covered an exclusive exploration concession of 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, 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 (Grote, 1979 and Dalidowicz, 1979). Flight line spacing for the airborne radiometric survey was 5 km with a clearance of 100 m above the surface. Exploration work by Anschutz outlined several large target areas including what are now the Yuty and Oviedo projects.

Anschutz carried out exploration on behalf of a joint venture with Korea Electric Power Corporation (KEPCO) and Taiwan Power Company (Taiwan Power). Exploration work to date has intersected uranium mineralisation in drill holes ranging from 0.02% eU_3O_8 to 0.20% eU_3O_8 (equivalent U_3O_8) associated with layers of sub-horizontal sandstones, and higher-grade intersections ranging from 0.115% eU_3O_8 over 10.2 m to 0.351% eU_3O_8 over 0.3 m in sandstones and siltstones (Anschutz, 1981). Work was suspended in 1983 due to low uranium prices and no further work was completed until 2006.

In July 2006, Cue Resources signed an option agreement with Transandes Paraguay S.A. for the Yuty prospecting licence and started a systematic exploration programme including rotary and diamond drilling in the San Antonio area. Between 2007 and 2010, Cue completed 256 drill holes totalling 31 000 m of core and rotary drilling. In 2012, Uranium Energy Corporation (UEC) acquired 100% interest in the Yuty project.

Recent and ongoing uranium exploration and mining development activities

The only company that has been recently working on uranium projects in Paraguay is Transandes Paraguay S.A. However, in September 2015, the company requested a two-year suspension of the project due to low uranium prices.

Historic exploration by the Anschutz/Taiwan Power/Korea Electric Power joint venture and by Cue Resources, plus recent exploration by UEC totalled approximately USD 50 million in advancing the uranium exploration projects.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Transandes Paraguay S.A. company has evaluated the identified resources in sandstone deposits as 3 429 tU RAR and 857 tU inferred for the Yuty project. The current resource for Yuty is based on the NI 43-101 "Updated Technical Report on the Yuty Uranium project, Republic of Paraguay", prepared for Cue Resources. The Coronel Oviedo Uranium project is an exploration project with insufficient data to calculate resources in accordance with international guidelines at this time.

Uranium production

There has been no past production of uranium.

The Yuty project covers 290 000 acres and is located approximately 200 km east and south-east of Asunción, the capital of Paraguay. It is located within the Paraná Basin, which is host to a number of known uranium deposits, including Figueira and Amorinópolis in Brazil. The area is underlain by Upper Permian-Carboniferous continental sedimentary rocks.

Preliminary studies indicate amenability to extraction by ISR methods. Metallurgical test work indicated that a satisfactory rate of extraction can be obtained using a sulphuric acid lixiviant. Aquifer testing, via pump tests, completed in 2011 and previous permeability and porosity testing on drill cores gave a preliminary indication that the parameters are comparable to successful ISR operations in other parts of the world. Since 2006, over USD 16 million has been spent developing Yuty by previous owner Cue Resources Ltd.

Reasonably assured conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	0	3 429
Total	0	0	0	3 429

* In situ resources.

Reasonably assured conventional resources by production method

(tonnes U*)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
In situ leaching acid	0	0	0	3 429
Total	0	0	0	3 429

* In situ resources.

Reasonably assured conventional resources by processing method

(tonnes U*)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
In situ leaching acid	0	0	0	3 429
Total	0	0	0	3 429

* In situ resources.

Inferred conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	0	0	857
Total	0	0	0	857

Inferred conventional resources by production method

(tonnes U*)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
In situ acid	0	0	0	857
Total	0	0	0	857

* In situ resources.

Inferred conventional resources by processing method

(tonnes U*)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
In situ leaching acid	0	0	0	857
Total	0	0	0	857

* In situ resources.

Peru

Uranium exploration and mining development

Historical review

Macusani Uraniferous District (Department of Puno) is located in the South-East of Peru. Uraniferous mineralisation is found in acid volcanic Mio-Pliocene rocks (10 to 4 Ma).

Radiometric prospecting revealed over 40 uraniferous areas; the most important of them are Chapi, Chilcuno-VI, “Pinocho”, Cerro Concharrumio and Cerro Calvario.

Uranium mineralisation consists mainly of autunite, meta-autunite and weeksite filling sub-vertical to sub-horizontal fractures, with impregnation on both sides of the fracture. The host rocks are rhyolites of Quenamari Volcanic Formation.

Historically, considering all the surveyed areas, Chapi is the most important site and detailed radiometry, emanometry, trench and gallery work, as well as diamond drilling have been carried out in it. The mineralisation is in sub-vertical fractures distributed in structural lineaments from 15 m to 150 m width and 20 m to 30 m thickness. The grades vary between 0.03% U to 0.75% U, with an average of 0.1% U. Based on the exploration results as well as the geological and emanometry information, a minimum potential of 10 000 tU has been assigned to Chapi site and 30 000 tU to the whole Macusani Uraniferous District.

Since 2003, private companies restarted the exploration in both Macusani and Santa Lucia-Rio Blanco area (250 km from Macusani), which are located also in a Tertiary volcanic environment. Uranium potential of other areas of the country is also considered important. Peruvian Institute Nuclear Energy (IPEN), through its promotional activities, has proposed highlighting new areas of interest such as San Ramón Oxapampa and Corongo in the central region of Peru, where some work has been conducted to identify potential uraniferous regions.

Several companies have focused on the Macusani uranium district in order to develop further uranium resources through drilling in different prospects. As already mentioned, since 2003, besides Macusani and Santa Lucia-Rio Blanco, Pampacolca (Arequipa), which is in a Tertiary volcanic environment, has also been explored for uranium.

Recent and ongoing uranium exploration and mining development activities

Uraniferous mineralisation in Macusani is hosted by young acidic rocks, namely rhyolites of Upper Miocene (8-6 Ma). There are more than 70 radiometric anomalies depicted to date on surface along Macusani plateau, from which less than 20 of them have been drilled.

Recent studies on mineralisation in Macusani’s district indicate that uranium mineralisation is cropping out at elevations of between ~4 100 m and 4 400 m around Quenamari Plateau, west and northwest of Macusani’s county; it comprises stockworks and associated disseminations of two coarse-grained yellow minerals, meta-autunite (hydrous calcium-uranyl phosphate), and subordinately, weeksite (hydrous potassium-uranyl silicate). From a mining standpoint, mineralised zones are mantos, but they are neither strictly stratiform nor stratabound. There is no evidence for precursor uraninite/pitchblende occurrence and the ore’s thorium content is negligible.

Deposits are hosted almost entirely by the Upper Miocene Macusani Formation, about 500 m thickness, gently dipping succession of subaerial, exceptionally-reduced, peraluminous sillimanite-andalusite-muscovite-biotite rhyolites, which, through crystal fractionation, were intensely enriched in alkali (Li, Rb, Cs) and lithophile metals (Sn, W, Nb, Ta, Be), as well as in F, B and P. Rhyolites lack ashflow petrographic features and were erupted as crystal-charged frothy debris-flows, with the absence of explosive degassing permitting the exceptional retention of ore metals. Background (whole-rock), uranium contents of the younger lava flows averages 28 ppm U, and attains 120 ppm U and 270 ppm U in coeval hypabyssal intrusions and residual glasses (obsidian), respectively.

Uranium potential in other parts of Peru is also important and IPEN has proposed to highlight new areas of interest. In 2012, IPEN discovered new uranium occurrences in San Ramón Oxapampa's region, where initial results demonstrate important uraniferous potential.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

As a result of a series of corporate mergers and acquisitions that took place over the last six years, all the drilled uranium resources at Macusani (124 M lbs U_3O_8 or 47 709 tU) are under the cover of Plateau Uranium Inc., a new company derived from Macusani Yellowcake Inc. Another active company on the plateau is Fission Uranium, also from Canada but with no registered resources.

Macusani Uranium District (tU, in situ)

Uranium resources (tonnes U)

Prospect	RAR	IR	Total
Corachapi	1 931	733	2 664
Chilcuno	7 608	9 117	16 725
Quebrada Blanca	1 538	3 616	5 154
Tantamaco	1 409	6 148	7 557
Isivilla	1 354	2 182	3 536
Colibri II-III	5 651	1 577	7 228
Nuevo Corani	479	678	1 157
Tuturumani	0	482	482
Calvario I-Real	0	554	554
Puncopata	0	1 277	1 277
Tupurumani	0	1 375	1 375
Total	19 970	27 739	47 709

Undiscovered conventional resources (prognosticated and speculative resources)

Macusani Uranium District	
Corachapi	6 610 tU
Remainder of Macusani Uranium District*	19 740 tU
Total	26 350 tU

* Extension of 1 000 km^2, distribution of Tertiary volcanic rocks with associated uranium.

Unconventional resources and other materials – At country level	
Permo-triasic granites**	20 000 tU
Bayovar 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 of 50-80 ppm U.

*** Currently, only exploited rock phosphate concentrate; the evaluated content is 46 ppm U.

**** Others in the rest of the country, uranium deposits associated with hydrothermal deposits (Cu Pb-Ni-W).

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Mining activities, formerly conducted by the government, entered into a privatisation process in 1992 with application of the Mining Investment Promotion's 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 allowing several foreign private companies to conduct exploration and evaluation programmes in the zones where IPEN had previously performed prospecting and exploration work.

Peruvian State, by promoting investment in uranium mining, plans to evaluate the potential for uranium in the country in areas other than Macusani. One such area is in the Eastern Cordillera, where occurrences of uranium in granite-type rocks also have thorium potential.

Technical Office of National Authority (OTAN) is responsible for policy and regulatory issues. A new law involving the promotion and development of nuclear energy for electricity generation is being developed.

Reasonably assured conventional resources by deposit type

(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

* In situ resources.

Reasonably assured conventional resources by production method

(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

* In situ resources.

Reasonably assured conventional resources by processing method

(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

* In situ resources.

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

Inferred conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Volcanic-related	0	27 739	27 739	27 739
Total	0	27 739	27 739	27 739

Inferred conventional resources by production method

(tonnes U*)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Open-pit mining (OP)	0	27 739	27 739	27 739
Total	0	27 739	27 739	27 739

* In situ resources.

Inferred conventional resources by processing method

(tonnes U*)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Heap leaching** from OP	0	27 739	27 739	27 739
Total	0	27 739	27 739	27 739

* In situ resources.

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

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
6 610	20 000	20 000

Speculative conventional resources

(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
19 740	19 740	0

Russia

Uranium exploration and mine development

Historical review

Since the beginning of uranium exploration in 1944, more than 100 uranium deposits have been discovered within 14 districts in Russia. The most significant deposits are located within four uranium-bearing districts:

- the Streltsovsk district, which includes 19 volcanic, caldera-related deposits where the 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 leach mining;
- the Elkon district that 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 prospecting aimed at new deposit discovery and evaluation and the second, involves exploration at earlier discovered deposits with a view to estimate and delineate deposit resources.

Uranium prospecting in Russia is financed from the state budget by the Federal Agency for Subsoil Use (Rosnedra). In 2014, the budget amounted to RUB 1.0 billion (Russian rubles), in 2015 and 2016 it decreased to RUB 0.7 billion and 0.5 billion respectively. The Republic of Buryatia, the Trans-Baikal and Irkutsk regions were the main areas for prospecting, followed by the Republic of Kalmykia.

These activities were focused on two main objectives: the resource increase near operating Khiagda and Priargunsky production centres and large deposits discovery in new areas, for either conventional or in situ leach mining.

The activities of 2015-2016 resulted in identification of 26 900 tU of prognosticated resources (category P1 in Russian classification) and 53 100 tU of speculative resources (P2 in Russian system).

The exploration of the phosphorus-rare-earth-uranium Shargadyk deposit in Ergeninsky uranium district of Kalmykia was completed in 2015. It resulted in 9 467 tU conversion from prognosticated into known uranium resources. These resources are planned for open-pit mining and heap leaching processing to recover uranium and rare earth elements.

The exploration for sandstone basal channel-type prognosticated resources evaluation was completed in 2016 in the North Amalat area, which is located within the Vitim uranium region and close to the Khiagda uranium field. The last one is under active development by ISL mining method. As a result 25 480 tU of P1 prognosticated resources and 26 800 tU of P2 speculative resources were identified within Kulariktin and Barkasun areas. Resources belong to <USD 80/kgU cost category.

Uranium exploration at the Shangulezh area within the Sayan potentially uranium district (Irkutsk region of Russia) resulted in 19 500 tU of P2 speculative resources estimation. Mineralisation belongs to the unconformity geological type.

6 100 tU and 2 520 kg of gold in P2 speculative category were identified during early stage exploration at the Kurumkan area of Central Aldan region (Republic Saha Yakutia).

Exploration of existing deposits

The subsidiaries of uranium holding company "Atomredmetzoloto" (ARMZ), which is incorporated within the Russian State Corporation "Rosatom", continued exploration and resource estimation of uranium deposits, which are being prepared for development.

During 2015-2016, Dalur mining company continued exploration and pilot mining at Khokhlovskoe deposit in Kurgan region.

The Priargunsky Mining-Chemical Production Association (PMCPA) focused exploration activities on additional resources identification at flanks and deep levels of operating deposits and on new high-grade deposits discovery within the Streltsovsk uranium district.

ARMZ's uranium exploration budget was RUB 75 million in 2015 and RUB 52 million in 2016.

Uranium exploration abroad

Russia, through the State Corporation Rosatom subsidiary Uranium One Group and its Canadian branch Uranium One Inc., performed geologic exploration and research studies in Kazakhstan and Tanzania.

In Kazakhstan, six mines jointly owned by Russian Uranium One Company with Kazatomprom and other shareholders were in commercial production during 2015-2016. In 2015 and 2016, exploration was performed at four mines Akdala, Southern Inkai, Khorasan and Zarechnoye in order to convert resources from inferred to RAR category and supply long-term production programmes with a reliable resource base. In 2015, exploration expenditures totalled USD 13.8 million and in 2016 USD 4.9 million (proportionally to Russian share in the JVs). Major 2015 expenditures were spent for South Inkai drilling programme. New technical report on Akdala mine resources estimation was finalised in 2017, for the other three mines reports will be completed in 2018. Recent technical reports for Karatau and Akbastau mines resources reassessment were issued and approved in 2015.

In Tanzania, Mantra Recourses Company performed additional exploration and ISL pilot test works at the Mkuju River uranium project. Uranium One Inc. was the project operator. In 2015, exploration expenditures totalled USD 3.3 million and in 2016, USD 1.2 million. Activities were focused on mining plan technical optimisation and verification drilling. The results of the research activities and the spot ISL tests performed during 2015-2016 confirmed good in situ leach mining potential for the part of resources located in permeable sediments below the water table.

Recent mine development activities

The activities for uranium deposits development in Russia were performed in two main areas: pilot operations at existing or under construction mines and feasibility studies or engineering works at prospective mines.

In 2016, Priargunsky Mining-Chemical Production Association started with preparatory development works for the new mine No. 6 construction based on Argunskoye and Zherlovoye deposits.

The Dalur mine (Kurgan region of Russia) continued advanced pilot in situ leach mining at the Khokhlovskoe deposit, which is located 110 km from the main mining centre. In 2016, the pilot plant capacity was expanded to 200 tU/yr.

The Khiagda mine (Republic of Buryatia) continued development of the Khiagda uranium ore field. In 2016, the local commercial processing plant with 200 tU capacity and auxiliary infrastructure was commenced at the Istochnoe deposit.

The Gornoe Mining Company continued pilot mining project development for Berezovoe deposit located in Trans-Baikal district.

The activities for uranium deposit development in Elkon and Trans-Baikal uranium regions have significantly decreased and were suspended due to unfavourable market conditions.

Uranium resources

Identified resources (reasonably assured and inferred resources)

In 2015-2016, a comprehensive exploration and technical economic evaluation of uranium resources continued.

As of 1 January 2017, total recoverable uranium resources in Russia attributable to category RAR and inferred amounted to 656 859 tU, while in situ known resources comprised 840 622 tU. It is a decrease of 38 341 tU or approximately 6% compared to 1 January 2015. The decrease mainly occurred due to high-cost resources reassessment and to mined uranium depletion.

74% of all recoverable resources are attributed to operating and prospective mines and the remaining 26% relate to stand by deposits in so-called undistributed state fund.

Recoverable reasonably assured resources amounted to 259 968 tU, 83% of which are recoverable at a cost less than USD 130/kgU and only 9% are recoverable at a cost less than USD 80/kgU. 68% of RAR resources may be mined by conventional underground mining method. All resources attributable to the category less than USD 80/kgU are planned for in situ leach mining method.

Inferred uranium resources amounted to 396 891 tU, of which only about 4% are recoverable at a cost of less than USD 80/kgU. Over 71% of inferred uranium resources are expected to be mined by conventional underground mining method.

Undiscovered conventional resources (prognosticated and speculative resources)

As of 1 January 2017, Russian prognosticated uranium resources amounted to 143 900 tU, and speculative resources to 591 100 tU. In the Russian classification system, "prognosticated" corresponds to P1 category and "speculative" to P2 category.

The majority of prognosticated resources are located in the Trans-Baikal region (Streltsovsk and East Trans-Baikal uranium ore districts), in the Republic of Buryatia (Vitim district), in the Republic of Sakha-Yakutia (Elkon district) and in the Republic of Kalmykia.

Uranium production

Historical review

Cumulative production at the Russian uranium mines totalled 164 904 tU through the end of 2016.

The first Russian uranium mine was the Lermontov Complex, also known as the Lermontov State Enterprise "Almaz". Almaz was located 1.5 km from the town of Lermontov in the Stavropol region of Russia. The Beshtau and Byk vein-type deposits were mined, and both are currently depleted. Their original resources totalled only 5 300 tU (at an average grade of 0.1% U) and were extracted by two underground mines starting in 1950. Mine 1 Beshtau was closed in 1975 and mine 2 Byk in 1990. The ore was processed at the local processing plant using sulphuric acid leaching. From 1965 to 1989, small amounts were also produced via stope (block) and heap leaching methods. From the 1980s until 1991, uranium ore transported from Ukraine and Kazakhstan was also processed at Almaz. Production from local deposits totalled 5 685 tU, with 3 930 tU extracted by underground mining and 1 755 tU by a combination of the different leaching technologies.

Between 1968 and 1980, 440 tU were produced by open-pit mining from the small Sanarskoye deposit in the Trans-Ural district by the Malyshevsk mine, which was the operator of this project.

The joint stock company "Priargunsky Mining-Chemical Production Association" (Priargunsky) has been the largest uranium production centre in Russia over the past several decades. As of 1 January 2017, about 148 000 tU has been produced at the Priargunsky, making it the largest (cumulative) uranium production centre in the world.

The Priargunsky production centre is located in the Chita region, 10-20 km from the town of Krasnokamensk (population of about 60 000). The production was based on volcanic-type deposits of the Streltsovsk uranium district, with overall original in situ resources 244 000 tU at an average grade of about 0.2% U. Mining has been conducted since 1968 by two open pits (both now depleted) and five underground mines. Milling and processing have been carried out since 1974 at the local hydrometallurgical plant using sulphuric acid leaching with subsequent recovery by ion-exchange extraction. Since the 1990s, low-grade ore has been processed by heap leaching method.

Starting from 2002, Russia began commercial sulphuric acid ISL production at Dalur mine, located in Kurgan region of Russia, and later in 2011 at Khiagda ISL mine in Republic of Buryatia. Cumulative ISL production at these two mines totalled 12 204 tU through the end of 2016.

Status of production capabilities

Atomredmetzoloto Uranium Holding – a mining division of the State Corporation Rosatom, owns three operating uranium mining centres in Russia.

In 2016, uranium production in Russia amounted to 3 005 tU, of which 1 873 tU were produced using conventional underground mining method and 1 132 tU produced using in situ leach method. Since 2014 uranium production by underground method decreased by 5% and by ISL method increased by 11%.

From the 1 873 tU initially mined by underground method in 2016, 1 621 tU was produced at the hydro-metallurgic plant by conventional ore processing, and 252 tU was processed by heap leaching with subsequent solutions treatment at the plant.

The PMCPA remains the key uranium mining centre in Russia. Its resource base is represented by the volcanic-type uranium deposits of the Streltsovsk uranium ore district with current in situ resources tonnage at about 103 000 tU as of 1 January 2017.

In 2016, Priargunsky mine produced 1 873 tU. 1 621 tU of total production came from the conventionally milled and processed ore and the remaining 252 tU were produced by the heap leaching method. As of January 2017, three underground mines No. 1, No. 8 and Glubokiy were in operation. Mine No. 1 has been active for more than 40 years. Underground mine No. 2 suspended mining activities in late 2016 due to low-cost resources depletion. In 2016, Priargunsky started preparations for the development of the Argunskoe and Zherlovoye deposits, which will be used in the future as a basis for a new mine construction (No. 6).

Uranium production centre technical details
(as of 1 January 2017)

	Centre #1	Centre #2	Centre #3	Centre #4	Centre #5
Name of production centre	Priargunsky Mining Combine (Priargunsky)	Dalur	Khiagda	Elkon Mining and Metallurgical Complex (Elkon)	Gornoe Uranium Mining Company (Gornoe)
Production centre classification	Existing	Existing	Existing	Prospective	Prospective
Date of first production	1968	2004	2010	2030	N/A
Source of ore:					
Deposit name(s)	Antei, Streltsovskoe and others	Dalmatovskoe Khokhlovskoe and others	Khiagda, Vershinnoe and others	Yuzhnoe, Severnoe	Gornoe, Berezovoe
Deposit type(s)	Volcanic	Sandstone basal channel	Sandstone basal channel	Metasomatic	Vein
Recoverable resources (tU)	80 000	5 800	28 500	303 600	3 200
Grade (% U)	0.16	0.04	0.05	0.15	0.20
Mining operation:					
Type (OP/UG/ISL)	UG, HL	ISL	ISL	UG	UG, HL, IPL
Size (tonnes ore/day)	6 700	N/A	N/A	5 500	1 900
Average mining recovery (%)	80	75	75	85	70
Processing plant:					
Acid/alkaline	Acid	Acid	Acid	Acid	Acid
Type (IX/SX)	IX	IX	IX	IX	IX
Size (tonnes ore/day)	4 700	No data	No data	No data	No data
Average process recovery (%)	90	98	98	85	95
Nominal production capacity (tU/year)	3 000	600	1 000	5 000	300
Plans for expansion	Yes	Yes	Yes	No	No
Other remarks					

In 2015-2016, Priargunsky centre implemented a set of activities focused on operational improvements, including mining operations optimisation, transition to a five-day working week for mining staff, decrease of drilling and backfilling costs.

Dalur mine in Kurgan region operates the Dalmatovskoye and Khokhlovskoe deposits using sulphuric acid in situ leaching method. 2016 production amounted to 592 tU. The known recoverable resources of these two deposits were estimated at around 8 000 tU as of 1 January 2017. In 2016 Dalur expanded pilot plant capacity at Khokhlovskoe deposit to 200 tU/year capacity.

Khiagda mine has been developing the deposits of Khiagda ore field by in situ leach method with total recoverable resources 38 000 tU. In 2016, uranium production was 540 tU, which is 11% above 2015 results. During 2015-2016 Khiagda completed main facilities construction, which will secure production capacity at a level of 1 000 tU/year in a mid-term period. The local satellite processing plant and auxiliary infrastructure was commissioned at Istochnoe deposit in 2016. The feasibility study for Vershinnoe deposit development was completed.

Employment in the uranium industry

In 2016, the Russian uranium industry employed 6 077 persons, which is 31% less than in 2014. Of this 2016 total, 5 138 were Priargunsky employees, 443 were employed at Dalur and 496 were employed at Khiagda. The Priargunsky has reduced staff by 35% since 2014. Of its employees, 4 017 were directly involved in uranium production and processing, while the remainder worked in auxiliary and service companies (coal open-pit mining, power plant, logistic company, etc.).

Future production centres

In 2015-2016, the uranium holding, Atomredmetzoloto and its daughter companies continued studies and research work to prepare deposits in the Trans-Baikal region and Sothern Yakutia for development.

The Gornoe Mining Company continued project development for pilot mining at Berezovoe deposit.

The activities for uranium deposit development in Elkon and Trans-Baikal uranium regions have significantly decreased and were suspended due to unfavourable market conditions.

Secondary supply

Fabrication and/or use of mixed oxide fuel

The fuel supply for large-scale nuclear power from a long-term perspective requires consideration of fast breeder reactors. The Beloyarsk NPP unit 4 with fast breeder reactor BN-800 started commercial operation in 2016. It was designed to use hybrid core containing fuel assemblies with both uranium and mixed oxide (MOX) fuel. The full transfer of the reactor installation core to MOX fuel will be accomplished most probably by 2019.

Reprocessed uranium

Russia has all competences for using the reprocessed uranium (RepU) in the thermal reactors fuel cycles. The reprocessed uranium is used as a secondary source to fabricate nuclear fuel for Russian nuclear power plants. Russia also provides services for foreign customers to produce nuclear fuel from RepU.

Uranium requirements

As of 1 January 2017, 10 nuclear power plants in Russia operated 35 units with a total installed capacity of 27.1 GWe. They generated 18.3% of the electricity produced in the country. In the European part of Russia, the share of nuclear power electricity reached 39%.

In 2016, Russian nuclear power plants generated 196.4 billion kWh of electricity. The current annual consumption of Russian NPPs in the uranium equivalent is about 4 600 tU. Uranium fuel requirements are being supplied by uranium produced in Russia and Kazakhstan, from uranium stockpiles and from secondary sources.

The development of nuclear energy and the construction of new power plants in Russia assume an installed capacity growth up to 32.6 GWe by 2030 and a proportional growth in uranium requirements up to 5 700 tons per year.

Uranium exploration and development expenditures and drilling effort – domestic

(RUB millions)

	2014	2015	2016	2017 (expected)
Industry exploration expenditures	266	75	52	41
Government exploration expenditures	982	730	491	216
Industry development expenditures	98	167	153	98
Government development expenditures	0	0	0	0
Total expenditures	1 346	971	696	355
Industry exploration drilling (m)	67 200	23 600	10 500	8 300
Industry exploration holes drilled	253	85	62	57
Government exploration drilling (m)	75 300	43 405	28 432	10 400
Government exploration holes drilled	300	423	271	65
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)	142 500	67 005	38 932	18 700
Subtotal exploration holes	553	508	333	122
Subtotal development drilling (m)	NA	NA	NA	NA
Subtotal development holes	NA	NA	NA	NA
Total drilling (m)	280 200	67 005	38 932	18 700
Total number of holes drilled	2 636	508	333	122

Uranium exploration and development expenditures (non-domestic)

(USD millions)

	2014	2015	2016	2017 (expected)
Industry* exploration expenditures	3.0	17.1	6.1	3.1
Government exploration expenditures	0.0	0.0	0.0	0.0
Industry* development expenditures	1.9	0.0	0.0	0.0
Government development expenditures	0.0	0.0	0.0	0.0
Total expenditures	4.9	17.1	6.1	3.1

* Russian State Corporation Rosatom.

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	176 026	176 026	80-90
In situ leaching acid	0	24 535	24 535	24 535	75
Co-product and by-product	0	0	0	45 424	65
Unspecified	0	0	13 983	13 983	75
Total	0	24 535	214 544	259 968	77

Recoverable resources, overall recovery factor was 77%.

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	157 458	157 458	80-85
In situ leaching acid	0	24 535	24 535	24 535	75
In-place leaching*	0	0	516	516	70
Heap leaching** from UG	0	0	18 052	18 052	70
Unspecified	0	0	13 983	59 407	65-75
Total	0	24 535	214 544	259 968	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

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	24 535	24 535	24 535
Granite-related	0	0	1 550	1 550
Intrusive	0	0	0	45 424
Volcanic-related	0	0	75 628	75 628
Metasomatite	0	0	103 982	103 982
Phosphate	0	0	8 850	8 850
Total	0	24 535	214 544	259 968

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	0	251 013	282 522	80-90
Open-pit mining (OP)	0	0	0	211	70
In situ leaching acid	0	15 293	15 293	23 597	75
Co-product and by-product	0	0	0	35 217	65
Unspecified	0	0	4 735	55 344	65-75
Total	0	15 293	271 042	396 891	79

Recoverable resources, overall recovery factor was 79%.

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 UG	0	0	242 521	271 896	85
In situ leaching acid	0	15 293	15 293	23 597	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	211	70
Unspecified	0	0	4 735	90 020	65-75
Total	0	15 293	271 042	396 891	80

* 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

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone	0	15 293	15 293	52 075
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	256 268
Phosphate	0	0	2 775	5 475
Total	0	15 293	271 042	396 891

Prognosticated conventional resources

(tonnes U)

Cost Ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
115 100	115 100	143 900

Speculative conventional resources

(tonnes U)

Cost Ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
390 100	591 100	NA

Historical uranium production by mining method

(tonnes U concentrate)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Open-pit mining	38 655	0	0	0	38 655	0
Underground mining	108 225	1 970	1 977	1 873	114 045	1 631
In situ leaching	8 973	1 021	1 078	1 132	12 204	1 243
Total	155 853	2 991	3 055	3 005	164 904	2 874

Historical uranium production by processing method

(tonnes U concentrate)

Processing method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Conventional	143 422	1 688	1 714	1 621	148 445	1 368
In-place leaching*	241	0	0	0	241	0
Heap leaching**	3 217	282	263	252	4 014	263
In situ leaching	8 973	1 021	1 078	1 132	12 204	1 243
Other methods	0	0	0	0	0	0
Total	155 853	2 991	3 055	3 005	164 904	2 874

* 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 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Sandstone	8 973	1 021	1 078	1 132	12 204	1 243
Volcanic and caldera-related	146 880	1 970	1 977	1 873	152 700	1 631
Total	155 853	2 991	3 055	3 005	164 904	2 874

Ownership of uranium production in 2016

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
3 005	100%	0	0	0	0	0	0	3 005	100

Uranium industry employment at existing production centres

(person-years)

	2014	2015	2016	2017 (expected)
Total employment related to existing production centres	8 790	6 857	6 077	5 788
Employment directly related to uranium production	6 126	5 395	4 956	4 669

Short-term production capability
(tonnes U/year)

2017				2020			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
1 243	1 243	2 874	2 874	1 550	1 550	2 780	2 780

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
1 660	1 660	1 660	3 960	1 890	1 890	1 890	8 490	1 800	1 800	1 800	6 800

Net nuclear electricity generation

	2015	2016
Nuclear electricity generated (TWh net)	195.2	196.4

Installed nuclear generating capacity to 2035
(MWe net)

2015	2016	2017		2020	
		Low	High	Low	High
26 200	27 100	27 900	27 900	30 360	30 360

2025		2030		2035	
Low	High	Low	High	Low	High
31 230	31 230	32 600	32 600	31 400	35 200

Annual reactor-related uranium requirements to 2035 (excluding MOX)
(tonnes U)

2015	2016	2017		2020	
		Low	High	Low	High
4 600	4 600	4 800	4 800	5 300	5 300

2025		2030		2035	
Low	High	Low	High	Low	High
5 450	5 450	5 700	5 700	5 500	6 100

Senegal

Historical review

Two periods stand out in the history of mining exploration for uranium in Senegal: i) the period 1957-1965, when a general inventory of the uranium potential of Africa was undertaken and at which time the large deposits in Niger and Gabon were discovered and ii) the second main period, which occurred from 1973 to 1985.

The first work undertaken in Senegal was by the French Atomic Energy Commission from 1957 to 1961, which was part of a systematic aerial survey of West Africa covering Senegal, Mali, Upper Volta and Niger.

It was during these survey flights in 1960 that an aerial radiometric anomaly, Saraya, was identified at Kedougou (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 N130 with yellow products and the other in a white 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 (Dalafinn site, for example), which were usually associated with laterites.

In 1961, the French Atomic Energy Commission (CEA) took the decision to suspend the study of the anomalies at Kedougou and nothing was undertaken in this area until the work resumed in 1974.

In 1966, as part of a joint study between Mauritania and Senegal, the teams of CEA also undertook systematic radiometric study of the continental sedimentary basin of the Ferlo (northern Senegal) and the bank of the Senegal River; this work furnished no interesting results.

The period from 1973 to present has been characterised by specific surveys focused on the Birimian Superior Precambrian sediments and secondary and tertiary basins with phosphates.

Following the collapse of uranium prices that began in 1980, the lack of validity of the surveys on areas away from the coast and the lack of infrastructure forced the decision to eliminate exploration targets where there was little hope of finding high enough concentrations of uranium.

On 29 May 1974, the Minister of Development of Senegal sent a letter to the general administrator of the CEA that later became the Compagnie Générale des Matières Nucléaires s (COGEMA), requesting them to consider the 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 were focused on a series of Cambrian and Precambrian Superior lithologies on the remaining area of the permit.

From 1979 to 1984, the magnetometry and electromagnetism surveys on the Saraya granite identified uranium mineralisation in conjunction with episyenites representing a geological potential estimated at about 1 500 tons of uranium metal at an average grade of 0.2%.

COGEMA has extensively explored for uranium in eastern Senegal in the period 1975-1985 (about 400 vertical and oblique drill holes). However, the drastic drop in the price of uranium in the context of rather mixed results (resources on the order of only 1 500 tons of uranium at an average grade of 0.2%) led to discontinuation of the exploration programme.

In 1975, Total Mining Company of Senegal led exploration studies on uranium anomalies associated with phosphates of secondary and tertiary basins of Cape Verde. The results were not encouraging.

In 2007, uranium exploration was revived, thanks to the soaring price of uranium and as a result the East Saraya licence was purchased the same year 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 show that the structural setting of Saraya granitic complex can be considered favourable for alaskite type uranium mineralisation.

The work of mining companies has, to the present, not identified any economic uranium resources, but they have nevertheless contributed greatly to a better understanding of the geology, particularly in eastern Senegal, on the upper Precambrian basin including equivalents that exist throughout West Africa (i.e. the uranium belt of Zaire), which has been prospected in the past by CEA-COGEMA teams.

The research that has been carried out in Senegal and also in Guinea and Mali helped establish a detailed map and understanding of the geological history of the country.

Recent and ongoing uranium exploration and mining development

There has been no recent exploration and mining development for uranium in Senegal.

Uranium resources

The national potential is estimated at about 1 500 tons of uranium as prognosticated resources at an average grade of 0.2% U.

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
N/A	N/A	1 500

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 operation 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 deposit was carried out in 1994. RAR are estimated to amount to 2 200 tU with an average grade of 0.14% U in the <USD 80/kgU category. Inferred resources total 5 000 tU in the <USD 80/kgU category and 10 000 tU in the <USD 130/kgU 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 reported earlier.

Uranium production

Historical review

The Žirovski Vrh uranium mine, located 20 km south-west of Škofja Loka, was the only uranium producer 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-mill complex totalled 382 tU (620 000 tonnes ore at an average grade of 0.072% U).

Status of production capability

In 1992, a decision for final closure and subsequent decommissioning of the Žirovski Vrh mine and mill was made and there has been no production at the facility since. All production was reserved for the former Yugoslavia. In 1994, the plan for decommissioning of the facility was adopted by the Slovenian government. The production facility has been dismantled and there is no more production facility.

Environmental activities and socio-cultural issues

The government-owned Žirovski Vrh 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 works, the remaining disposal sites and the mine water effluents are put under long-term environmental surveillance that is carried out by the national organisation for radioactive waste management – the Agency for Radioactive Waste Management. The mine effluents are monitored for uranium, radium and other chemical contaminants, the disposal sites are monitored for radon exhalation and uranium and radium in water effluents.

The annual effective dose contribution from all mine objects has significantly decreased as a result of remediation activities. Since 2011 its value dropped below 0.1 mSv/a, compared to about 0.4 mSv/a during operation. Background annual effective levels are 5 mSv/a in the area surrounding the mine.

Associated with the uranium production site are a hydrometallurgical tailings disposal site and the waste rock disposal site. Environmental remediation of the disposal site for hydrometallurgical tailings is in its final stage, the critical factor being the stability of the site. All remediation works are finished on the site of the mine waste pile, 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, modified when production stopped in 1990, is ongoing. Emissions to surface waters and air are monitored, and doses to the critical group of inhabitants have been calculated since 1980. Treatment of the mine's effluents is not planned considering the low concentrations of radioactive contaminants.

Tailings impoundment

There is one 4.5 ha specially designed long-term site for hydrometallurgical tailings, called Boršt. It is situated on the slope of a hill between 530 and 570 m above sea level. At this disposal site, 610 000 tons of hydrometallurgical waste, 111 000 tons of mine waste and 9 450 tons of material, collected during decontamination of the mill tailings in the Boršt site vicinity, have been disposed, with a total activity of 48.8 TBq. The tailings have been stored in dry condition as a result of the filtration of the leached liquor. The surface is covered with a two-metre thick, engineered multilayer soil cover with a clay base to prevent leaching of contaminants, and is covered with grass. Although the remediation of the site was completed in 2010, it will probably require additional remediation measures considering activation of the landslide beneath the disposal site. At the time of reporting, the remediation measures have not been completed yet. Additional works for stabilising the slope have to be performed to meet the conditions for site closure and to start the long-term environmental surveillance.

Waste rock management

All waste piles were relocated to the central mine waste pile Jazbec. All other sites have been decontaminated to a green field condition. The 5 ha Jazbec facility contains 1 910 425 tonnes of mine waste, neutralised hydrometallurgical tailing and contaminated material from decommissioning of mining and milling facilities, with a total activity of 21.7 TBq. It is covered with an engineered multilayer, two-metre-thick soil cover, and planted with 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 have been completed and the administrative procedure for the site closure finished in 2015. The responsibility for long-term surveillance and maintenance of the site was transferred to the the Agency for Radioactive Waste Management in 2015.

Uranium requirements

The sole nuclear power plant in Slovenia is based at Krško. It started commercial operation in January 1983 and was modernised in 2000 with replacement steam generators that increased net capacity to 676 MWe. Net capacity was increased in 2006 to 696 MWe with low-pressure turbine replacement and again in 2009 to 698 MWe after modernisation of the turbine control system. The power plant is 50% owned by Slovenia and Croatia.

There has been no significant change in the Slovenian nuclear energy programme in the last few years (2011-2017). One nuclear power plant (Nuklearna Elektrarna Krško) is in operation. Uranium requirements for Nuklearna Elektrarna Krško are relatively stable. The current fuel cycles are 18 months in duration and planned to continue at this cycle basis. In 2012, the Slovenian Nuclear Safety Administration approved the ageing management programme; a prerequisite for the operation of the Nuklearna Elektrarna Krško beyond 2030 up until the year 2043.

Supply and procurement strategy

The total uranium requirement of Nuklearna Elektrarna Krško per operating cycle remains as reported in 2016. 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 till 2020. 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 Nuklearna Elektrarna Krško 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 Nuklearna Elektrarna Krško. The strategy for commercial spent nuclear fuel management currently does not include the use of reprocessed uranium and Nuklearna Elektrarna Krško 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 the nuclear power plant (Nuklearna Elektrarna Krško) as final products (manufactured nuclear fuel assemblies).

Uranium stocks

There is no uranium stock policy in Slovenia. Nuklearna Elektrarna Krško has no uranium stocks or intention to create a uranium stock 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 deposit type

(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

* In situ resources.

Reasonably assured conventional resources by production method

(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

* In situ resources.

Reasonably assured conventional resources by deposit type

(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

* In situ resources.

Inferred conventional resources by deposit type

(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

* In situ resources.

Inferred conventional resources by production method

(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

* In situ resources.

Prognosticated resources

(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 2013	2014	2015	2016	Total through end of 2016	2017 (preliminary)
Underground mining[1]	382	0	0	0	382	0
Total	382	0	0	0	382	0

1. Pre-2010 totals may include uranium recovered by heap and in-place leaching.

Net nuclear electricity generation

	2015	2016
Nuclear electricity generated (TWh net)	5.371	5.431

Installed nuclear generating capacity to 2035

(MWe net)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
698	698	666	698	666	698	666	698	666	698	666	698

Note: Low and high values were taken as dependable power and maximum designed net power, respectively.

Annual reactor-related uranium requirements to 2035 (excluding MOX)

(tonnes U)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
149	149	119	179	119	179	119	179	119	179	119	179

Note: The 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. 2015, 2018 and 2021). 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 the 2016 edition, 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.

Spain

Uranium exploration and mine development

Historical review

Uranium exploration started in 1951 and was carried out by the Junta de Energía Nuclear (JEN). 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, located 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. (ENUSA) (today ENUSA Industrias Avanzadas, S.A.), 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), holding the remaining 40%. Exploration activities by the 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 Energia Ltd has been granted one mining licence in the province of Salamanca covering 2 720 Ha and a total of 25 investigation licences spanning the provinces of Salamanca Cáceres and Badajoz covering a total of 105 762 ha. This company has been actively exploring for uranium for several years, with a focus on a number of historically known uranium projects located within their tenements.

Berkeley's "Salamanca" Project comprises the Retortillo, Zona 7 and Alameda deposits (in the Salamanca province) and also the Gambuta one (in the Cáceres province), which now accounts, according to that company, for 59.8 Mlb of U_3O_8 (23 000 tU) in the measured and indicated categories, and an additional 29.5 Mlb of U_3O_8 (11 350 tU) in the inferred category.

As Zona 7 is located within 10 km of the proposed centralised processing plant at Retortillo, as previously said, it has been integrated with planned development of Retortillo and Alameda, which would increase the production capacity of the project to 4.4 Mlb/yr (1 690 tU) and the life of the project to 14 years.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Total reported identified resources are 89.3 Mlb of U_3O_8 (34 350 tU), which would include 12.3 Mlb (4 730 tU) in the measured category, 47.5 Mlb (18 270 tU) as indicated, and 29.5 Mlb (11 350 tU) as inferred.

All reported resources are mineable by conventional open pit.

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 in 1993 and was shut down in December 2000. The licence for a definitive shutdown of the 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 decommissioning plan was presented to regulatory authorities in 2005. However, due firstly to the need to decommission the former Elefante processing plant and restore mines at the same site before decommissioning Quercus and secondly, a 2009 agreement between ENUSA and Berkeley to complete a feasibility study on the state reserves in the Salamanca province, the decommissioning plan was put on standby. Nevertheless, by September 2015, a new plan for decommissioning was presented to the regulatory authorities that is pending approval.

Ownership structure of the uranium industry

Quercus, the only production facility in Spain, still pending decommissioning, belongs to the company ENUSA Industrias Avanzadas, S.A.

Employment in the uranium industry

Employment at the Fe mine totalled 26 at the end of 2016. All of these workers are dedicated to the mining restoration, surveillance and decommissioning programmes.

Berkeley has between 45-55 employees, depending on the activity being carried out. Berkeley's activity is focused on the project development of the Salamanca Project, pending several authorisations.

Future production centres

Berkeley Minera España has announced its intention to bring four potential open-pit uranium mines into production: Retortillo-Santidad, Alameda, Zona 7 and Gambuta (the former three in the Salamanca region and the latter in the Cáceres region). Berkeley applied to the competent authority (autonomous regional government) for an exploitation permit for the Retortillo-Santidad mining project in October 2011 and the mining licence was granted in April 2014, once the Environmental Licence was in place and the Nuclear Safety Council informed favourably. Likewise, according to the nuclear regulation, Berkeley requested the site authorisation for the radioactive facility to the Ministry of Industry, Energy and Tourism (former MINETUR, now MINETAD), in March 2012, which was granted by September 2015, after favourable report of the Nuclear Safety Council, allowing Berkeley to request a construction authorisation. The project, according to Berkeley and including only Retortillo, Zona 7 and Alameda deposits, should have an average production of 4.4 Mlbs U_3O_8/yr (1 690 tU/yr) during a 14-year period of operation.

Secondary sources of uranium

Spain reports mixed oxide fuel and re-enriched tails production and use as zero.

Environmental activities and socio-cultural issues

The present condition of 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 sent to regulatory authorities for approval. A monitoring and control programme has been in place since.
- 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 the same site before turning to the decommissioning of Quercus – owing to the 2009 agreement between ENUSA and Berkeley – this decommissioning plan was put on standby. By September 2015, a new plan for decommissioning was presented to the regulatory authorities and is still pending of approval. During this time, a surveillance and maintenance programme has been in place for the plant and associated facilities.

Uranium mining regulatory regime

In Spain, the mining regime is regulated by the Mines Act (Act 22/1973), modified by Act 54/1980 and by Royal Decree 2857/1978. 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 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 MINETAD (former MINETUR), 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 MINETAD 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 as regards 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 of 12 June 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 MINETAD, 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 have to be set up by the company before starting any mining activity, one for the rehabilitation of the environment affected by the exploitation of the ores and the second one for the management of the generated waste, both to 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.

Regarding decommissioning of the associated milling facilities, those are considered, by 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 and are subject to previous 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. The last amendment of the RINR, by Royal Decree 102/2014, requires the constitution of a financial guarantee before granting this licence.

Uranium requirements

As of 1 May 2017, 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. Through 2010 and 2011, the Spanish government approved ten-year licence renewal for Ascó units 1 and 2, Almaraz units 1 and 2, Vandellós unit 2 and the lone Cofrentes unit. In 2014, the Trillo NPP received its renewal for operation until 2024. Accordingly, uranium requirements for the Spanish nuclear fleet in the coming years will foreseeably range from 1 150 to 1 200 tU/yr.

Supply and procurement strategy

All uranium procurement activities are carried out by ENUSA Industrias Avanzadas S.A. 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. The Spanish legislation leaves uranium exploration and production open to national and foreign companies.

Uranium stocks

Present Spanish regulation provides that a strategic uranium inventory contained in enriched uranium should be held jointly by the utilities that own NPPs. 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

(USD)

	2014	2015	2016	2017 (expected)
Industry* exploration expenditures	5 400 000	9 106 000	5 702 000	4 191 000
Total expenditures	5 400 000	9 106 000	5 702 000	4 191 000
Industry* exploration drilling (m)	8 539	14 400	8 980	6 600
Industry* exploration holes drilled	133	216	108	25
Subtotal exploration drilling (m)	8 539	14 400	8 980	6 600
Subtotal exploration holes drilled	133	216	108	25
Total drilling (m)	8 539	14 400	8 980	6 600
Total number of holes drilled	133	216	108	25

* Non-government.

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/metasediments-hosted	9 800	23 000	23 000	23 000
Total	9 800	23 000	23 000	23 000

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 (%)
Open-pit mining (OP)	9 800	23 000	23 000	23 000	95
Total	9 800	23 000	23 000	23 000	

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 OP	9 800	23 000	23 000	23 000	87
Total	9 800	23 000	23 000	23 000	

Inferred resources by deposit type
(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Granite-related/metasediments-hosted	0	11 350	11 350	11 350
Total	0	11 350	11 350	11 350

Inferred 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	11 350	11 350	11 350	95
Total	0	11 350	11 350	11 350	

Inferred 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	11 350	11 350	11 350	87
Total	0	11 350	11 350	11 350	

Historical uranium production by deposit type
(tonnes U in concentrates)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Granite-related	5 028	0	0	0	5 028	0
Total	5 028	0	0	0	5 028	0

Historical uranium production by production method
(tonnes U in concentrates)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Open-pit mining*	5 028	0	0	0	5 028	0
Total	5 028	0	0	0	5 028	0

* 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 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Conventional	4 961	0	0	0	4 961	0
Other methods*	67	0	0	0	67	0
Total	5 028	0	0	0	5 028	0

* Includes mine water treatment and environmental restoration.

Uranium industry employment at existing production centres

(person-years)

	2014	2015	2016	2017 (expected)
Total employment related to existing production centres	23	21	76	78
Employment directly related to uranium production	0	0	0	0

Net nuclear electricity generation

	2015	2016
Nuclear electricity generated (TWh net)	54.7	56.14

Installed nuclear generating capacity to 2035

(MWe net)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
7 069	7 069	7 069	7 069	7 069	7 069	N/A	N/A	N/A	N/A	N/A	N/A

Annual reactor-related uranium requirements to 2035 (excluding MOX)

(tonnes U)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
1 408	1 163	1 300	1 350	1 150	1 200	1 150	1 200	N/A	N/A	N/A	N/A

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	0	0	0	0	0
Utility	N/A	608	0	N/A	N/A
Total	N/A	608	0	N/A	N/A

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 country-wide 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 was stopped because of declining uranium prices. Targets of this survey were anomalies in the Karoo, in younger surficial sediments, in phosphatic sediments of 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 rekindled after the rise of uranium prices in 2007 and the Tanzanian government issues over 70 licences. Major exploration activities were focused on identification of sandstone-type uranium deposits in the Karoo Basin in southern part and surficial-type deposits in the central part of the country.

Since 2007, three companies discovered four uranium deposits and identified JORC and NI-43/101 compliant uranium resources (measured, indicated and inferred) presented in the following table below. The total in situ resources amounted to 72 756 tU, including 49 596 tU in measured and indicated categories.

In situ uranium resources of Tanzania*

Deposit name	Resources (tU)		Grade (% U)	Estimated in	Type	Subtype	Current owner
	Measured + indicated	Inferred					
Likuyu North		2 346	0.020	2011	Sandstone	Tabular	Uranium Africa Ltd.
Manyoni (Bahi)	1 669	9 477	0.012	2010	Surficial	Lacustrine -playa	Uranium Africa Ltd.
Mtonya		775	0.022	2013	Sandstone	Tabular/ roll-front	Uranium Resources Inc.
Nyota (Mkuju River)	47 927	10 562	0.026	2013	Sandstone	Tabular	Mantra/ Uranium One

Note: The biggest deposit so far is the Nyota deposit, part of the Mantra/Uranium One Mkuju River Project.

Over 80% of the resources total relates to the large Nyota sandstone-type deposit, also known as Mkuju River Project. The systematic exploration at Nyota started in 2007 and in 2009, maiden inferred resources estimate of 13 800 tU (35.9 Mlbs U_3O_8) and a pre-feasibility

* NEA/IAEA estimate based on company reports and other publicly available data.

study were released. In 2011, Mantra Resources was acquired by the Russian Atomredmetzoloto and Uranium One Inc. was appointed as the project operator. An updated resource 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 2012-2013 Mantra Resources continued exploration focused on new resources estimation and engineering optimisation. Drilling activities and historical data analysis resulted in a further resources increase in June 2013 to 58 489 tU (152.1 Mlbs U_3O_8), including 124.6 Mlbs U_3O_8 (47 927 tU) in 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 to Mantra for the project development. During 2013-2014, Mantra Resources main exploration activities were focused on Nyota deposit resources verification and ISL on-site push-pull testing to identify mineralisation principal amenability for ISL mining.

Exploration drilling by Uranex at Likuyu North deposit during 2009-2012 has 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) with grading of 255 ppm U_3O_8 (0.00216% U) at the Mtonya deposit. The uranium mineralisation occurs to depths of 350 m in continuous 30 to 50 metre-wide roll fronts. The resource is potentially amenable to in situ leach recovery mining method.

Recent and ongoing uranium exploration and mine development activities

Major 2015-2016 activities at the Nyota deposit were focused on the additional investigations and resources amenability for ISL miming. In 2015, Mantra Resources obtained official approval and started a more advanced hydrogeology and two spot ISL test works. 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 hydrogeological test confirmed good aquifer permeability. The ISL test was conducted within 10 months in 2016 using two-well pattern. The results confirmed the principle uranium ISL mining amenability for a part of resources located below the water table.

Other companies have not reported uranium-related exploration activities since 2014.

Identified conventional resources (reasonably assured and inferred resources)

There are no major changes in Tanzanian uranium resources since the previous report. The minor changes to the totals compared with the last report are a result of review and verification of the deposit data. Total identified in situ uranium resources from four deposits in Tanzania amount to 72 756 tU. Over 80% of the total relates to the Nyota sandstone deposit at Mkuju River Project. It contains 47 927 tU of 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 is inferred. The remaining inferred resource includes two sandstone-type deposits: the Likuju North with 2 346 tU and the Mtonya deposit, which comprises 775 tU and is potentially in situ recovery (ISL) amenable. An 80% recovery factor was applied for resources conversion into the recoverable category.

Undiscovered conventional resources (prognosticated and speculative resources)

Undiscovered resources are not reported, however there is 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.

Uranium production centre technical details

(As of 1 January 2017)

	Centre #1
Name of production centre	Mkuju River
Production centre classification	Prospective
Date of first production (year)	N/A
Source of ore:	
Deposit name(s)	Nyota
Deposit type(s)	Sandstone
Recoverable resources (tU)	38 342
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

Future production centres

The Mkuju River feasibility study was completed in 2013 and the Tanzanian government issued a special mining licence to Mantra for the project development. Front-end engineering and design (FEED) and Pre-FEED initiatives continued until June 2014.

According to the current definitive feasibility study, uranium 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 outside designed pits and below the water table. One-third of the total resource is below the water table, so the ISL potential could be greater.

Activities for 2015-2016 at the project were 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 for its special mining licence suspension of mining operation due to an unfavourable uranium market. In September 2017, the ministry approved the amendment to the special mining licence programme of mining operations.

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 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 of 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 mandated 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.

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 deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone		38 342	38 342	38 342
Surficial			1 335	1 335
Total		38 342	39 677	39 677

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 (%)
Open-pit mining (OP)		38 342	39 677	39 677	80
Total		38 342	39 677	39 677	80

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 OP		38 342	39 677	39 677	80
Total		38 342	39 677	39 677	80

Inferred conventional resources by deposit type
(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone		8 462	10 947	10 947
Surficial			7 581	7 581
Total		8 462	18 528	18 528

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)		8 462	17 908	17 908	80
In situ leaching acid			620	620	80
Total		8 462	18 528	18 528	80

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		8 462	17 908	17 908	80
In situ leaching acid			620	620	80
Total		8 462	18 528	18 528	80

Short-term production capability
(tonnes U/year)

2015				2020			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	0	0	0	0	0	0	0

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
0	0	0	0	0	2 000	0	2 000	0	2 000	0	3 000

Thailand

Uranium exploration and mine development

Historical review

Uranium exploration was carried out in the early 1970s by the Royal Thai Department of Mineral Resources (DMR). Uranium occurrences were found in various geological environments including sandstone and granite host rocks. Sandstone-type mineralisation occurs in the Phu Wiang district of the Khon Kaen province, north-eastern Thailand. This area had been independently investigated by the DMR. The area was investigated in co-operation with foreign organisations. The granite-hosted uranium occurrences associated with fluorite were discovered in the Doi Tao district, Chiang Mai province and the Muang district of Tak province, northern Thailand. These occurrences have received the most attention.

The most important uranium exploration activity carried out in Thailand is the nationwide airborne geophysical survey completed between 1985 and 1987. The survey was conducted by Kenting Earth Sciences International Limited of Canada, as contractor to DMR.

Recent and ongoing uranium exploration and mine development activities

There are no direct ongoing uranium exploration or mine development activities in any part of Thailand. However, the DMR has been conducting reconnaissance survey activities for rare earth elements in various parts of Thailand since 2011 in order to define high potential areas, emphasising surveying regions where there are granitic weathering crusts. According to the preliminary results, the associated uranium and thorium concentrations, which have accumulated along the weathering profiles, have been determined in some areas.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

There has been no production history of conventional resources and there is no identified conventional resource.

Undiscovered conventional resources (prognosticated and speculative resources)

There are no known undiscovered conventional resources.

Unconventional resources and other materials

There has been active study in uranium extraction from Thailand's seawater since the end of 2011. To date, no U_3O_8 has been separated and purified yet. However, the objective of the study has been to improve the extraction technique, rather than the actual amount and rate of recovery of the uranium.

According to the rare earth exploration activities in the Muang district of Chiang Rai province, unconventional resources of 31 800 metric tons of U (37 500 metric tons U_3O_8) and 101 800 metric tons of Th (138 000 metric tons ThO_2) have been assessed from thick weathering horizons above the underlying granitic basement with average concentrations of 22 and 72 ppm, respectively.

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 is no past or current production facility in Thailand.

Ownership structure of the uranium industry

N/A.

Employment in the uranium industry

None.

Future production centres

In the future, if uranium extraction from seawater becomes economically competitive, the Electricity Generating Authority of Thailand (EGAT) may consider investment in a production centre. Currently, there is no foreseeable plan.

Regulatory regime

There is no regulatory regime for uranium mining in Thailand as there is no uranium industry. However, the Office of Atoms for Peace (OAP) is currently the regulator on the use of atomic energy in Thailand. So, 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 Thailand's Power Development Plan 2015 (PDP 2015), which covers the years 2015-2036, the first two nuclear power plants will be connected to the grid in 2035 and 2036. However, the government has not yet made any formal decision to begin construction. The uranium requirement is based on the assumption that the first plant will start operation in 2035 and the second plant in 2036. Each unit will produce about 1 000 MWe.

Supply and procurement strategy

All fuel assemblies for future nuclear power plants will be purchased from overseas. Currently there is no plan for the future procurement strategy. There is also no plan in the foreseeable future to set up a fuel production plant in Thailand.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

There is no current government policy on uranium. However, there are laws and regulations on the use of atomic energy and radioactive materials. Uranium import and export is included in these laws. The 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).

Installed nuclear generating capacity to 2035

(MWe net)

2011	2012	2013		2015		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
0	0	0	0	0	0	0	0	0	0	0	0	0	1 000

Annual reactor-related uranium requirements to 2035 (excluding MOX)

(tonnes U)

2011	2012	2013		2015		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
0	0	0	0	0	0	0	0	0	0	0	0	0	160

Note: No first core load for the new plant is included in the uranium requirements data. The uranium requirement figures provided do not include plans to build an inventory of uranium.

Turkey

Uranium exploration and mine development

Historical background

General Directorate of Mineral Research and Exploration (MTA)

Uranium exploration in Turkey 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 pitchblende mineralisation was found, but these occurrences were not accepted as economic deposits. Since 1960, studies have been conducted in sedimentary rocks that surround the crystalline rock, and some small orebodies containing autunite and torbernite mineralisation have been found in different parts of the country. In the mid-1970s, the first hidden uranium deposit with black coloured ore, below the water table, was found in the Koprubaşı area of Manisa. As a result of these exploration activities, a total of 9 129 tonnes U_3O_8 (7 740 tU) in situ resources were identified in the Manisa-Köprübaşı (2 852 tonnes U_3O_8; 2 419 tU), Uşak-Eşme (490 tU_3O_8; 415 tU), Aydın-Koçarlı (208 tU_3O_8; 176 tU), Aydın-Söke (1 729 tU_3O_8; 1 466 tU) and Yozgat-Sorgun (3 850 tU_3O_8; 3 265 tU) regions.

Eti Maden İşletmeleri Genel Müdürlüğü (Eti Maden)

State-owned organisation Eti Maden is responsible for a total of six uranium mine sites with uranium resources. Geological exploration has been performed by the General Directorate of Mineral Research and Exploration at these sites in the past. Between 1960-1980, uranium exploration was performed by aerial prospecting, general and detailed prospecting on-site, geologic mapping studies and drilling activities. These uranium sites were transferred to Eti Maden as possible mines, which can be operated by the state under law number 2840 on the "Operation of Boron Salts, Trona and Asphaltite Mines and Nuclear Energy Raw Materials" (10 June 1983).

Recent and ongoing uranium exploration and mine development activities

General Directorate of Mineral Research and Exploration

In 2015, granite, acidic igneous and sedimentary rocks around Denizli and Aydın (an area of approximately 5 000 km^2) were explored for radioactive raw materials. Exploration for radioactive raw materials was also performed in sites licensed by MTA inside Manisa and Nevşehir.

In 2016, granite, acidic igneous and sedimentary rocks around Aydın and Muğla (an area of approximately 5 000 km^2) were explored for radioactive raw materials. Exploration for radioactive raw materials was also performed in sites licensed by MTA inside Nevşehir.

In 2017, granite, acidic igneous and sedimentary rocks around Edirne, Kırklareli and Tekirdağ (an area of approximately 5 000 km^2) will be explored for radioactive raw materials. Exploration for radioactive raw materials will be also performed in sites licensed by MTA inside Nevşehir.

Private sector exploration

Adur, a wholly owned subsidiary of Uranium Resources, Inc of the United States, a Turkish uranium exploration company with current and active drill programmes at the Temrezli and Sefaatli uranium sites, has carried out exploration and resource evaluation drilling with a total of 206 drill holes completed for a total drill advance of over 26 800 m since 2011 in both the Sefaatli and Temrezli projects. Over 16 800 m of drilling was conducted in the Temrezli region. Until now, 123 holes have been completed in the Temrezli project. The drilling in Temrezli, mostly twinning the earlier MTA drill holes but also infill and step-out holes, confirmed work conducted in the 1980s and extended the uranium mineralisation to the north-east over a strike length of more than 3 000 m.

All drill holes were geologically and geophysically logged, the latter using the company's matrix system from Mount Sopris with a probe-type 2PGA-1000 to record gamma ray intensity in counts per second (cps), electrical self-potential and single-point electrical resistance.

In 2014, CSA Global Pty Ltd prepared a JORC compliant mineral resource estimate for the Temrezli deposit of 13.282 Mlb U_3O_8 (6 025 tU) (in situ measured, indicated and inferred) at an average grade of 1 157 ppm U (0.117% U_3O_8).

Preliminary metallurgical bottle-roll leach test work confirmed MTA's earlier work and 93% and 90% uranium recovery was obtained by using an acid or alkali leach method, respectively.

Several hydrological test wells were drilled at Temrezli since 2012 in order to assess the regional groundwater conditions and to conduct hydraulic testing of the mineralised horizons at a scale typically seen at in situ recovery (ISR) operations. Test work was performed by HydroSolutions, a US-based hydrogeological company with considerable experience in groundwater conditions relating to uranium ISR operations throughout the western United States. The test confirmed the aquifer has a sufficient flow rate for ISR mining.

Regional exploration identified new areas of mineralisation at West Sorgun and Akoluk. The rotary and diamond drill programme tested a number of regional sites that are considered prospective for Eocene-aged sediment-hosted uranium mineralisation, similar to what is seen at the Temrezli uranium deposit.

A limited drilling programme in the Sefaatli area confirmed sporadic uranium mineralisation first discovered by the MTA in the 1980s. This is the region's second most significant occurrence of uranium mineralisation with equivalent uranium values up to 1 310 ppm eU_3O_8 for mineralised lenses 1.4 m thick and at depths between 20 and 43 m. These results combined with a high water table and a sandstone-rich stratigraphy, suggest that the mineralisation style appears similar to that observed at Temrezli and thus may be amenable to ISR mining.

Since early stage studies indicate that the Temrezli uranium deposit will be amenable to ISR mining, a preliminary economic assessment contract was awarded to US-based WWC Engineering of Sheridan, Wyoming. The preliminary economic assessment was completed and followed by a preliminary feasibility study that was awarded to Tetra Tech, a US-origin company; the preliminary feasibility study was completed and issued in early 2015, which indicated the project is economically feasible to proceed, with a total expected recovery of 9.7 Mlbs U_3O_8 (9 730 tU) over 12 years, with operating costs of less than USD 17 per lb U_3O_8 (USD 44.2/kgU). Adur initiated the environmental impact assessment process by preparing and submitting a project description to the Ministry of Environment and Urban Planning in 2015. Adur also initiated the permitting process with the Turkish Atomic Energy Commission regarding licensing the Temrezli site as a nuclear facility, since ISR operations are considered to be nuclear facilities. However, in 2016, uranium prices fell sharply to a low of USD 18/lb U_3O_8, which prevented further work on the project. As a result, most of the project-related work has halted. Currently, Adur is waiting for uranium prices to recover. Once the prices begin recovering, the permitting process will be initiated again.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

In 2015 and 2016, an additional 698 tonnes U_3O_8 (592 tU) in situ resources were added to the Manisa-Köprübaşı original estimates by MTA. These recently identified resources occur within the Neogene sediments and limestones.

Identified conventional uranium resources in Turkey, determined from exploration activities performed by MTA in the past, with the addition of JORC compliant resources identified through recent work by Adur exploration, are described in more detail below:

- 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: 415 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: 1 466 tU at 0.08% U_3O_8 (0.068% U) in gneiss fracture zones;

The Temrezli (Yozgat/Sorgun) uranium deposit is one of Turkey's largest and highest-grade uranium deposits, with a JORC compliant mineral resource estimate of 13 282 Mlb U_3O_8 (5 110 tU) at an average grade of 1 157 ppm (0.117%) U_3O_8 and an average depth of 120 m. The mineral resource estimate is as follows in detail:

Class	Tonnes	Grade (ppm U_3O_8)	Contained metal (pounds U_3O_8)	Contained metal (tonnes U_3O_8)
Measured*	2 008 000	1 378	6 100 000	2 767
Indicated*	2 178 000	1 080	5 185 000	2 352
Inferred*	1 020 000	888	1 997 000	906
Total resource*	5 206 000	1 157	13 282 000	6 025

* Numbers rounded for reporting purposes.

Undiscovered conventional resources (prognosticated and speculative resources)

- Temrezli Project: The ongoing exploration and development drilling is to be continued and is expected to increase the resource by a potential of 1-3 Mlb U_3O_8.
- Sefaatli Prospect: Exploration and development drilling conducted in 2015 is expected to increase the known uranium resource values by approximately 5-6 Mlb U_3O_8. The recent drill results include 1.10 m mineralisation at a grade of 2 150 ppm eU_3O_8 from 39 m.

Unconventional resources and other materials

None reported, but grassroots exploration is in place.

Uranium production

Historical review

Research on laboratory-scale production of uranium and the production of nuclear fuel was performed in the past (7th National Development Plan of the Republic of Turkey between 1996 and 2000).

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 assessment (EIA) by the Ministry of Environment and Urbanization. Mine production activities for 25 ha and above, together with the mine enrichment activities, are evaluated within the scope of Annex-I list of the EIA by-law.

Regulatory regime

The Turkish Atomic Energy Authority (TAEK), as the regulatory body of Turkey, undertakes all the regulatory activities concerning nuclear and radiation safety together with the co-ordination and support of research and development activities in the nuclear field.

TAEK was established by the Act of Turkish Atomic Energy Authority, which was issued in the Official Gazette number 17753 on 13 July 1982 as a government body reporting to the Prime Minister. TAEK had been affiliated with the Ministry of Energy and Natural Resources since 2002.

TAEK is responsible for defining safety measures for all nuclear activities and for drawing up regulations concerning radiological protection and the licensing and safety of nuclear installations.

In Turkey, nuclear installations are licensed by TAEK regarding nuclear safety, security and radiological protection issues. The licensing procedure for nuclear fuel cycle facilities is laid out in the Decree on Licensing of Nuclear Installations. According to this decree nuclear fuel cycle facilities are:

- mining, milling and refining facilities;
- conversion facilities;
- enrichment facilities;
- nuclear fuel element fabrication facilities;
- reprocessing facilities for used fuel elements;
- radioactive waste management facilities for processing the radioactive wastes (including final storage).

The licensing procedure for nuclear fuel cycle facilities is initiated by an application from the owner to be recognised as such. The licensing process comprises three main stages in succession: site licence, construction licence and operating licence. There are several permits functioning as hold points during the licensing process, such as a limited work permit, start test operating, pre-operational test permit, full capacity work permit, permission to restart operations and permission to modify the installation. For each authorisation, documents required for review and assessment of TAEK are defined in the decree. The authorisation process for the decommissioning stage is not defined in the decree however; authorisation for decommissioning will be defined in a draft law and other relevant legislation.

The Law on Mining (number 3213) of 4 June 1985 includes articles for environmental remediation during and after mining activities. Mining organisations must submit a financial bond for environmental remediation prior to the issuance of a mining licence.

After mining activities have been completed and the site has been environmentally remediated, the submitted financial bond is returned to the mining organisation. In case the financial bond is not sufficient to implement environmental remediation activities, additional costs are requested from the operator according to law number 6183.

Uranium requirements

There are no nuclear power plants in operation, under construction or decommissioned in Turkey. However, Turkey has been considering building a nuclear power plant since the 1970s. Rising energy demand, import dependence and industrial activity are the driving forces behind Turkey's move towards developing a civil nuclear power generation programme. Turkey's recent efforts in this area can be characterised as a first-of-a-kind approach in the nuclear sector and has been referred to as an intergovernmental agreement (IGA) model, with long-term contracts in the frame 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.

An IGA, signed with Russia for the construction of four VVER-1200 units at the Mediterranean Akkuyu site, entered into force on 21 July 2010. The Russian side established a "project company" in Turkey, it finished site surveys and environmental impact assessment studies and developed design documentation on the Akkuyu Nuclear Power Plant (NPP). In March 2017, the "project company" made a construction licence application to TAEK. It is planned to start construction of the first NPP unit in the third quarter of 2017, while pouring of concrete is planned in the first quarter of 2018 after obtaining a construction licence from TAEK. Currently the Russian side owns 100% of the shares of the power plant and will maintain the majority of the shares during the NPP's entire operation lifetime.

Turkey also signed an IGA with Japan on 3 May 2013 to build four ATMEA1 units at the Black Sea Sinop site. This agreement was ratified by the Turkish parliament on 1 April 2015 together with the respective annexes. For the Sinop NPP project, a memorandum of understanding was signed between the Ministry of Energy and Natural Resources of the Republic of Turkey (MENR) and the Ministry of Economy, Trade and Industry of Japan (METI) on 7 September 2016. The technical and economic feasibility studies for the Sinop NPP will be completed in March 2018.

Another memorandum of understanding was signed between MENR and the China National Energy Administration for Civil Nuclear Cooperation on 29 June 2016. The site selection for the third NPP project is expected to be completed in the short term.

Supply and procurement strategy

In order to promote private sector investments for the construction and operation of NPPs, the Law on the Construction and Operation of Nuclear Power Plants and Energy Sale, numbered 5710 and dated 9 November 2007 ("Nuclear Law") was enacted in Turkey. Article 3 of the Nuclear Law states that the procedures and principles regarding fuel supply shall be prepared by the Ministry of Energy and Natural Resources and set up in a regulation that shall come into force with the approval of the Council of Ministers.

Provisions related to fuel supply for the Akkuyu NPP have been included under the IGA signed with Russia for the construction of four VVER-1200 units. Under Article 12 of this agreement, it is stated that nuclear fuel shall be sourced from suppliers on the basis of long-term agreements between the "project company" established by the Russian side in Turkey and the suppliers. Currently, the "project company" is negotiating with the

Russian company TVEL (the nuclear fuel producer) in order to sign the long-term contract on a lifetime supply of fresh nuclear fuel for the Akkuyu NPP. The nuclear fuel will be of Russian origin.

Provisions related to fuel supply for the Sinop NPP will be established once the feasibility study is completed.

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" numbered 2840 and dated 10 June 1983 states that the exploration and operation of such mines are carried out by the state.

Mining Law numbered 3213 (dated 4 June 1985) classifies uranium reserves under the 6th group of mines together with all other radioactive minerals and supersedes law number 2840. Article 49 of law number 3213 states that provisions under law number 2840 are preserved, although private companies are now allowed to explore for and operate thorium and uranium mines. Article 50 states that exploration and operation of thorium and uranium mines are subject to this law and the minerals extracted can only be sold to entities determined by the Council of Ministers.

Uranium exploration and development expenditures and drilling effort – domestic

(TRY [Turkish lira] – excluding VAT)

	2014	2015	2016	2017 (expected)
Industry* exploration expenditures	5 452 657	1 500 000		
Government exploration expenditures	2 595 000	1 767 725	643 394	5 000 000
Industry* development expenditures	2 336 851	15 000 000		
Government development expenditures				
Total expenditures	10 384 508	18 267 725	643 394	5 000 000
Industry* exploration drilling (m)	6 466	3 000		
Industry* exploration holes drilled	61	30		
Industry* exploration trenches (m)				
Industry* exploration trenches				
Government exploration drilling (m)	14 591	4 999	3 489	11 500
Government exploration holes drilled	91	34	19	75
Government exploration trenches (m)				
Government exploration trenches				
Industry* development drilling (m)	2 877	4 500		
Industry* development holes drilled	23	30		
Government development drilling (m)				
Government development holes drilled				
Subtotal exploration drilling (m)	21 057	7 999	3 489	11 500
Subtotal exploration holes drilled	152	64	19	75
Subtotal development drilling (m)	2 877	4 500		
Subtotal development holes drilled	23	30		
Total drilling (m)	23 934	12 499	3 489	11 500
Total number of holes drilled	175	94	19	75

* Non-government.

The law on the "Amendment of mining law and other laws" numbered 6592 and dated 18 February 2015 has reclassified the uranium reserves under the 4th group of minerals together with all radioactive minerals. With this amendment the radioactive minerals are placed in the same group with complex minerals.

Uranium stocks

Uranium stocks in Turkey consist of natural uranium used by the Çekmece Nuclear Research and Training Center affiliated to Turkish Atomic Energy Authority for research purposes.

Reasonably assured conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone		7 000	7 000	7 000
Metamorphite		1 466	1 466	1 466
Carbonate		538	538	538
Total		9 004	9 004	9 004

* In situ resources.

Reasonably assured conventional resources by production method

(tonnes U*)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Open-pit mining (OP)		5 067	5 067	5 067
Unspecified		3 937	3 937	3 937
Total		9 004	9 004	9 004

* In situ resources.

Reasonably assured conventional resources by processing method

(tonnes U*)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Heap leaching** from OP		5 067	5 067	5 067
Unspecified		3 937	3 937	3 937
Total		9 004	9 004	9 004

* In situ resources.

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

Inferred conventional resources by deposit type

(tonnes U*)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone		696	696	696
Total		696	696	696

* In situ resources.

Inferred conventional resources by production method

(tonnes U*)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Unspecified		696	696	696
Total		696	696	696

* In situ resources.

Inferred conventional resources by processing method

(tonnes U*)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Unspecified		696	696	696
Total		696	696	696

* In situ resources.

Installed nuclear generating capacity to 2035

(MWe net)

2017		2020		2025		2030		2035	
Low	High	Low	High	Low	High	Low	High	Low	High
0	0	0	0	1 200	2 400	N/A	N/A	N/A	N/A

Annual reactor-related uranium requirements to 2035 (excluding MOX)

(tonnes U)

2017		2020		2025		2030		2035	
Low	High	Low	High	Low	High	Low	High	Low	High
0	0	0	0	109	131	N/A	N/A	N/A	N/A

Total uranium stocks

(tonnes natural U-equivalent)

Holder	Natural uranium stocks in concentrates	Enriched uranium stocks	Enrichment tails	LWR reprocessed uranium stocks	Total
Government	1.97				
Total	1.97				

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 Krivoy Rog ore basin. The Pervomayskoye and Zheltorechenskoye uranium deposits were discovered in the 1950s. These deposits were mined out in 1967 and 1989, respectively.

During the same period of time, the first 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. Deposits such as Michurinskiy, Vatutinskiy, Severinskiy, Central and Novokonstantinovskiy were discovered in this area.

Metasomatite-type deposits make up the main part of uranium resources of Ukraine. The average ore grade in these deposits is 0.1-0.2% U.

The second uranium resources source is sandstone-type deposits, with an average ore grade between 0.02 and 0.06% U. They are suitable for mining by ISL.

Ongoing uranium exploration and mine development activities

During 2014, 2015 and 2016, SE Kirovgeology finalised the geological survey mapping at a scale of 1:10 000 and 1:25 000 on all exploration targets mentioned in the Red Book 2016 report. Starting with 2017, all exploration will be carried out around the existing uranium mines. The evaluation of potential thorium resources in the Ukrainian Shield rocks will continue.

Ukraine thorium deposit types and speculative resources

(tonnes Th)

Deposit type	Resources tTh (in situ)
Carbonatite	
Placer	
Granite-related	53 940
Alkaline rocks	37 037
Metasomatite	150 439
Metamorphite	10 253
Other	
Total	251 669

The Ukrainian state and private companies do not carry out any exploration for uranium in other countries. Foreign or private companies do not carry out any uranium exploration activities in Ukraine.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

As of 1 January 2017, identified uranium resources (reasonably assured and inferred resources) recoverable at costs <USD 260/kgU were 219 065 tU. Uranium resources recoverable at costs <USD 80/kgU were 58 268 tU. Mining and processing losses are taken into account in these figures.

The main uranium resources of economic interest are found in two types of deposits:

- Metasomatite-type, monometallic 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 (17.3 thousand km^2). The uranium ore grade is 0.01-0.06% U. In addition to uranium, in these ores, molybdenum, selenium and rare earth elements of the lanthanide group occur. These deposits are suitable for mining by ISL.

Undiscovered resources (prognosticated and speculative resources)

After review, undiscovered resources were recalculated and amount to 277 500 tU, including:

- Prognosticated resources amount to 22 500 tU and are found at the flanks of identified deposits.
- Speculative resources amount to 255 000 tU. The calculation is based on the data from the uranium prognostic map (scale of 1:500 000), which was drawn up by SE Kirovgeology. Speculative resources are subdivided according to geological types as follows:
  - 133 500 tU metasomatite-type;
  - 20 000 tU in sandstone deposits in 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

The mining of uranium ore began in 1946 at the deposits of Pervomayskoye and Zheltorechenskoye, using conventional underground methods.

In 1949, the first production began in Ukraine at a uranium processing plant, Pridneprovskiy Chemical Plant (PCP), in the town of Dneprodzerzhinsk.

In 1951, the government founded the Vostochnyi Mining-process Combinat (VostGOK) in Zheltiye Vody in the Dnepropetrovsk region, for the mining and processing of ore from Pervomayskoye and Zheltorechenskoye deposits. The Pervomayskoye deposit was mined out in 1967 and the Zheltorechenskoye deposit was mined out in 1989.

In 1959, the second uranium processing plant was built in Zheltiye Vody.

Today, VostGok operates uranium production facilities in the Central Ukrainian ore province. The company is mining the Michurinskiy (3 km to south from Kirovograd), Central (on the south-east end of Kirovograd), Vatutinskiy (near the town Smolino) and Novokonstantinovskiy (40 km west of Kirovograd) deposits. VostGOK plans to start mining the Severinskiy (4 km north of Kirovograd) deposit in 2020.

The Michurinskiy deposit was discovered in 1964. In 1967, construction of the Ingulskiy mine began. The average ore grade of these ore bodies is 0.1% U. Radiometric sorting of ore at the mine increases the uranium content in the ore delivered to the process plant up to 0.1-0.2% U. Two shafts, each 7 m in diameter, were sunk. The ore is hoisted through the northern shaft with two buckets with a loading capacity of 11 t. The southern shaft is used for transporting workers and provision, and for other technical aims. A ventilation shaft supplies 480 m^3 of fresh air per second to the underground mine works. Mining is conducted in blocks of 60-70 m in height at depths of 90 m, 150 m and 240 m below the surface.

The Central deposit is developed by two shafts to horizons 380 m and 1 000 m. It is connected to the Michurinskiy deposit by an underground transport tunnel 5.2 km long at the 300 m level. Ore is delivered through the tunnel to the elevating shaft of the Ingulskiy mine.

The Vatutinskiy deposit was discovered in 1965, and in 1973, construction of the Smolinskiy mine began. The industrial infrastructure of the Smolinskiy mine is situated near the town of Smolino, 80 km west of Kirovograd. Mined rock is delivered to the surface by two shafts (the "main" and "additional"). Both shafts are sunk to a depth of 460 m. The lower part of the deposit, trending to the depth 640 m, was stripped by two blind shafts ("blind-1" and "blind-2").

Stationary compressor terminals were installed on the surface of each shaft to produce compressed air used for blast drilling operations. Within each cleaned block, after the blasting, ore is moved to a loading pocket, unloaded from mine cars and transported by electric-powered trams to the main shaft, where it is crushed before being hoisted to the surface. Radiometric ore-sorting, storage, loading to railway carriages and shipping for process are carried out on the surface. Mined-out space is backfilled by hardening hydro-packing.

The Novokonstantinovskiy deposit has been developed by three shafts to horizons 480 m and 1 100 m below the surface. Mining of the Novokonstantinovskiy deposit began in 2011.

On the Severinkovskiy and Podgayscevskiy deposits two shafts were sank down to a depth of 650 m during exploration.

ISL uranium mining began in Ukraine in 1961. From 1966 to 1983, uranium in the Devladovskoye and Bratskoye deposits was extracted by using sulphuric acid ISL at depths of about 100 m. At present, both deposits are under monitoring.

The government still plans to mine Safonovskiy and Sadoviy deposits by ISL method.

Status of production facilities, production capability, recent and ongoing activities and other issues

Hydrometallurgical processing plant

The VostGOK hydrometallurgical process plant is situated in the town of Zheltiye Vody. The annual capacity of the plant is 1.5 Mt of ore. The plant's staff is made up of 30 to 35 persons per shift. The ore is transported to the plant by specially equipped trains from two mines – Ingulskiy (100 km west) and Navokonstantinovskiy (130 km west). After crushing and radiometric sorting, the ore is leached in autoclaves using sulphuric acid at the temperature of 150 to 200°C at 20 atmospheres for 4 hours. Acid consumption is

80 kg/t of ore. For the uranium extraction, ion-exchange resin is used. After washing with a mixture of sulphuric and nitric acids, the uranium-bearing solution is subjected to further concentration and purification by solvents extraction. Ammonium gas is used for precipitation. The dewatered precipitate is subjected to calcination at 800°C until a product of dark colour is obtained.

Innovation techniques in uranium production

Metasomatite-type deposits in Ukraine have a uranium ore grade of about 0.1% U, with mineralisation (uraninite, brannerite, coffinite, nasturane) disseminated throughout the volume of ore in steeply dipping ore bodies. Since the mines are located some 100 km and 150 km from the hydrometallurgical plant, transportation costs add to mining and processing costs.

Mining is carried out with the underground method. Processing of ore begins from crushing underground, followed by extraction by sulphuric acid leaching in autoclaves. Low-grade uranium ore, combined with an expensive mining and ore process technology, makes uranium production unprofitable at current market prices. In order to decrease production costs, innovative technologies are being introduced, such as underground radiometric sorting, in-place leaching, heap leaching and reprocessing of materials in dumps of operating mines.

A multistage radiometric separator, designed by VostGOK for different sized piles, allows sorting of both mined ore and material in mine dumps. After the radiometric sorting, uranium content in the ore may reach 0.03-0.3% U. The uranium content in "tailings" following this sorting is 0.006% U or less.

The rocks in the dumps have an average X-ray specific activity at the level of 1 500-1 600 Bk/kg. After the radiometric sorting, rocks going to the waste dump have X-ray levels of only 350-650 Bk/kg and thus can be used as second class construction material.

Separators may be installed both on the surface and underground. The capacity of two separators (for different machine classes) is 1 500 thousand tons of ore per year.

Three products are obtained after the radiometric separation of dump rocks:

- 30% – uranium ore grading 0.05-0.06% U;
- 55% – "tailings" with specific activity less than 740 Bk/kg for use as second class construction material;
- 15% – inert material for use as hydro-backfill of mined-out space in the mine.

After the crushing, uranium ore undergoes heap leaching (HL). Extraction of uranium during HL is about 70-75% U per year of leaching. The cost of 1 kg of U_3O_8 after HL is 62% of the cost of processing 1 kg U_3O_8 at the hydrometallurgical process plant.

Low-grade ore bodies with a uranium content of 0.04-0.06% U are mined using the in-place leaching (IPL) method. A special technology of explosion has been used for disaggregating the ore blocks. The uranium concentration in pregnant solutions changes from 50 mg/l at the beginning to 1 000 mg/l at the end of leaching the disaggregated ore blocks. The cost of IPL is 58% less than conventional technology of ore mining and processing. Three blocks have been prepared now for mining by the IPL method.

Although most metasomatite-type ore deposits are suitable for HL, finely disseminated uranium mineralisation, as in the case of highly durable abilities of low permeability, is necessary for effective HL. Therefore, the degree of crushing is the most important parameter, which determines the degree of uranium recovery and permeability. 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.

Uranium production centre technical details

(as of 1 January 2017)

	Centre #1	Centre #2	Centre #3	Centre #4	Centre #5
Name of production centre	Ingulskiy mine	Smolinskiy mine	Novokonstantinovskiy mine	Safonovskiy mine	Severinskiy mine
Production centre classification	Existing	Existing	Existing	Planned	Planned
Date of first production (year)	1968	1973	2011	2019	2020
Source of ore:					
Deposit name(s)	Michyrinskiy, Centralniy	Vatutinskiy	Novokonstantinovskiy	Safonovskiy	Severinskiy Podgaytsevskiy
Deposit type(s)	Metasomatic	Metasomatic	Metasomatic	Sandstone	Metasomatic
Recoverable resources (tU)	59 465	4 923	91 884	2 248	48 120
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	15 000 litre/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
Other remarks					
Plans for extension					

The heaps contain ore grades of 0.050-0.080% U, obtained as a result of the dump radiometric sorting. The volume of the heap is 40 000 tonnes of ore. At the Vatutinskiy deposits, the HL site has been built. On the site, there are four heaps with total volume 160 kt of ore. At the Michurinskiy deposits HL is still in the planning stage.

Ownership of uranium industry

All enterprises in the uranium industry (geology, mining, fuel processing) are owned by the state. The mining and processing enterprise VostGOK is part of the Department Strategic Policy of Investments and Nuclear Energy Complex in the Ministry of Energy and Coal Industry of Ukraine. SE "Kirovgeology" is responsible for the balance of uranium mineral resources of Ukraine (geological survey, evaluation and exploration of deposit) and is part of the State Service of Geology and Resources of Ukraine, the Ministry of Ecology and Natural Resources.

In April 2008, the government of Ukraine founded a new entity called "Nuclear Fuel" through the merger of existing organisations in the sphere of the directorate of the Ministry of Fuel and Energy.

Secondary sources of uranium

- mixed oxide fuel (MOX) has never been produced in Ukraine or used in its NPPs;
- re-enrichment tails have never been produced or used in Ukraine;
- reprocessing spent nuclear fuel is not conducted in Ukraine nor has it been used.

Environmental activities and socio-cultural issues

The main environmental impact of uranium production at mines result from ore stockpiles, tailings, radiometric ore-sorting sites, waste dumps, ventilation systems infrastructure, and transport (railways, technological motor roads).

The main environmental impact 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. In order to minimise the environmental impacts, permanent monitoring is being conducted.

On the hydrometallurgical plant (Zheltye Vody), process water is recycled for the technological process. There are two tailings impoundments, one situated 9 km from the hydrometallurgical plant consisting of two sections (135 and 163 ha), and the second 0.5 km from the plant (55 ha). The latter has been used, and reclamation is ongoing.

There are issues connected with the decommissioning of uranium mining and uranium processing enterprises.

At the closed Prydnieprovskiy Chemical Plant, there are nine tailings impoundments (covering a total area of 268 ha containing 42 Mt of wastes) with total activity of 75 000 Ci (Curie) and some buildings and other facilities are contaminated by radioactive elements. The Cabinet of Ministers of Ukraine initiated a state programme for reclamation with state funds amounting to UAN 22.3 million (Ukrainian hryvnia, about USD 4.5 million) since 2005.

The total cost of improving radiological protection at all enterprises of the atomic industry and all contaminated areas resulting from 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

Uranium production in Ukraine meets 30% of domestic nuclear energy requirements. Nuclear fuel requirements have always been provided by importing fuel from Russia (provided by TVEL). Annual fuel loadings of the 4 operating NPPs (comprised of 13 VVER-1000 units and 2 VVER-440 units) are 15 sets of fuel elements at a total cost of about USD 300 million. The government has been set a target that by 2020, 100% of uranium requirements for the Ukrainian nuclear fleet will be met by domestic production.

Installed nuclear generating capacity by 2035

At present, 15 reactors are operating at 4 NPPs: 6 VVER-1000 units at Zaporozhskiy, 3 VVER-1000 units at South-Ukrainian, 2 VVER-1000 and 2 VVER-400 units at Rovenskiy and 2 VVER-1000 units at Khmelnitskiy.

The national programme for nuclear energy production foresees to produce about 45% of electricity by nuclear power plants by 2030. To fulfil this requirement, annual nuclear energy production will have to increase to 75.2 billion KWe/h. This will require life extension of operating NPPs, the construction of 12 additional units (with 10 of these having a total capacity 1 500 MWe) and during this time frame, the decommissioning of 12 NPPs that will be at the end of their operational lifetime.

Uranium policy, uranium stock and uranium price

Ukrainian government policy is increasing the production of natural uranium and improving the foreign investment climate in order to develop uranium projects in Ukraine.

Resolution N1004, the “Complex Program of Nuclear Fuel creation in Ukraine” (23 September 2009) was approved by the Cabinet of Ministers. It specifies that uranium enrichment will be conducted abroad.

On 17 April 2009, the Cabinet of Ministers of Ukraine passed Resolution N 650-p “Some Questions of Liquidation and Organisation of State Mergers in the Nuclear Industry”. The resolution founded the company “Nuclear Fuel”, by the merger of all state enterprises and research and design institutes in the field of the nuclear fuel cycle. The aim of the resolution is to improve investment conditions.

The joint venture “plant for the manufacture of nuclear fuel for nuclear reactors VVER-1000 type” was established in Ukraine in October 2011. The plant is situated in the Kirovograd region, close to “Vatutinskiy” uranium deposits. In the JV, 50% +1 share belongs to the state Russian company TVEL.

The technical economical assessment for construction of the plant was approved by the Cabinet of Ministers of Ukraine (statement N437 dated 27 June 2012). The total cost of construction was estimated at UAH 3.7 billion. The schedule of construction was as follows: Stage I was commissioned in 2015 and stage II was planned for 2020. Planned capacity of the plant was 800 nuclear fuel sets per year. However, the construction of the plant has been postponed.

The decision to build in the zone of alienation of the Chernobyl NPP, the centralised storage facility of the used fuel from domestic reactors VVER, has been made (Law of Ukraine N4384, dated 2 September 2012). Initially, the commissioning was planned for 2016. Currently, the storage facility is under construction by the company “Holtec International” USA.

In September 2012, the decision to build two NPPs, N3 and N4 on the Khmelnitsky site, in collaboration with Russia was made (the Law of Ukraine N4384 dated 2 September 2012). Commissioning of these units was initially set for 2018 (N3), and 2020 (N4), respectively. Meanwhile, the new build activities have been postponed.

The government of Ukraine made the decision to build a new process plant for the Novokonstantinovskiy uranium deposit (Resolution of the Ministry of Energy and Coal Industry of Ukraine N 933-P dated 24 February 2012). The process plant production capacity is 1 500 000 tons of ore per year or 2 000 tons of uranium. There is no activity at the present time.

Uranium exploration and development expenditures and drilling efforts – domestic

(UAH million as of 1 January 2017)

	2014	2015	2016	2017 (preliminary)
Industry* exploration expenditures	0	0	0	0
Government exploration expenditures	10.3	7.7	5.2	5.8
Industry* development expenditures	0	0	0	0
Government development expenditures	5.6	6.9	6.9	8.7
Total expenditures	15.9	14.6	12.1	13.9
Industry* exploration drilling (m)	0	0	0	0
Industry* exploration holes drilled	0	0	0	0
Government exploration drilling (m)	856	802	822	684
Government exploration holes drilled	7	2	2	2
Industry* development drilling (m)	0	0	0	0
Industry* development holes drilled	0	0	0	0
Government development drilling (m)	11 197	11 097	10 307	11 435
Government development holes drilled	201	386	348	342
Subtotal exploration drilling (m)	856	802	822	584
Subtotal exploration holes drilled	7	2	2	2
Subtotal development drilling (m)	11 197	11 097	10 307	11 435
Subtotal development holes drilled	201	386	348	342
Total drilling (m)	12 053	11 899	11 129	12 119
Total number of holes drilled	208	388	350	210

* Non-government

Reasonably assured conventional resources by deposits type

(tonnes U)

Deposits type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Proterozoic unconformity	0	0	0	0
Sandstone	0	6 730	6 730	6 730
Metasomatite	0	34 606	74 443	131 001
Total	0	41 336	81 173	137 731

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		34 606	74 443	131 001	88.4
Open-pit mining	0	0	0	0	0.0
In situ leaching acid		6 730	6 730	6 730	75.0
In situ leaching alkaline	0	0	0	0	0.0
Co-product and by-product	0	0	0	0	0.0
Unspecified	0	0	0	0	
Total		41 336	81 173	137 731	

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	34 606	74 443	131 001	88.4
In situ leaching acid		6 730	6 730	6 730	75.0
Total		41 336	81 173	137 731	

Inferred conventional resources by deposit type
(tonnes U)

Deposits type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Sandstone		897	897	897	75.0
Metasomatite		16 035	31 982	80 437	88.4
Total		16 932	32 879	81 334	

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		16 035	31 982	80 437	88.7
In situ leaching acid		897	897	897	75.0
Total		16 932	32 879	81 334	

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 UG		16 035	31 982	80 437	88.7
In situ leaching acid		897	897	897	75.0
Total		16 932	32 879	81 334	

Prognosticated conventional resources
(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
0	8 400	22 500

Speculative conventional resources
(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	120 000	255 000

Historical uranium production by deposits type
(tonnes U in concentrate)

Deposits type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (preliminary)
Sandstone	3 925	0	0	0	3 925	-
Granite-related	35 000				35 000	
Metasomatite	89 925	954	824	808	92 511	950
Total	128 850	954	824	808	131 436	950

Historical uranium production by production method
(tonnes U in concentrate)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (preliminary)
Open-pit mining*	10 000	-	-	-	10 000	-
Underground mining*	104 925	954	824	808	107 511	950
In situ leaching	3 925	-	-	-	3 925	
Co-product/by-product	10 000	-	-	-	10 000	-
Total	128 850	954	824	808	131 436	950

* Pre-2011 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 2013	2014	2015	2016	Total through end of 2016	2017 (preliminary)
Conventional	128 786	935	787	777	132 285	923
In-place leaching*	16	2	2	1	21	2
Heap leaching**	48	17	35	30	130	25
Total	128 850	954	824	808	131 436	950

* Also known as stope leaching or block leaching.

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

Ownership of uranium production in 2016

Domestic				Abroad				Total	
Government		Private		Government		Private			
(t U)	(%)	(t U)	(%)	(t U)	(%)	(t U)	(%)	(t U)	(%)
808	100							808	100

Uranium industry employment at existing production centres

(persons/years)

	2014	2015	2016	2017 (preliminary)
Total employment at existing production centres	4 500	4 555	4 426	4 450
Direct employment at uranium production	1 610	1 600	1 585	1 550

Short-term production capability at existing, committed and planned centres by prime-cost from USD 80/kg (I) and USD 130/kg (II) up to 2035

(tonnes U/year)

2017				2020			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
350	350	950	N/A	N/A	N/A	2 480	2 480

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
N/A	N/A	2 000	N/A	N/A	N/A	1 700	N/A	N/A	N/A	N/A	N/A

Net nuclear electricity generation

	2015	2016
Net nuclear electricity generation (TWh net)	87.8	81.2

Installed nuclear generating capacity till 2035

(GWe net)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
13.8	13.8	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 till 2035 (excluding MOX)

(tonnes U)

2013	2014	2015		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
2 480	2 480	2 480	2 480	2 480	2 480	3 020	3 660	3 600	4 800	4 800	5 300

United Kingdom

Uranium exploration and mine development

Historical review

Some uranium mining occurred in Cornwall, as a sideline to other mineral mining, especially tin, in the late 1800s. Systematic exploration occurred in the periods 1945-1951, 1957-1960 and 1968-1982, but no significant uranium reserves were located.

Recent and ongoing uranium exploration and mine development activities

Exploration in overseas countries is carried out by private companies operating through autonomous subsidiary or affiliate organisations established in the country concerned (e.g. Rio Tinto).

There were no industry expenditures reported for domestic exploration from 1988 to the end of 2016, nor were there any government expenditures reported for exploration either domestic or abroad. Since 1983, all domestic exploration activities have been halted.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

The reasonably assured resource and inferred resources are essentially zero. There has been no geological appraisal of the UK uranium resources since 1980.

Undiscovered conventional resources (prognosticated and speculative resources)

There are small quantities of in situ undiscovered resources as well as speculative resources. Two districts are believed to contain uranium resources: the metalliferous mining region of south-west England (Cornwall and Devon) and north Scotland including Orkney.

Unconventional resources and other materials

None to report.

Uranium production

The United Kingdom is not a uranium producer.

Secondary sources of uranium

Production and/or use of mixed oxide fuels

The United Kingdom no longer produces MOX fuel, and the Sellafield MOX Plant is no longer operational – it closed in 2011.

Production and/or use of re-enriched tails

Urenco has a long-term contractual agreement to upgrade tails material, but considers this to be commercially confidential. In November 2012, the Capenhurst site (the location of a gaseous diffusion enrichment facility that was closed in 1982), including legacy uranium enrichment tails, was transferred to Urenco, operator of the adjacent centrifuge enrichment plant. An agreement between the UK Nuclear Decommissioning Authority (NDA) and Urenco was signed for the processing of these NDA-owned legacy materials.

Uranium requirements

On 1 January 2017, there were 15 licensed reactors with a combined capacity of 8.9 GW operating in the United Kingdom. On the basis of current scheduled closure rates, most of the UK's existing nuclear power stations will have shut by 2030. Successive UK governments have taken a series of facilitative actions to encourage nuclear new build, and industry has set out proposals to develop 18 GW of new nuclear power at six sites in the United Kingdom, broken down as follows:

- Électricité de France (EDF) and China General Nuclear Power Corporation (as NNB Generation Company – NNBG) will build two EPR reactors at Hinkley Point C (3.2 GW) and propose plans for two more at Sizewell (3.2 GW). The two companies also plan to build two HPR1000 reactors at Bradwell (2.2 GW).
- Horizon Nuclear Power, owned by Japan's Hitachi-GE Nuclear Energy Ltd, proposes to build two advanced boiling water reactors (ABWR) at each of its sites in Wylfa and Oldbury (2.7 GW each).
- NuGen, a consortium of Japan's Toshiba-Westinghouse and France's ENGIE (Toshiba will shortly be purchasing ENGIE's shares in the consortium), proposes to build three AP1000 reactors (3.4 GW) at Moorside near Sellafield.

The UK government decided to proceed with Hinkley Point C in September 2016, signing contracts with NNBGenco, including directing the Low Carbon Contracts Company (LCCC) to offer a "contract for difference" (CfD) for Hinkley Point C. Key terms include a 35-year CfD, the "strike price" of GBP 92.50/megawatt-hours (MWh) (2012 figures). EDF expects the plant to be operational in 2025. Generic design assessment (GDA) is one of the facilitative actions set out in the Nuclear White Paper 2008 and is undertaken by the UK Office for Nuclear Regulation (ONR) and the UK Environment Agency. GDA is a voluntary process that allows regulators to begin consideration of the generic safety, security and environmental aspects of designs for NPPs prior to applications for site-specific licensing and planning consents. Any reactor deployed in the United Kingdom must meet the UK's robust and independent regulatory requirements. This includes meeting design safety requirements via the GDA process. The AP1000 (to be used by NuGen at Moorside) completed the GDA process in March 2017, and the ABWR (to be used by Horizon at two sites, Wylfa and Oldbury) is expected to complete GDA by the end of 2017. The HPR1000 (proposed for use at Bradwell) entered the GDA process in January 2017. For new nuclear build, Section 45 of the

Energy Act 2008 requires prospective nuclear operators to submit a funded decommissioning programme (FDP) for approval by the Secretary of State for the Department for Business, Energy and Industrial Strategy (BEIS). The UK government published FDP statutory guidance in December 2011 to assist operators to develop their programmes. The purpose of FDP is to ensure operators set aside sufficient funds to cover the cost of decommissioning and waste management including their share of the costs of geological disposal.

The government received an FDP submission from NNBG in March 2012 and discussions were concluded in October 2015 whereby the FDP for Hinkley Point C was approved by the UK government. In the near to medium future, the uranium requirements in the United Kingdom will be difficult to predict owing to the proposed new build programme and the potential for commercial operators of existing power plants to obtain regulatory approval for life extensions beyond their current scheduled closure dates.

Uranium policies, uranium stocks and uranium prices

Uranium stocks

The UK uranium stockpile practices are the responsibility of the individual bodies concerned. Actual stock levels are commercially confidential.

Uranium prices

Uranium prices are commercially confidential in the United Kingdom.

United States

Uranium exploration and mine development

Historical review

From 1947 through 1970, the United States (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 being brought into production by private industry and production capability had increased sufficiently to meet projected requirements. Federal exploration programmes were ended at that time.

Private exploration by the US uranium industry increased throughout the 1970s in response to rising prices and the projected large demand for uranium to fuel an increasing number of nuclear reactors being built or planned for civilian electric power stations. Total annual surface drilling peaked in 1978.

Exploration has been primarily for sandstone-type uranium deposits in districts such as the Grants Mineral Belt and Uravan Mineral Belt of the Colorado Plateau, the Wyoming basins and Texas Gulf Coastal Plain region.

Recent and ongoing uranium exploration and mine development activities

From a recent peak of USD 352.9 million in 2012, US uranium expenditures decreased by 52% to USD 169.9 million in 2016. In 2016, expenditures for uranium surface drilling totalled USD 22.3 million, down USD 6.4 million (22%) from expenditures in 2015 (see table).

Private industry total expenditures for uranium exploration and mine development activities in 2016 were USD 71.9 million, a decrease of more than 31% from 2015 expenditures of USD 104.9 million.

In 2016, expenditures on US uranium production, including facility expenses, were USD 98.0 million, 17% less than the USD 118.5 million spent in 2015. Expenditures for land in 2016 were USD 9.9 million, an 18% decrease from the USD 12.1 million spent in 2015.

The total expenditures for land, exploration, drilling, production and reclamation decreased to USD 169.9 million in 2016, down 24% from USD 223.5 million in 2015. Reclamation expenditures in 2016 were USD 37.2 million, a 37% decrease compared with 2015 expenditures of USD 59.4 million.

The trend of decreasing drilling beginning in 2013 continued in 2016. The number of holes drilled for uranium decreased by 24% from 2015 to 2016, from 1 518 holes to 1 158 holes (see table below). The total metres (m) drilled decreased 14% from 267 614 m in 2015 to 230 734 m in 2016, an 89% decrease from the 2012 peak of 2 181 149 m.

In 2015 and 2016, the US government made no exploration expenditures for uranium domestically or abroad. Data on industry exploration expenses abroad are not available.

The decrease in drilling, production and related expenditures were due in large part to a global oversupply of uranium. Additionally, the ten-year contract between Centrus Energy Corporation and Techsnabexport (TENEX) to supply commercial-origin, Russian low-enriched uranium will replace some of the material previously provided by the Megatons-to-Megawatts programme, which ended in 2013. Deliveries under this contract began in 2013 and, in 2015, the contract term was extended through 2026. According to

Centrus, the contract was modified to reflect the reduction in global enrichment demand since 2011. The Centrus-TENEX contract maintains the original commitment to purchase 17 million separative work units (SWU) through 2022 and allows delivery deferments through 2026.

United States uranium expenditures, 2006-2016

(USD million)

Year	Drilling	Production	Land and other				Total expenditures
			Total land and other	Land	Exploration	Reclamation	
2006	40.1	65.9	155.2	41.0	23.3	50.9	221.2
2007	67.5	90.4	178.2	77.7	50.3	50.2	336.2
2008	81.9	221.2	164.4	65.2	50.2	49.1	467.6
2009	35.4	141.0	104.0	17.3	24.2	62.4	280.5
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

Notes: Expenditures in nominal USD. Totals may not equal sum of components because of independent rounding.

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 in the course of exploration, reclamation and restoration work; and overhead and administrative charges directly associated with supervising and supporting field activities.

Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 8.

United States uranium drilling activities, 2006-2016

Year	Exploration drilling		Development drilling		Exploration and development drilling	
	Number of holes	Metres (thousand)	Number of holes	Metres (thousand)	Number of holes	Metres (thousand)
2006	1 473	250	3 430	577	4 903	827
2007	4 351	671	4 996	898	9 347	1 569
2008	5 198	775	4 157	778	9 355	1 553
2009	1 790	320	3 889	820	5 679	1 141
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

Note: Totals may not equal sum of components because of independent rounding.

W = Data withheld to avoid disclosure of individual company data.

Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 1.

Conventional mine development

No uranium was extracted from underground or surface mines in the United States during 2016 and 2017. The last conventional mining in the United States was completed at Energy Fuels Pinenut mine, a breccia-pipe-type deposit in Arizona, in 2015. Ore from Pinenut is stockpiled at the Energy Fuels Inc. White Mesa Mill. Approximately half of the production from the White Mesa Mill during 2015 and 2016 was from alternate feed material (and half from conventional ore). Alternate feed material is not primary mined uranium, and it is recycled from a number of sources, not all of which originate in the United States. This material includes uranium extracted during municipal water treatment, process residues from uranium conversion, uranium-bearing tails from other metal recovery operations, and others.

A number of small (400-2 000 tU) underground or open-pit mines or properties with some degree of development are on standby status awaiting higher uranium prices throughout the western United States. Properties with more significant resources, including conventional mines on standby status, deposits in development, or significant exploration projects are listed below. Conventional mines previously detailed in the 2016 report are included only if conditions have significantly changed.

Arizona

- Canyon Mine (Energy Fuels): Fully permitted and in development. Development drilling delineated additional high-grade uranium and copper mineralisation that is being evaluated for production of both uranium and copper.
- Anderson (Uranium Energy Corporation): NI 43-101 compliant resource estimate published and preliminary economic assessment completed, but no permitting or development work completed. (NI 43-101 are the Canadian standards of disclosure for mineral projects designed to ensure that misleading, erroneous, or fraudulent information about mineral properties is not published.)
- Los Cuatros (Uranium Energy Corporation): NI 43-101 compliant resource estimate published, but no economic assessment, permitting, or development work completed.
- Workman Creek (Uranium Energy Corporation): NI 43-101 compliant resource estimate published and historic feasibility study completed, but no recent development work completed.

Colorado

- Hansen/Taylor – Tallahassee Creek (Western Uranium): Historic resource with a feasibility study and permitting in process. Western Uranium is attempting to permit mining by Laser Ablation, which complicates the process because neither the state of Colorado nor the US Nuclear Regulatory Commission (NRC) has determined whether this type of mining is in situ milling (such as ISL mining) or mining. Different permits are required for mining and milling.

New Mexico

- Mt. Taylor (General Atomics/Rio Grande Resources): Fully permitted and developed. This mine has been on standby status since 1989.
- Churchrock/Crownpoint (Laramide Resources): NI 43-101 compliant resource estimate published and preliminary economic assessment completed, but no permitting or development work completed.
- Crownpoint/Hosta Butte (enCore Energy): Still in exploration stage.
- LaJara Mesa (Laramide Resources): NI 43-101 compliant resource estimate published and permitting is being pursued slowly, but no development work has occurred.

Utah

- Henry Mountains Complex (Energy Fuels): NI 43-101 compliant resource estimate published. The Tony M mine is on standby (fully permitted and developed), but the Bullfrog portion of the project requires permitting.

Virginia

- Coles Hill deposit (Virginia Uranium): This is the largest undeveloped uranium deposit in the United States. A feasibility study has been completed, but development cannot proceed until a state moratorium on uranium mining is lifted.

Wyoming

- Sheep Mountain (Energy Fuels): NI 43-101 compliant resource estimate published, a pre-feasibility study has been completed, and permitting is at an advanced stage.

ISL mine development

At the end of 2016, six US uranium ISL plants were operating with a combined capacity of 12.2 million pounds U_3O_8 per year (Crow Butte Operation in Nebraska and Lost Creek Project, Nichols Ranch ISL Project, Ross Central processing Plant, Smith Ranch-Highland Operation and Willow Creek Project in Wyoming). Seven other ISL plants are planned in New Mexico, South Dakota, Texas and Wyoming.

Smith Ranch/Highland has been producing uranium since 1988, adding the North Butte satellite deposit to the production stream in 2015. Crow Butte has been producing uranium since 1991. Production at Crowe Butte has been dropping since 2013 as the resources are depleted. At both mines, satellite properties were in the process of permitting to continue production from the central processing plants, including the Gas Hills/Peach, Ruby Ranch, North Butte and Brown Ranch projects at Smith Ranch; and North Trend, Marsland and Three Crow projects at Crowe Butte. However, in April 2016, Cameco announced that it would defer wellfield development at Smith Ranch and Crowe Butte and was interested in divesting its US assets. The company will continue to operate existing facilities and restore depleted wellfields.

Energy Fuels Inc. purchased the Nichols Ranch mine from Uranerz in 2015, and in 2016 completed construction of the processing facility, so resins could be processed on-site rather than at the Smith Ranch mine. Energy Fuels has completed permitting of the Hank deposit and is in the process of permitting the Jane Dough deposit, each planned as satellite well fields for the Nichols Ranch mine.

At Lost Creek, actual production exceeded production that was projected from resource estimates. Consequently, the resource estimate for the property was increased by about 30% in 2016. The reason for over production is not yet clear; studies of this phenomenon are focused on the mineralogy of uranium at Lost Creek and details of downhole geophysical surveying. Production at the Lance Mine began in December, 2015 with the first delivery of drummed product in June, 2016. Production fell in late 2016, however, in response to low uranium prices.

The Ross Central Processing Plant (Lance mine) in Wyoming initiated production in 2015. The Hobson/La Palangana and Alta Mesa mines in Texas moved to standby status, in 2016 and 2015, respectively.

There are a number of small (<400 to 2 000 tU) ISL-amenable properties with some degree of development that are on standby status awaiting higher uranium prices in the western United States. Most exploration and development is concentrated in Texas and Wyoming. In addition to permitting of satellite properties adjacent to existing processing plants, other significant ISL properties include those listed below. These deposits either have a significant identified uranium resource (most containing >2 000 tU), and/or are in some stage of feasibility, permitting, or development that indicates they are measurably progressing towards production. ISL mines previously detailed in the 2014 report are included only if conditions have significantly changed.

Colorado

- Centennial (Azarga Uranium): preliminary economic assessment completed, permitting in progress. Permitting may be difficult due to the Colorado Mined Land Reclamation Act (2015) requiring every ISL permit application to include proof that five mines have returned all constituents in groundwater to baseline after mining and restoration. To date this documentation for five ISL mines has not been found.

New Mexico

- Churchrock (Laramide Resources): Preliminary feasibility study completed and some permitting completed, but no significant work since 2012.
- Crownpoint, Mancos and Strathmore/Churchrock (Laramide Resources): These three properties all have significant historic resources and are being evaluated by Laramide Resources for mining using ISL technology. However, none have resources that are NI 43-101 compliant, and no recent economic analyses, permitting, or development activities have been initiated.

South Dakota

- Dewey-Burdock, South Dakota (Azarga Uranium): Preliminary economic assessment completed and permitting in progress.

Texas

- Goliad (Uranium Energy Corporation): Fully permitted and development is proceeding slowly.
- Burke Hollow (Uranium Energy Corporation): NI 43-101 compliant resource estimate published, and a feasibility study, permitting, and exploration drilling activities are all in progress.

Wyoming

- Shirley Basin (Ur-Energy): NI 43-101 compliant resource estimate published, a preliminary economic assessment completed, and permitting in progress.
- Lost Soldier (Ur-Energy): NI 43-101 compliant resource estimate published, but no development or permitting activities completed.
- Reno Creek (Energy Fuels & Uranium Energy Corporation): NI 43-101 compliant resource estimate published for most of the deposit (including Pine Tree, Bing and Moore), and a feasibility study and permitting completed for the Reno Creek ore deposit.
- Juniper Ridge (Energy Fuels): NI 43-101 compliant resource estimate published and feasibility study completed, but no permitting activities completed.

Exploration continues for ISL mines in the Wyoming basins, along the Texas Gulf Coast and in the Grants district of New Mexico.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Estimates of reasonably assured resources (RAR) in the United States are not changed from the prior estimates that were reported as of the last edition of the 2016 report.

At the end of 2016, estimated uranium resources were 17 425 tU at a maximum forward cost of up to USD 80/kgU. At up to USD 130/kgU, estimated resources were 62 890 tU. At up to USD 260/kgU, estimated resources were 138 204 tU.

There have been some changes since the last reporting period for estimated reserves. At the end of 2016, estimated uranium reserves for mines in production were 10 658 tU at a maximum forward cost of up to USD 80/kgU. Estimated reserves for properties with exploration completed, exploration continuing and only assessment work were 15 145 tU at a maximum forward cost of up to USD 80/kgU.

Reserve estimates are available on 70 mines and properties for end of 2015 and on 68 mines and properties for end of 2016. These uranium reserve estimates cannot be compared with the much larger historical data set of uranium reserves that was published in the July 2010 US Department of Energy (DOE) report, *US Uranium Reserves Estimates*. Those estimates were made by the US Energy Information Administration (US EIA) based on data collected by US EIA and data developed by the National Uranium Resource Evaluation (NURE) programme, operated out of Grand Junction, Colorado, by DOE and predecessor organisations. The US EIA data covered approximately 200 uranium properties, with reserve estimates collected from 1984 through 2002. The NURE data covered approximately 800 uranium properties with reserve estimates, developed from 1974 through 1983. Although the 2014 data collected on the Form EIA-851A survey, Domestic Uranium Report (Annual), cover a much smaller set of properties than the earlier US EIA and NURE data, US EIA believes that, within its scope, the EIA-851A survey data provide more reliable estimates of the uranium recoverable at the specified forward cost than estimates derived from 1974 through 2002. In particular, this is because the NURE data have not been comprehensively updated in many years and are therefore no longer considered a current data source.

The United States has not historically reported inferred resources. In 2014, the United States began an evaluation of the relative importance of the inferred resource category available in published estimates of US uranium properties. Based on this limited analysis, it is estimated that minimal uranium resources for the United States would be increased by 10%, if inferred resources were tabulated in addition to RAR. In recognition of the importance of this class of resource, mechanisms for collecting inferred uranium resource data for the United States are being considered.

Undiscovered conventional resources (prognosticated and speculative resources)

Prognosticated and speculative uranium resources for the United States were last comprehensively assessed in 1980. Records of these estimates are no longer available; therefore they are no longer reported for the United States. The US Geological Survey (USGS) is now re-estimating undiscovered resources for the United States. Estimates for different regions and deposit types have been prioritised, and will be completed in an ongoing fashion. The first of the new undiscovered estimates, for sandstone-hosted roll-type deposits in the Texas Coastal Plain, was completed in 2015. A comprehensive deposit model paper developed as part of the assessment was published in 2016. The USGS undiscovered resource estimate methodology produces probabilistic estimates of potential resources, but not their associated cost categories. The Texas assessment calculated recoverable resources and conversion to in situ resources will require significant conjecture. USGS is now in the process of estimating the undiscovered resources of surficial calcrete-type uranium deposits in the Southern High Plains region of Texas and New Mexico. Historic records of the Kerr-McGee Corporation identified two calcrete-type uranium deposits in northern Texas that have historic resource estimates. These deposits were visited in 2016, and samples collected to help in the development of a deposit model for the region. In other work, a deposit model is in development for the Coles Hill Deposit in Virginia as part of an evaluation of undiscovered resources in the southeast United States.

Unconventional resources and other materials

Phos Energy Ltd and Cameco Corporation have developed the "PhosEnergy" process to extract uranium from the processing stream at operating phosphate mines. A demonstration plant was tested at a phosphate fertiliser production site in Florida in 2015 with good results, and a pre-feasibility study was completed for a relatively small facility (< 150 tU/yr), and returned operating costs in the lower quartile of USD 50/kgU. The construction of a commercial model awaits favourable economic conditions.

Uranium production

Historical review

Following passage of the Atomic Energy Act of 1946 (AEA), designed to meet US government uranium procurement needs, the Atomic Energy Commission (AEC) from 1947 through 1970 fostered development of a domestic uranium industry (chiefly in the western United States) through incentive programmes for exploration, development and production. To assure that 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, pursuant to 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 amortise plant costs during their procurement-contract period. By 1961, a total of 27 mills were being operated. Overall, 32 conventional mills and several pilot plants, concentrators, up graders, heap leach and solution-mining facilities were operated at various times. The AEC, as the sole government purchasing agent, provided the only US market for uranium. While many of the mills were 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, in order to foster utilisation of atomic energy for peaceful purposes, domestic producers of ore and concentrate 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 a "stretch out" of its procurement programme that committed the government to take only set annual quantities of uranium for 1967 through 1970. This also assisted in sustaining 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; however, the government continues to monitor private industry exploration and development activities to meet 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 fuel an increasing number of commercial nuclear power plants that were under construction or planned. US production peaked in 1980 (16 809 tU), after which the industry experienced generally declining production from 1981 to 2003. Beginning in 2004, production began increasing again in response to higher uranium prices. Production began decreasing in 2013 in response to an oversupply of uranium on the world market and consequent lower uranium prices. The oversupply was the result of reactor shutdowns in Germany and Japan following the accident at Fukushima Daiichi. Since 1991, production from ISL mining has dominated US annual production.

Status of production facilities, production capability, recent and ongoing activities and other issues

US uranium mines produced 1 427 tU in 2015, 24% less than in 2014. In 2016, US uranium mines produced 979 tU, 31% less than in 2015. Total production of US uranium concentrate in 2016 was 1 121 tU, 13% less than in 2015, from nine facilities: one mill in Utah (White Mesa Mill) and eight ISL plants. The eight ISL plants are located in Nebraska, Texas and Wyoming. Uranium ore from underground mines is stockpiled and shipped to the White Mesa Mill for milling into uranium oxide (U_3O_8) concentrate (yellowcake).

Total shipments of uranium concentrate from US mill and ISL plants were 1 161 tU in 2016, 25% less than in 2015. US producers sold 1 035 tU of uranium concentrate in 2016, 26% less than in 2015.

Uranium production centre technical details

(as of 31 December 2016)

	Centre #1	Centre #2	Centre #3	Centre #4
Name of production centre	Crow Butte Operation	Lost Creek Project	Smith Ranch/Highland (including North Butte satellite mine)	Ross Central Processing Plant
Production centre classification[1]	Existing	Existing	Existing	Existing
Date of first production	1991	NA	1988	2015
Source of ore:				
Deposit name(s)	Crow Butte and North Trend	Lost Creek	Smith Ranch-Highland	Late Cretaceous Lance and Fox Hills Formations
Deposit type(s)	Sandstone	Sandstone	Sandstone	Sandstone
Recoverable resources (tU)	W	NA	W	W
Grade (% U)	W	NA	W	W
Mining operation:				
Type (OP/UG/ISL)	ISL	ISL	ISL	ISL
Size (tonnes ore/day)	NA	NA	NA	NA
Average mining recovery (%)	NA	NA	NA	NA
Processing plant:				
Acid/alkaline				
Type (IX/SX)	ISX	IX	IX	IX
Size (tonnes ore/day)				
Average process recovery (%)	NA	NA	NA	NA
Nominal production capacity (tU/year)[1]	386	771	2 121	145
Plans for expansion	Unknown	Unknown	Unknown	Planned stage expansion, depending on market conditions
Other remarks[1]	Operating	Operating	Operating	Operating
State	Nebraska	Wyoming	Wyoming	Wyoming

1. US Energy Information Administration, Domestic Uranium Production Report, 2016, Tables 4 and 5.

NA = Not available. W = Data withheld to avoid disclosure of individual company data.

Uranium production centre technical details *(cont'd)*

(as of 31 December 2016)

	Centre #5	Centre #6	Centre #7	Centre #8
Name of production centre	Nichols Ranch ISL Project	Willow Creek Project	White Mesa Mill	Alta Mesa
Production centre classification[1]	Existing	Existing	Existing	Existing
Date of first production	NA	NA	1980	2005
Source of ore:				
Deposit name(s)	Nichols Ranch and Hank	Willow Creek	Various	Alta Mesa
Deposit type(s)	Sandstone	Sandstone	Sandstone, breccia pipe	Sandstone
Recoverable resources (tU)	NA	NA	W	W
Grade (% U)	NA	NA	W	W
Mining operation:				
Type (OP/UG/ISL)	ISL	ISL	UG	ISL
Size (tonnes ore/day)	NA	NA	NA	NA
Average mining recovery (%)	NA	NA	NA	NA
Processing plant:				
Acid/alkaline			Acid	
Type (IX/SX)	IX	IX	SX	IX
Size (tonnes ore/day)			1 538	
Average process recovery (%)	NA	NA	NA	NA
Nominal production capacity (tU/year)[1]	771	501	NA	578
Plans for expansion	Unknown	Unknown	Unknown	Unknown
Other remarks[1]	Operating	Operating	Operating	Standby
State	Wyoming	Wyoming	Utah	Texas

1. US Energy Information Administration, Domestic Uranium Production Report, 2016, Tables 4 and 5.

NA = Not available. W = Data withheld to avoid disclosure of individual company data.

At the end of 2016, one uranium mill (White Mesa in Utah) was operating with a capacity of 1 538 tonnes of ore per day. Two mills (Shootaring Canyon in Utah and Sweetwater in Wyoming) were on standby status with a combined capacity of 2 884 tonnes of ore per day. Both the Sweetwater and Shootaring Canyon mills have been on standby status since the early 1980s and will require rehabilitation. After acquiring the mill in 2015, Anfield Resources Inc. submitted a plan in 2016 to the Utah Division of Waste Management and Radiation Control to renew its Shootaring Canyon mill's operating licence. The Piñon Ridge mill in Colorado is planned and fully licensed for Colorado, but construction has not begun. The NRC received letters of intent for mill licence applications from Uranium Resources Inc. (Juan Tafoya mine area, New Mexico) and General Atomics (Mt. Taylor Mine area, New Mexico), however both of these licensing actions have been delayed by the applicant.

Seven ISL mines were operating in 2016 with a combined capacity of 5 465 tU per year (Crow Butte Operation, Hobson ISL Plant/La Palangana, Lost Creek Project, Nichols Ranch ISL Project, Ross Central Processing Plant, Smith Ranch-Highland Operation and Willow Creek Project). Smith Ranch, Crow Butte and Willow Creek processed lixiviant at the mine site.

Ownership structure of the uranium industry

Ownership of uranium facilities that produced uranium in 2015 and 2016 are public and privately held firms with both foreign and domestic participation. Declining uranium prices have led to some consolidation and shifting in the ownership of US uranium production and processing facilities. EnCore Energy Corp. acquired properties from Energy Fuels, including the Marquez/Nose Rock deposit in New Mexico, the Moonshine deposit in Arizona and the White Canyon District in Utah. Western Uranium merged with Black Range Minerals, adding the Hansen and Taylor deposits, and acquired properties on the Colorado Plateau, including the Sunday Complex, from Energy Fuels Inc. URI is negotiating the sale of its US assets to Laramide Resources.

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 levels in 2009 showed the first significant decrease over the preceding five years, but from 2009 through 2012 there were marginal gains in total employment. Since 2012, however, employment has declined with the decrease in production. In 2016, total employment in the US uranium production industry was 560 person-years, a decrease of 10% from the 2015 total of 625 person-years at the lowest since 2004. Exploration employment in 2016 was 38 person-years, a 34% decrease compared with 2015. Milling and processing employment data are withheld for 2015 and 2016. Uranium mining employment in 2016 was 255 person-years, 2% more than in 2015. Reclamation employment decreased 16% from 116 person-years in 2015 to 98 person-years in 2016. Uranium production industry employment in 2016 was in nine states: Arizona, Colorado, Nebraska, New Mexico, Oregon, Texas, Utah, Washington and Wyoming.

Future production centres

There are a number of future production centres that are currently in either the permitting or licensing process or under development. Fully permitted centres are listed in the table below, and other developing centres are described in the previous sections on conventional and ISL mine development.

Secondary sources of uranium

Production and/or use of mixed oxide fuels

In 1999, DOE issued a final environmental impact statement and record of decision to make 34 tonnes of surplus weapons-usable plutonium available as mixed oxide (MOX) fuel for use in commercial nuclear reactors.

On April 29, 2015, DOE and Tennessee Valley Authority (TVA) issued the Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement. This work supports international nuclear non-proliferation agreements pursuant to which the United States and Russia will decommission 68 tonnes of surplus plutonium. Following completion of the Mixed Oxide Fuel Fabrication Facility at the DOE Savannah River site in South Carolina, mixed oxide (MOX) fuel will be fabricated for commercial reactors using surplus military plutonium. In February 2011, the TVA and Areva signed a letter of intent to begin evaluating the use of MOX at TVA's Sequoyah plant in Tennessee and the Browns Ferry plant in Alabama. In order to use MOX at the TVA nuclear power plants, TVA must submit requests for licence amendments for the plants to the NRC. As of 31 December 2016, no such applications had been filed with the NRC. Once filed, it is likely to take the NRC one to two years to complete its review of the applications.

Production and/or use of re-enriched tails

DOE and the Bonneville Power Administration initiated a pilot project to re-enrich a portion of DOE's tails inventory. This project produced approximately 1 940 tonnes of low-enriched uranium between 2005 and 2006 for use by Energy Northwest's 1 190 MWe Columbia Generating Station between 2007 and 2015. In mid-2012, Energy Northwest and United States Enrichment Corporation (USEC), in conjunction with DOE, developed a new plan to re-enrich a portion of DOE's high assay tails. The 2013 project produced approximately 3 738 tonnes of natural uranium, which will be used through 2029 to fuel Energy Northwest and TVA reactors.

In 2016, DOE agreed to sell depleted uranium to GE-Hitachi Global Laser Enrichment, LLC (GLE) over a 40-year period, which would be enriched at a proposed GLE facility. GLE will finance, construct, own and operate the Paducah Laser Enrichment Facility (PLEF) adjacent to the DOE site. Silex Systems, an Australian-owned company developing the laser enrichment technology, has licensed GLE to supply the depleted uranium.

Production and/or use of reprocessed uranium

Reprocessed uranium use and production is zero.

In June 2008, DOE submitted a licence application to the NRC to receive authorisation to begin construction of a repository at Yucca Mountain, and in September 2008, the NRC formally docketed the application. President Obama announced in March 2009 that the proposed permanent repository at Yucca Mountain was no longer an option and that the Blue Ribbon Commission on America's Nuclear Future (BRC) would evaluate alternatives to deal with spent nuclear fuel. On 26 January 2012, the BRC issued its final report that recommended moving forward with a publicly supported siting process for a permanent repository and federally chartering an organisation to manage this process. The BRC also recommended development of an interim storage site for spent nuclear fuel until a permanent repository is available. With regard to reprocessing or recycling, the BRC noted that "…no currently available or reasonably foreseeable reactor and fuel cycle technology developments – including advances in reprocessing and recycling technologies – have the potential to fundamentally alter the waste management challenge this nation confronts over at least the next several decades, if not longer…".

Environmental activities and socio-cultural issues

Remediation activities

Navajo Nation

The US Environmental Protection Agency (EPA) is engaged in remediating uranium mining and milling impacted sites on the Navajo Nation. Between 2008 and 2012, high-priority remediation for 34 contaminated homes, 9 mine sites, and drinking water supplies for 1 825 families was completed. In addition, 240 water supplies and 520 mines were assessed. The remediation effort completed between 2008 and 2012 cost in excess of 100 million USD. Plans for a second phase of remediation from 2014 to 2018 were completed by EPA. The main objectives are to remediate homes, increase water infrastructure to mining areas, focus on 43 priority mines located near homes, clean up the NE Church Rock mine and Tuba City dump, treat groundwater at mill sites, conduct health studies and expand interagency outreach. Implementation of this plan has begun and as of 2016 includes: a) detailed clean-up investigations of six mines, with urgent actions completed at five high-priority mines; b) provision of safe drinking water to 3 013 homes in abandoned uranium mine regions; c) a community outreach effort organised to inform residents of agency work and health dangers related to uranium mining on the Navajo Nation; and d) an ongoing survey of Navajo Nation mine sites. Part of this work is financed by settlements from the Kerr-McGee Corporation, which had mines on the Navajo Nation. Most mining took place before 1978.

Piketown

Decommissioning and environmental remediation continues at the Portsmouth Gaseous Diffusion Plant in Piketown, Ohio, which closed in 2001. In 2015, DOE created a comprehensive plan to demolish the process buildings and support structures at the Portsmouth Gaseous Diffusion Plant. Three large buildings are currently being demolished by DOE contractor Fluor-BWXT.

DOE report to Congress on defence-related uranium mines

In 2014, DOE provided to the US Congress a database of locations and degree of restoration of mines that provided uranium ore for US atomic energy defence activities. The DOE determined that 4 225 mines provided uranium ore for defence-related activities. Of these mines, 26 could not be located. Approximately 69% of the mines are in Colorado and Utah, and 23% in Arizona, New Mexico and Wyoming. New Mexico provided the most uranium to this national effort, while Colorado had the largest number of individual mines. Nearly half of the mines are located on federal land managed by the Bureau of Land Management, an agency within the US Department of the Interior (DOI). About 11% of the mines are on tribal lands. The remaining mines are located on non-federal and non-Indian land or land of unknown ownership.

The status of remediation was available for only 15% of the sites identified in the report. Field checking of these locations and the degree of restoration of the sites is now in progress by the DOE Office of Legacy Management.

Legislation

Federal

In 2012, over one million acres of federal land near the Grand Canyon in Arizona were withdrawn from mineral entry for 20 years due to concerns about environmental impacts of mining in this scenic area of the Colorado Plateau. Interdisciplinary studies of exploration and mining impacts in the region were initiated by the USGS in 2014 and are planned to continue throughout the course of the moratorium. These studies are focused on the impacts of mining and exploration on the Grand Canyon watershed, wildlife, water resource and people. Research is focused on exposure pathways such as wind-borne dust, surface and groundwater, soil, and food-chain pathways. Soil samples throughout the region and adjacent to the developing Canyon Mine were collected and compiled to provide background geochemical data. Pre-mining biologic samples were collected near the Canyon Mine, and showed bioaccumulation of heavy metals (As, Pb, Se, Tl and U) in tadpoles living in the mine containment pond, and little to no accumulation of mine related analytes in other biota (vegetation, birds, rodents, or terrestrial invertebrates). Analysis of springs near the Pigeon mine show elevated uranium and other elements related to natural uranium sources and not mining activity. A more precise permissive area for breccia pipe deposits has been delineated in support of land use planning.

State

The state of Wyoming is implementing legislation passed in 2015 that directs the state to work with the NRC to transfer oversight of aspects of the uranium mining industry to the state. Regulations will remain the same, but the state would take primacy with regulatory oversight by the NRC. The proposal is designed to lower costs and shorten regulatory timelines, in particular for uranium recovery licensing applications. Texas, Utah and Colorado are currently “agreement states” with regulatory primacy granted to these states by the NRC.

Litigation

A detailed summary of ongoing litigation related to the Secretary of Energy’s 2014 determination regarding management of excess uranium inventory is provided in the “National policies relating to uranium” section below. See the legislation section above for information on litigation of land withdrawn from mineral entry near the Grand Canyon.

Regulatory regime

Regulation

Uranium recovery is regulated by the NRC and EPA, and individual states, while mining regulations for federal lands are administered through the federal agency that controls this land (such as the Bureau of Land Management). Before mining commences, Environmental Impact Statements must be completed, adequate bonding must be posted, and additional regulatory requirements specified by federal and state agencies must be satisfied.

The NRC is reviewing uranium recovery licence applications for eight ISL facilities, four of which are on hold as requested by the applicant. NRC has received a letter of intent from seven additional applicants, all of which have been delayed by the applicants. Two applications are close to approval, AUC LLC’s Reno Creek deposit and the Jane Dough expansion to Energy Fuel’s Nichols Creek mine. Additional licensing actions may be in progress in Texas, Colorado and Utah, all of which are “agreement states” that have primacy in uranium recovery licensing.

The EPA is reviewing and revising its standards for post-closure monitoring of uranium ISL sites (40 CFR 192). The proposed rule would focus on groundwater protection and restoration at ISL mining facilities. Post-restoration groundwater standards would be set for 12 constituents and monitoring requirements would be added. Post-restoration remediation and monitoring is currently administered by individual states, after EPA exempts the aquifer to be mined using ISL techniques from regulation under the Federal Clean Water Act of 1972. After reviewing public comments in 2015, EPA re-proposed the rule and solicited additional public comment rather than finalising the rule. Any new or revised standards must be adopted by the NRC, and its agreement states.

Uranium requirements

Annual US uranium requirements for the period 2016 to 2035 are projected to decrease from 21 068 tU in 2016 to 18 057 tU in 2035 (high case). This decrease is based on the possibility that some nuclear power plants may retire early due to financial uncertainties in competitive markets. These estimates include the operations of the new Watts Bar unit 2 in Tennessee and the construction of Vogtle units 3 and 4 and V.C. Summer units 2 and 3. The V.C. Summer construction project was suspended in 2017 and its future is uncertain. Illinois and New York passed zero-emission credit legislation in 2016 to provide price support for nuclear power plants operating at a loss in those states. Several other US states are also examining legislative options for their nuclear power industry.

Supply and procurement strategy

The United States allows supply and procurement of uranium to be driven by market forces with resultant sales and purchases conducted solely in the private sector by firms involved in the uranium mining and nuclear power industries.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

In July 2013, DOE released the revised *DOE Excess Uranium Inventory Management Plan* (2013 Plan). The 2013 Plan identified uranium inventories that have entered the commercial uranium market since the issuance of the December 2008 Plan, as well as transactions that are ongoing or being considered by DOE through 2021. In the 2013 Plan, the guideline that the annual inventory release rate should not exceed 10% of US uranium requirements was removed. Several determinations have been made by the Secretary of Energy since 2008 to assess whether these transactions would have an adverse impact on the domestic uranium mining, conversion, or enrichment industries. The determinations are required every two years. The June 2014 Secretarial determination found that continued transfers would have no impact on the domestic industry.

On 26 April 2017, US Secretary of Energy Rick Perry issued a determination permitting DOE to continue making uranium transfers to support ongoing clean-up work at the Portsmouth Gaseous Diffusion Plant in Ohio, while also reducing the total amount of those transfers per year from 1 600 tU to 1 200 tU.

Uranium stocks

As of 2016, total commercial inventories (producer and utility stocks) were 55 615 tU, a 7% increase from the 52 115 tU of inventories held in 2015. Over 89% of the commercial inventories, or 49 230 tU, were held by owners and operators of commercial reactors. This was a 5% increase from the 46 577 tU owned by this group at the end of 2015.

Enriched uranium inventories held by utilities (including fuel elements in storage) increased 2% from 2015 to 2016 (20 140 tU in 2015 to 20 591 tU in 2016), whereas natural uranium inventories held by utilities (including UF_6 in storage) increased 9% from 2015 to 2016 (26 453 tU in 2015 to 28 857 in 2016).

Excess uranium inventories held by the US government were last reported in 2013. At that time, the government possessed 56 031 tU, which includes 17 596 tU of uranium concentrates, 12 485 tU of enriched uranium, and 25 950 tU of depleted uranium.

Uranium prices

Owners and operators of US civilian nuclear power reactors (civilian owner/operators or COOs) purchased a total of 19 463 tU of deliveries from US suppliers and foreign suppliers during 2016, at a weighted-average price of USD 80.62/kgU.

The 2016 total of 19 463 tU decreased 10% compared with the 2015 total of 21 733 tU. The 2016 weighted-average price of USD 80.62/kgU decreased 4% compared with the 2015 weighted-average price of USD 83.85/kgU.

Of the 19 463 tU delivered in 2016, 11% was US-origin uranium at a weighted-average price of USD 83.45/kgU. Foreign-origin uranium accounted for the remaining 89% of deliveries at a weighted-average price of USD 80.30/kgU. Uranium originating in Kazakhstan, Russia and Uzbekistan accounted for 38% of the 19 463 tU. Australian- and Canadian-origin uranium together accounted for 40%. The remaining 22% originated from Brazil, Bulgaria, China, Czech Republic, Germany, Malawi, Namibia, Niger, South Africa and Ukraine.

COOs purchased uranium of three material types for 2016 deliveries from 36 sellers, the same number of sellers as in 2015. Uranium concentrate was 54% of the 19 463 tU delivered in 2016. Natural UF_6 was 29% and enriched UF_6 was 17%. During 2016, 22% of the uranium delivered was purchased under spot contracts at a weighted-average price of USD 56.28/kgU. The remaining 78% was purchased under long-term contracts at a weighted-average price of USD 87.61/kgU. Spot contracts are contracts with a one-time uranium delivery (usually) for the entire contract period and delivery typically occurs within one year of contract execution (signed date). Long-term contracts are contracts with one or more uranium deliveries to occur after a year following the contract execution (signed date) and as such may reflect some agreements of short and medium terms as well as longer term.

In 2016, COOs signed 50 new purchase contracts with deliveries in 2016 of 3 346 tU at a weighted-average price of USD 47.23/kgU. Five new contracts were long-term contracts with 28% of the 2016 deliveries and 45 new contracts were spot contracts with 72% of the deliveries in 2016.

COOs report minimum and maximum quantities of future deliveries under contract, to allow for the option of either decreasing or increasing quantities. As of the end of 2016, the maximum uranium deliveries for 2017 through 2026 under existing purchase contracts for COOs totalled 67 313 tU. Also as of the end of 2016, unfilled uranium market requirements for 2017 through 2026 totalled 89 623 tU. These contracted deliveries and unfilled market requirements combined represent the maximum anticipated market requirements of 156 937 tU over the ten-year period for COOs.

Average US uranium prices, 2002-2016

(USD per kilogram U-equivalent)

Year	Spot contracts	Long-term contracts
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
2007	229.44	63.57
2006	102.64	42.59
2005	52.1	35.62
2004	38.4	31.82
2003	26.26	28.44
2002	24.15	27.51

Source: US Energy Information Administration, Uranium Marketing Annual Report, 2016, Table 7.

Uranium exploration and development expenditures and drilling effort – domestic

(Expenditures in USD million)

	2014	2015	2016	2017 (expected)
Industry* exploration expenditures[1]	10.7	4.7	2.5	NA
Government exploration expenditures	0	0	0	NA
Industry* development expenditures[2]	91.5	100.2	69.4	NA
Government development expenditures	0	0	0	NA
Total expenditures	102.1	105	71.9	NA
Industry* exploration drilling (m)[3]	W	W	W	NA
Industry* exploration holes drilled[4]	W	W	W	NA
Industry exploration trenches (m)	NA	NA	NA	NA
Industry exploration trenches	NA	NA	NA	NA
Government exploration drilling (m)	0	0	0	NA
Government exploration holes drilled	0	0	0	NA
Government exploration trenches (m)	NA	NA	NA	NA
Government exploration trenches	NA	NA	NA	NA
Industry* development drilling (m)[5]	W	W	W	NA
Industry* development holes drilled[6]	W	W	W	NA
Government development drilling (m)	0	0	0	NA
Government development holes drilled	0	0	0	NA
Subtotal exploration drilling (m)	W	W	W	NA
Subtotal exploration holes	W	W	W	NA
Subtotal development drilling (m)	W	W	W	NA
Subtotal development holes	W	W	W	NA
Total drilling (m)	395 935	267 614	230 734	NA
Total number of holes drilled	1 752	1 518	1 158	NA

* Non-government.

NA = Not available.

1. Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 8, Exploration.
2. Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 8, Drilling + Land + Reclamation.
3. Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 1, Exploration, feet (converted to metres using US EIA Uranium Industry Annual Appendix D Uranium Conversion Guide).
4. Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 1, Exploration, Number of Holes.
5. Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 1, Development Drilling.
6. Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 1, Development Drilling.

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	17 425	62 890	138 204	NA
Intrusive	0	0	0	0	NA
Volcanic and caldera-related	0	0	0	0	NA
Other*	0	0	0	0	NA
Total	0	17 425	62 890	138 204	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.

Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 10.

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	80 199	NA
Open-pit mining (OP)	0	W	W	See note 1	NA
In situ leaching alkaline	0	W	W	58 005	NA
Unspecified	0	0	0	0	NA
Total	0	17 425	62 890	138 204	NA

W = Data withheld to avoid disclosure of individual company data. NA = Not available.

Note 1: US reserves data do not draw a distinction between UG and OP; the combined value is assigned to UG.

Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 10.

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	17 425	62 890	138 204	NA

* Also known as stope leaching or block leaching.

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

NA = Not available.

Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 10.

Historical uranium production by deposit type

(tonnes U in concentrate)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (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.

Historical uranium production by production method

(tonnes U in concentrate)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Open-pit mining*	0	0	0	0	0	0
Underground mining*	NA	W	W	W	W	NA
In situ leaching	NA	W	W	W	W	NA
Co-product/by-product	NA	W	W	W	W	NA
Total	371 909	1 889	1 427	979	376 204	442

Note: Data not available prior to 1968. W = Data withheld to avoid disclosure of individual company data. NA = Not available.

* Pre-2008 totals may include uranium recovered by heap and in-place leaching.

Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 2.

Historical uranium production by processing method

(tonnes U in concentrate)

Processing method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Conventional	NA	W	W	W	W	NA
In-place leaching*	NA	W	W	W	W	NA
Heap leaching**	0	0	0	0	0	NA
In situ leaching	0	0	0	0	0	NA
U recovered from phosphate rocks	0	0	0	0	0	NA
Other methods***	0	0	0	0	0	NA
Total	371 189	1 881	1 286	1 121	375 477	940

Note: Data are available from 1947 to present. W = Data withheld to avoid disclosure of individual company data. NA = Not available.

* 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.

Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 3.

Ownership of uranium production in 2016

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
0	0	W	W	0	0	W	W	979	100

W = Data withheld to avoid disclosure of individual company data.

Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 2.

Uranium industry employment at existing production centres

(person-years)

	2014	2015	2016	2017 (expected)
Total employment related to existing production centres[1]	787	625	560	424
Employment directly related to uranium production[2]	246	251	255	136

1. Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 6, all sectors except Reclamation.
2. Source: US Energy Information Administration, Domestic Uranium Production Report, 2016, Table 6, all sectors except Exploration and Reclamation.

NA = Not available.

Short-term production capability

(tonnes U/year)

2016				2017				2020			
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

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

NA = Not available.

Mixed oxide fuel production and use[1]

(tonnes of natural U-equivalent)

Mixed oxide (MOX) fuel	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Production	0	0	0	0	0	0
Use	0	0	0	0	0	0
Number of commercial reactors using MOX	0	0	0	0	0	0

1. *OECD-NEA Nuclear Energy Data 2017*.

Re-enriched tails production and use[1]

(tonnes of natural U-equivalent)

Re-enriched tails	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Production	5 678	0	0	0	5 678	0
Use	1 940	0	0	0	1 940	0

1. Data provided by Energy Northwest, owner-operator of the Columbia Generating Station.

Reprocessed uranium use[1]

(tonnes natural U-equivalent)

Reprocessed uranium	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Production	0	0	0	0	0	0
Use	0	0	0	0	0	0

1. *OECD-NEA Nuclear Energy Data 2017*.

Net nuclear electricity generation[1]

	2015	2016
Nuclear electricity generated (TWh net)	797	805p

1. *OECD-NEA Nuclear Energy Data 2017*. p = provisional data.

Installed nuclear generating capacity to 2035[1]

(MWe net)

2015	2016	2020		2025		2030		2035		2040	
		Low	High	Low	High	Low	High	Low	High	Low	High
99 200	99 090p	97 132	97 132	96 325	97 162	94 401	96 501	88 171	91 396	84 140	95 525

1. *OECD-NEA Nuclear Energy Data 2017;* p = provisional data.

Annual reactor-related uranium requirements to 2035 (excluding MOX)[1]

(tonnes U)

2015	2016	2017		2020		2025		2030		2035	
		Low	High	Low	High	Low	High	Low	High	Low	High
21 235	21 068p	17 675	17 926	16 360	19 087	18 377	19 475	19 121	19 177	17 754	18 057

1. *OECD-NEA Nuclear Energy Data 2017;* p = provisional data.

Total uranium stocks

(tonnes natural U-equivalent)

Holder	Natural uranium stocks in concentrates	Enriched uranium stocks	Depleted uranium stocks	LWR reprocessed uranium stocks	Total
Government[1]	12 939	5 471	30 000	NA	48 410
Producer[2]	NA	NA	NA	NA	5 889
Utility[2]	28 857[3]	20 591[4]	NA	NA	49 448
Total	NA	NA	NA	NA	103 747

1. US Department of Energy, Excess Uranium Inventory Management Plan, July 2013.

2. US Energy Information Administration, Uranium Marketing Annual Report, 2016, Tables 22 and 23.

3. The value for natural uranium stocks in this table does not include natural uranium hexafluoride (UF_6). 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.

NA = Not available.

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 (Shakaptaz, Uiguz Sai, and others) in the Fergana Valley of Eastern Uzbekistan. Exploration, including airborne geophysical surveys, ground radiometry and underground work conducted during the early 1950s over the remote Kyzylkum desert in central Uzbekistan, led to the discovery of the Uchkuduk uranium deposit and Ketmenchi deposits in 1952, Bukinai deposit in 1959, Sabyrsai deposit in 1960 and South Bukinai, Sugraly and Lyavlyakan deposits in 1961. All deposits were discovered and explored for by the Krasnokholmskaya exploration company, in 1990 it was renamed Kyzyltepageologia. Drilling confirmed the initial discovery and development of the first mine at Uchkuduk deposit in 1959, followed by Sabyrsai deposit development. Both mines initially used open-pit and underground mining methods until 1975.

Development of the in situ leaching (ISL) mining technique for recovery of uranium from sandstone deposits in the early 1960s led to a re-evaluation of previously ignored deposits including Lavlakan and Ketmenchi, and to an increase in exploration efforts in the sedimentary environments of the Kyzylkum desert. Three uranium districts with 24 sandstone-type deposits amenable for ISL mining have been established since the Uchkuduk discovery in 1952.

A number of black shale type uranium deposits, including Dzhantuar, Rudnoye, Kostcheka, Voskhod and Dzitym, were identified during 1960s within 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. Grades range from 0.02 to 0.13% U averaging 0.05% U.

Since 1994, the Navoi Mining and Metallurgical Complex (NMMC) has funded all uranium exploration activities in Uzbekistan. In 1995-1996, Kyzyltepageologia developed the known resources of the Severny (north) Kanimekh, Alendy, Kendykijube and Tokhumbet deposits. In addition, assessments of undiscovered resources were completed in the Kyzylkum, the Bukhara-Khiva and Fergana Provinces.

Between 1997 and 2000, Kyzyltepageologia evaluated the known resources of the Kendiktyube, Severny, Kanimeh, Tokhumbet and Ulus deposits. A portion of the resources of these deposits were turned over to NMMC for development.

In 2002, delineation drilling was carried out on the Kendytyube and Tokhumbet deposits. Part of the resources were transferred to Mining Division No. 5 for commercial development.

* Report prepared by the NEA/IAEA, based on previous Red Books and public data.

From 2003-2004, Kyzyltepageologia completed exploration and evaluation works in Kendyktyube and Tokhumbet deposits, the southwestern flanks of Sugraly deposit and the western and eastern flanks of Ketmenchi deposit. Kyzyltepageologiya explored the northern and southern areas of the Central Kyzylkum at the expense of the government.

Recent and ongoing uranium exploration and mine development activities

In August 2009, Goscomgeo (State Geology and Mineral Resources Committee) and 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 Boztauarea, in the Central Kyzylkum Desert of the Navoi region. Some 5 500 tU resources have been reported. From 2011-2013, CGN-URC was to develop technology for the separate production of uranium and vanadium from these black shale deposits with a view to commencing production from them. 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 Juzkuduk and Tamdiykuduk-Tulyantash prospective fields upon the terms of business risk for a period of five years. The minimum amount of funding for the first year of operations was USD 3 million. Uranium reserves discovered at the licensed sites total about 13 000 tonnes U, according to Uzbek government data.

Uranium resources

Uzbekistan's uranium resources occur in sandstone-type and black shale deposits.

All significant sandstone roll-front type uranium resources are located in the Central Kyzylkum area, comprising a 125 km-wide belt extending over a distance of about 400 km from Uchkuduk in the northwest, to Nurabad in the southeast. Only sandstone-type deposits were exploited.

The Centre of the State Committee for Geology and Mineral Resources (Goskomgeo) evaluated in 2014 that in situ resources of uranium in Uzbekistan amounted to 185 800 tU, with 138 800 tU of sandstone type and the other 47 000 tU of black shale type.

As of 1 January 2017, Uzbekistan's total identified uranium resources at a cost <USD 130/kgU amounted to about 140 000 tU. Prognosticated resources are evaluated at about 25 000 tU.

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 occurred from the late 1940s to the early 1960s. Cumulative production is estimated in the order of several thousand tonnes U. The ore was processed in the Leninabad uranium production centre in Tajikistan.

The mining operator for sandstone-type Uchkuduk and Sabyrsai deposits was Mining Complex No. 2, which was established in 1958. In 1967 it was renamed NMMC. NMMC is part of the Uzbekistan state holding company Kyzylkumredmetzoloto that undertakes all uranium mining in the country.

NMMC commenced operation focused on uranium and gold at the end of the 1950s in the desert region of Central Kyzylkum province. Early uranium mining was underground (to 1990) and open pit (to 1994).

The first ISL tests occurred at the Uchkuduk deposit in 1963, followed by ISL tests at Sabyrsai, South Bukinai and Ketmenchi deposits in 1968. Commercial ISL mining in Uzbekistan began in 1975. In 1980, ISL production comprised 29% and by 1985 – 56% of total production. Since 1998, 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 deep with 77% of uranium reserves present at 400-500 m depth. NMMC has also started building a pilot plant for ISL at the Alendy and Yarkuduk deposits and has started operation of the Aulbek ISL mine in Central Kyzylkum, and additionally, the Meilysai deposit.

Before 1992, all uranium mined and milled in Uzbekistan was shipped to Russia. Since 1992, all Uzbekistan's uranium production is exported and sold to the United States, China and other countries.

Status of production capability and recent and ongoing activities

Three NMMC mining divisions produce uranium by in situ leaching:

- the Northern Mining Unit (Uchkuduk) with an annual production of 700-750 tU;
- the Southern Mining Unit (Nurabad) with an annual production of 600-650 tU;
- Mining Unit No. 5 (Zafarabad) with an annual production of 1 000-1 200 tU.

All mining units produce "yellow cake" uranium concentrates on-site and send it to the Hydrometallurgical Plant No. 1, located in Navoi, by rail for further processing and purification.

Annual production is estimated to have amounted to about 2 400 tU in 2015 and 2016.

Future projects

In 2012, NMMC invested USD 230.5 million into modernisation of existing uranium processing facilities and was planning to invest USD 55.2 million in two new uranium mines. The first mine at the Aulbek deposit began operations in May 2012; mine construction was continuing, however, and the second stage was expected to be completed in 2013. The total cost of construction was expected to be USD 20.9 million, of which USD 8.9 million would be spent in 2012. Construction of another new mine at the North Kanimekh deposit started in 2012 and was expected to be finished in 2013; the total cost of the project was estimated to be USD 34.3 million. The ores of the two new mines had higher carbonate content and were located deeper underground than were existing mines operated by NMMC.

In April 2015, NMMC announced plans approved by the government to implement 27 projects to modernise its production facilities by 2019, at a total cost of USD 985 million. Among the projects under construction include a gold mining and processing complex in Samarkand region, the development of the resource base for Muruntau gold mine, and the modernisation and technical re-equipment of other production facilities.

In 2015, NMMC was planning to complete the construction of three uranium mines in the Central Kyzylkum Desert, at a cost of USD 75 million. Completion of the Alendy, Aulbek and North Kanimekh mines would allow uranium production at NMMC to increase by 40%. However, in 2013, NMMC suspended construction of these mines due to high carbonate content in the ore rendering ISL technology inefficient, according to a government source. More recently, it was outlined that a new uranium production development programme has been developed and is being implemented from 2014 to 2020. According to this programme, Kendyktyube, Lyavlyakan, Tohumbet, Aksay, Sugrali, Alendy and Aulbek deposits have been put into operation, the North Kanimekh deposit was brought up to its designed production capacity and uranium mining technology at the Maylisay deposit was optimised.

Ownership structure of the uranium industry

The entire uranium production of the NMMC is owned by the government of Uzbekistan.

Employment in the uranium industry

During the Soviet era, Uzbekistan provided much of the uranium to the Soviet military-industrial complex. Five "company towns" were constructed to support uranium production activities: Uchkuduk, Zarafshan, Zafarabad, Nurabad and Navoi, with a combined population of some 500 000. They remain centres of five mining districts. Uranium industry employment in 2005 was estimated at about 7 000, though some 59 000 were employed by NMMC overall in 2015, including gold mining and other activities (Navoi Mining and Metalurgical Combinat, 2015)

Uranium policies, uranium stocks and uranium prices

Until 1992, all uranium produced in Uzbekistan was shipped to Russia. From 1992 through 2013, practically all Uzbekistan's uranium production has been exported to the United States and other countries through the Nukem company. In 2008, Korea's KEPCO signed agreements to purchase 2 600 tU over six years to 2015, for about USD 400 million. In 2013, 1 663 tU was supplied to China according to the country's custom import statistics. In May 2014, China's CGN agreed to buy USD 800 million of uranium through to 2021. Uzbekistan state-owned NMMC has also signed a contract to supply 2 000 tU to India from 2014 through 2018.

Reasonably assured conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Sandstone	37 370	37 370	57 610	57 610	80

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 (%)
In situ leaching acid	37 370	37 370	57 610	57 610	80

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 (%)
In situ leaching acid	37 370	37 370	57 610	57 610	80

Inferred conventional resources by deposit type

(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
Sandstone	24 320	24 320	48 640	48 640	80
Black shales	0	0	32 900	32 900	70
Total	24 320	24 320	81 540	81 540	

Inferred conventional resources by production method

(tonnes U)

Production method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
In situ leaching acid	24 320	24 320	48 640	48 640	80
Black shales	0	0	32 900	32 900	70
Total	24 320	24 320	81 540	81 540	

Inferred conventional resources by processing method

(tonnes U)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU	Recovery factor (%)
In situ leaching acid	24 320	24 320	48 640	48 640	70
Black shales	0	0	32 900	32 900	70
Total	24 320	24 320	81 540	81 540	

Prognosticated conventional resources

(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
24 800	24 800	24 800

Speculative conventional resources

(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
0	0	0

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2014	2014	2015	2016	Total through end of 2016	2017 (preliminary)
Open-pit mining*	36 249	0	0	0	36 249	0
Underground mining*	19 719	0	0	0	19 719	0
In situ leaching	70 070	2 700	2 400	2 400	77 570	2 400
Total	127 891	2 700	2 400	2 400	135 391	2 400

* Pre-2010 totals may include uranium recovered by heap and in-place leaching.

Ownership of uranium production in 2016

Domestic				Foreign				Totals	
Government		Private		Government		Private			
(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)	(tU)	(%)
2 400	100	0	0	0	0	0	0	2 400	100

Short-term production capability

(tonnes U/year)

2015				2020				2025			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
2 400	2 400	2 400	2 400	2 400	2 400	2 700	2 700	2 400	2 400	3 000	3 000

2030				2035			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
2 200	2 200	3 000	3 000	2 000	2 000	3 000	3 000

Viet Nam

Uranium exploration and mine development

Historical review

The first exploration programmes were started prior to 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 an airborne radiometric/magnetic survey at a scale of 1:25 000 and 1:50 000. This led to the discovery of a large number of promising areas in the provinces of Cao Bang, Lao Cai, Yen Bai and Quang Nam. Uranium mineralisation in Viet Nam is associated with rare earth deposits (Lao Cai province), phosphate deposits (Cao Bang province), and sandstone and coal deposits (Quang Nam province).

Between 1997 and 2002, the Geological Division for Radioactive and Rare Elements (GDRRE) carried out detailed uranium exploration and evaluation (including drilling, trenching and bulk sampling) in the Palua and Parong areas of the Quang Nam province.

Recent and ongoing uranium exploration and mine development activities

Since 2010, the GDRRE in the Ministry of Natural Resources and Environment has been carrying out uranium exploration in the Parong area in the Quang Nam province in central Viet Nam. The project consists of an investigation and evaluation of Triassic sandstone-type 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^2 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^2 and 50 x 25 m^2).

A mining test was conducted via a 130 m adit from which 3 holes have been drilled to 300 m for hydrogeological tests. Results show 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 that varies in thickness from a few centimetres to a few metres.

In support of this exploration project, research on leaching ore 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. The results show that the heap leach method is suitable for the low-grade Parong ore, with uranium recovery greater than 75% achieved.

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^2 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 can be 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, estimation of the uranium potential of remaining parts "B", "C", "D" and "F" of the Palua-Parong is continuing.

Results of a previous evaluation (uranium resources as of 31 December 2008) in the main area of the Quang Nam province concluded that:

- the Palua deposit consists of five orebodies with total resources amounting to 4 596 tU, including 984 tU inferred resources and 3 612 tU prognosticated;
- the Parong deposit consists of seven orebodies with total resources amounting to 3 867 tU, including 1 200 tU of inferred and 2 667 tU prognosticated;
- the Khehoa-Khecao deposit consists of four orebodies with total resources amounting to 5 803 tU, including 1 125 tU inferred and 4 678 tU prognosticated;
- the Dong Nam Ben Giang deposit consists of eight orebodies with total resources amounting to 1 556 tU, including 337 tU inferred 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.

Undiscovered conventional resources (prognosticated and speculative resources)

The results of geological exploration, which has been conducted by the GDRRE, shows 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), in the highlands and in the central provinces.

Uranium deposits located in the Lai Chau province are associated with rare earth 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 in 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 includes: 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 Diemand.

Uranium production

No uranium has been produced in Viet Nam.

Future production centres

The objective of the current "Uranium Exploration Project" 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 determining the feasibility of mining these deposits. The Institute for Technology of Radioactive and Rare Elements has carried out research on ore processing and has started to survey the environmental conditions of future mining operations. As of 31 December 2016, no production centre is planned.

Environmental activities and socio-cultural issues

Environmental activities, such as monitoring the environmental impacts resulting from exploration, are being carried out.

Uranium requirements

Viet Nam had a plan to develop a nuclear power plant that was expected to include 14 nuclear units with a total net nuclear electricity generating capacity of about 15 000 MWe to 16 000 MWe by the year 2030. Seven sites for the construction of an NPP 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 overall plan for the implementation of the NinhThuan Nuclear Power Project, which included the PhuocDinh and Vinh Hai NPPs.

Under this plan, the first nuclear plant would have consisted of two VVER-type 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 plant, to have been built in co-operation with Japan Atomic Power Co. would have had the same generating electricity capacity (2 x 1 000 MWe) and 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 by domestic production.

Because of lack of funding at the end of 2016 the Viet Nam government decided to stop the above-mentioned plans to build the NinhThuan nuclear power plant project. However, uranium exploration activities and the research on uranium extraction from uranium ores are continuing.

Uranium exploration and development expenditures and drilling effort –domestic

(Vietnamese dong)

	2010	2011	2012	2013
Industry* exploration expenditures	-	-	-	-
Government exploration expenditures	59 488 000 000	110 648 637 600	35 476 771 200	30 000 000 000
Total expenditures	59 488 000 000	110 648 637 600	35 476 771 200	30 000 000 000
Government exploration drilling (m)	26 086.2	34 867.5	0	N/A
Government exploration holes drilled	298	414	0	N/A
Total drilling (m)	26 086.2	34 867.5	0	N/A
Total number of holes drilled	298	414	0	N/A

	2014	2015	2016	2017
Industry* exploration expenditures				
Government exploration expenditures	40 000 000 000	57 000 000 000	40 000 000 000	35 000 000 000
Total expenditures	40 000 000 000	57 000 000 000	40 000 000 000	35 000 000 000
Government exploration drilling (m)	N/A	12 097		
Government exploration holes drilled	N/A	N/A		
Total drilling (m)	N/A	N/A		
Total number of holes drilled	N/A	N/A		

* Non-government.

1 USD = 21 500 Vietnamese dong

Reasonably assured conventional resources by deposit type

(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

* In situ resources.

Reasonably assured conventional resources by production method

(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

* In situ resources.

Reasonably assured conventional resources by processing method

(tonnes U*)

Processing method	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Heap leaching* from UG	0	0	0	1 200
Total	0	0	0	1 200

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

Inferred conventional resources by deposit type

(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

* In situ resources.

Inferred conventional resources by production method

(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

* In situ resources.

Inferred conventional resources by processing method
(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

* In situ resources.

Prognosticated conventional resources
(tonnes U)

Cost ranges		
<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
N/A	N/A	81 200

Speculative conventional resources
(tonnes U)

Cost ranges		
<USD 130/kgU	<USD 260/kgU	Unassigned
N/A	N/A	321 600

Expected installed nuclear generating capacity to 2035
(MWe net)

2020		2025		2030		2035	
Low	High	Low	High	Low	High	Low	High
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Expected annual reactor-related uranium requirements to 2030
(tonnes U)

2020		2025		2030		2035	
Low	High	Low	High	Low	High	Low	High
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Zambia*

Uranium exploration and mine development

Historical review

Uranium was first observed 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 from 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 1990s but primary attention was 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. Prior to this date, all mineral rights were held privately, but in 1969 these rights reverted to the state. In 1969, 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.

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 at a later date 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 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. However, much of this 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. Activity continues on a number of key initiatives to lower costs, including improvements to operating systems and processes.

* Report prepared by the NEA/IAEA, based on previous Red Books and company reports.

Denison completed extensive drilling in 2011 and 2012 on their Mutanga Project. Airborne geophysics techniques were used to locate anomalies and potential uranium mineralisation. Near-surface mineralisation at Dibwe East zones 1 and 2 is consistent over 4 km, with high-grade ore in its core. Future exploration activities are expected to be focused on field programmes including extensive surficial geochemistry and surface radon surveys, geological mapping and airborne geophysics all of which will be used to assist in defining drill targets.

At the end of 2012, African Energy concluded baseline environmental studies for the Chirundu uranium project, the only work completed by African Energy on its uranium projects. The Chirundu Project near the Zimbabwe border is focused on exploring the Njame and Gwabe deposits and reports 4 270 tU as measured, indicated and inferred resources. A mining licence was granted for the project in October 2009, with a view to a 500 tU/yr acid heap leach operation. It includes the Siamboka prospect. A feasibility study was commenced but then deferred because of low uranium prices. The company was also exploring the Chisebuka deposit, 250 km along strike south-west.

In June 2016, GoviEx Uranium acquired Denison's Mutanga Project, and in October 2017 completed the acquisition of Africa Energy's Chirundu Project consolidating these adjacent projects. In 2017, GoviEx released a new preliminary economic assessment for the Mutanga uranium project including the mineral resource estimate for Mutanga, Dibwe, Dibwe East, Gwabe, Njame and Njma South ore deposits.

Uranium resources

Identified conventional resources (reasonably assured and inferred resources)

Only three properties in Zambia have reached the stage of development when NI 43-101 or JORC compliant resources have been published in 2017. GoviEx's Mutanga and Chirundu projects have identified recoverable resources of 20 311 tU. The third project is the Lumwana copper mine, where resources are hosted by mica-quartz-kyanite schists of the Katangan Supergroup with identified recoverable 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 have known associated 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 March 2011, the stockpile amounted to 4.2 Mt of ore grading at 0.1% U.

Future projects

GoviEx Uranium of Canada is planning to develop a USD 123 million project at Mutanga and Chirundu, when uranium prices have improved to >USD 55/lb. Following successful licence renewal, a preliminary economic study has been undertaken for an open-pit mine with acid heap leaching. The project is licensed with a 25-year mining licence, environmental approval and radioactive materials licence. The project is forecast to produce 920 tU/yr for 11 years.

Uranium production centre technical details
(as of 1 January 2017)

	Centre #1	Centre #2
Name of production centre	Lumwana	Mutanga
Production centre classification	Planned	Planned
Date of first production (year)	N/A	N/A
Source of ore:		
Deposit name(s)	Malundwe-Chimiwungo	Dibwe-Mutanga-Gwabe-Njame
Deposit type(s)	Metasomatic (metamorphosed schists)	Sandstone
Recoverable resources (tU)	6 967	20 311
Grade (% U)	0.07	0.033
Mining operation:		
Type (OP/UG/ISL)	OP	OP
Size (tonnes ore/day)	2 800	11 000
Average mining recovery (%)	N/A	N/A
Processing plant:		
Acid/alkaline	Acid	Acid
Type (IX/SX)	SX	HL
Size (tonnes ore/day)		
Average process recovery (%)	93.1	88.0
Nominal production capacity (tU/year)	650	920
Plans for expansion (yes/no)		
Other remarks	Mine currently operated by Barrick: uranium bankable feasibility study completed by Equinox Minerals	Mine construction on hold until uranium price increases

Environmental activities and socio-cultural issues

Waste rock management

Equinox Minerals' original plans in 2003 were 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 may 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.

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 2 villages to allow for the construction of the mine infrastructure.

Denison/GoviEx has been providing funding to a number of communities and sustainability projects including construction of schools and clinics, water boreholes and agricultural programmes.

African Energy assisted the construction of a community health post and also did a water borehole at Sikoongo Village near their Chirundu Project.

Barrick have invested in a wide range of sustainable development initiatives in 2012, including funding for infrastructure (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, Rosatom signed an intergovernmental agreement on co-operation in the peaceful uses of nuclear energy, which 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 first is for the training of Zambian specialists in Russia so that within 15 years, Russia will assist Zambia with training young nuclear energy engineers, plan for nuclear power plant personnel, develop a nuclear energy regulator and build a research reactor, which will provide medicine, agricultural services and energy. Zambia aims to become a regional centre for nuclear medicine. In respect to energy, nuclear power is needed to prevent load shedding due to unreliable supply.

Uranium policies, uranium stocks and uranium prices

National policies relating to uranium

Mining activities in general were regulated by the Mines and Minerals Act (1995), but until recently there was no legislation specifically relating to exploration for 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 IAEA guidelines.

A study by the Council of Churches concluded that current legislation and enforcement was inadequate for uranium mining. They recommended that current regulations be revised to address the concerns of local communities and that educational and awareness programmes be initiated prior to any uranium exploration and mining activities.

In 2011, Zambia and Finland signed co-operating projects aimed at helping the southern African nation 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 geo-information infrastructure. These projects are designed to help the country evaluate, update and review regulations regarding the safety of uranium mining.

Reasonably assured conventional resources by deposit type
(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone			5 113	5 113
Metasomatite			6 016	6 016
Total			11 129	11 129

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 (%)
Open-pit mining (OP)			11 129	11 129	88-93
Total			11 129	11 129	88-93

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 OP			11 129	11 129	88-93
Total			11 129	11 129	88-93

Inferred conventional resources by deposit type
(tonnes U)

Deposit type	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
Sandstone			15 198	15 198
Metasomatite			951	951
Total			16 149	16 149

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)			16 149	16 149	88-93
Total			16 149	16 149	88-93

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			16 149	16 149	88-93
Total			16 149	16 149	88-93

Historical uranium production by deposit type

(tonnes U in concentrates)

Deposit type	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Metasomatite	86	0	0	0	86	0
Total	86	0	0	0	86	0

Historical uranium production by production method

(tonnes U in concentrates)

Production method	Total through end of 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Underground mining[1]	86	0	0	0	86	0
Total	86	0	0	0	86	0

1. 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 2013	2014	2015	2016	Total through end of 2016	2017 (expected)
Conventional	86	0	0	0	86	0
Total	86	0	0	0	86	0

Short-term production capabilities

(tonnes U/year)

2015				2017				2020			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
0	0	0	0	0	0	0	0	0	0	0	0

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
0	0	0	0	0	0	0	0	0	0	0	1 570

Appendix 1. **List of reporting organisations and contact persons**

NEA	OECD Nuclear Energy Agency – Division of Nuclear Technology Development and Economics, Paris Contact person: Ms Luminita Grancea (*Scientific Secretary)*
IAEA	International Atomic Energy Agency, Division of Nuclear Fuel Cycle and Waste Technology, Vienna Contact person: Ms Adrienne Hanly *(Scientific Secretary)*
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Argentina	Comisión Nacional de Energía Atómica, Gerencia Exploración de Materias Primas/Gerencia Producción de Materias Primas, Avenida del Libertador 8250, 1429 Buenos Aires Contact persons: Mr Roberto E. Bianchi and Mr Luis Eduardo Lopez
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Viet Nam	Institute for Technology of Radioactive and Rare Elements, 48 Langha Str., Dongda District, Hanoi Contact person: Mr Van Lien THAN

Appendix 2. **Members of the Joint NEA-IAEA Uranium Group participating in 2016-2017 meetings**

NEA	Ms L. Grancea *(Scientific Secretary)*	Division of Nuclear Technology Development and Economics, Paris
IAEA	Ms A. Hanly *(Scientific Secretary)*	Division of Nuclear Fuel Cycle and Waste Technology, Vienna
	Mr. Martin Fairclough	
Algeria	Mr A. Khaldi	Centre de Recherche Nucléaire de Draria, Draria
Argentina	Mr Roberto Eugenio Bianchi Mr Roberto Enrique Gruner Mr Luis Edourado Lopez	National Atomic Energy Commission
Australia	Mr Paul Kay	Geoscience Australia, Canberra
Austria	Mr Nikolaus Arnold	Institute of Safety and Risk Sciences
Belgium	Ms F. Renneboog	Synatom S.A., Brussels
Brazil	Mr L. Filipe Da Silva	Indústrias Núcleares do Brasil INB-S/A, Rio de Janeiro
Canada	Mr T. Calvert *(Vice-chair)*	Natural Resources Canada, Ottawa
	Mr Robert Lojk	Canadian Nuclear Safety Commission
China	Mr Sicong Zou	China Atomic Energy Authority (CAEA), Beijing

Czech Republic	Mr P. Vostarek	DIAMO, State Enterprise, Stráž pod Ralskem
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	Mme Farahnaz Laldjee	Electricité de France (EDF)
	Mr C. Polak *(Vice-chair)*	AREVA MINES, Courbevoie
Germany	Mr M. Schauer	Federal Institute for Geoscience and Natural Resources, Hannover
Hungary	Mr András Barabás	MECSEKERC LTD, Pecs
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	Mr Kambiz Sadeghi	TAMAS, Tehran
Kazakhstan	Ms Aliya Akzholova Mr Yuriy Demekhov Ms O. Gorbatenko *(Vice-chair)*	National Atomic Company (KAZATOMPROM), Astana
Kyrgyzstan	Ms Aigul Sulaimanova	Institute of Mining and Mining Technologies, Bishkek

Mongolia	Mr Mavag Chadraabal	Executive Office of the Nuclear Energy Commission, Ulaanbaatar
Pakistan	Mr Muhammad Abbas Qureshi	Pakistan Atomic Energy Commission, Islamabad
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Poland	Ms G. Zakrzewska-Koltuniewicz	Institute of Nuclear Chemistry and Technology, Warsaw
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Thailand	Ms Uthaiwan Injarean	Thailand Institute of Nuclear Technology, Nakorn Nayok

Turkey	Mr Gorken Gungor	Nasuh Akar mah. Türkocagi cad, Ankara
Ukraine	Mr A. Bakarzhiyev Mr Y. Bakarzhiyev	The State Geological Enterprise “Kirovgeology”, Kiev
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	Mr Michael Scott	U.S. Energy Information Administration, Washington, DC
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European Commission	Mr D. Kozak	Euratom Supply Agency, Luxembourg

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.

Conventional resources are further divided, according to different confidence levels of occurrence, into four categories. 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**

<table>
<tr><td rowspan="1"></td><td colspan="3">Identified resources</td><td colspan="3">Undiscovered resources</td></tr>
<tr><td>NEA/IAEA</td><td colspan="2">Reasonably assured</td><td>Inferred</td><td>Prognosticated</td><td colspan="2">Speculative</td></tr>
<tr><td rowspan="2">Australia</td><td colspan="2">Demonstrated</td><td rowspan="2">Inferred</td><td colspan="3" rowspan="2">Undiscovered</td></tr>
<tr><td>Measured</td><td>Indicated</td></tr>
<tr><td>Canada (NRCan)</td><td>Measured</td><td>Indicated</td><td>Inferred</td><td>Prognosticated</td><td colspan="2">Speculative</td></tr>
<tr><td>United States (DOE)</td><td colspan="2">Reasonably assured</td><td colspan="2">Estimated additional</td><td colspan="2">Speculative</td></tr>
<tr><td>Russia, Kazakhstan, Ukraine, Uzbekistan</td><td>A + B + C1</td><td>C2</td><td>C2+P1</td><td>P1</td><td>P2</td><td>P3</td></tr>
</table>

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 80/kgU, <USD 130/kgU and <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**

Decreasing economic attractiveness ↓	Recoverable at costs	Identified resources		Undiscovered resources	
	<USD 40/kgU	Reasonably assured resources	Inferred resources	Prognosticated resources	Speculative resources
	USD 40-80/kgU	Reasonably assured resources	Inferred resources	Prognosticated resources	
	USD 80-130/kgU	Reasonably assured resources	Inferred resources	Prognosticated resources	
	USD 130-260/kgU	Reasonably assured resources	Inferred resources	Prognosticated resources	

Decreasing confidence in estimates →

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.

1. IAEA (1984), *Manual on the Projection of Uranium Production Capability,* General Guidelines, Technical Report Series No. 238, IAEA, Vienna.

Production capacity and capability

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 the resources tributary to them. Projections of production capability are supported only by RAR and/or IR. The projection is presented based on those resources recoverable at costs <USD 130/kgU.

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).

Mining and milling

In situ leaching (ISL): 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. This process is sometimes referred to as in situ recovery (ISR).

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-m-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.

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.

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 exploited at present or in the future.

2. Definitions based on those published in OECD (2002), *Environmental Remediation of Uranium Production Facilities*, Paris.

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. Metasomatic 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).
   - 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

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).

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 the 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 Tumalappalle deposit 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 synsedimentary, 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
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	Empresa Nacional del Uranio, S.A. (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 (1965-2018) and national reports**

Listing of Red Book editions (1965-2018)

OECD/ENEA[1]	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

1. 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. A listing of all Red Book editions is shown at the end of this Index.)

	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990
Algeria						1976	1977	1979	1982				
Argentina		1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990
Armenia													
Australia		1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990
Austria							1977						
Bangladesh											1986	1988	
Belgium									1982	1983	1986	1988	1990
Benin													1990
Bolivia							1977	1979	1982	1983	1986		
Bophuthatswana[2]									1982				
Botswana								1979		1983	1986	1988	
Brazil				1970	1973	1976	1977	1979	1982	1983	1986		
Bulgaria													1990
Cameroon							1977		1982	1983			
Canada	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990
Central African Republic				1970	1973		1977	1979			1986		
Chad													
Chile							1977	1979	1982	1983	1986	1988	
China													1990
Colombia							1977	1979	1982	1983	1986	1988	1990
Congo		1967											
Costa Rica									1982	1983	1986	1988	1990
Côte d'Ivoire									1982				
Cuba												1988	
Czech Republic													
Czech and Slovak Rep.													1990
Denmark (Greenland)	1965	1967		1970	1973	1976	1977	1979	1982	1983	1986		1990
Dominican Republic									1982				
Ecuador							1977		1982	1983	1986	1988	
Egypt							1977	1979			1986	1988	1990
El Salvador										1983	1986		
Estonia													
Ethiopia								1979		1983	1986		
Finland					1973	1976	1977	1979	1982	1983	1986	1988	1990
France	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990
Gabon		1967		1970	1973				1982	1983	1986		
Germany				1970		1976	1977	1979	1982	1983	1986	1988	1990

2. 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)*

1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	
					2002	2004	2006	2008		2012	2014	2016	2018	Algeria
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Argentina
				2000	2002	2004	2006		2010	2012	2014	2016	2018	Armenia
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Australia
														Austria
														Bangladesh
1992	1994	1996	1998	2000	2002	2004	2006	2008						Belgium
														Benin
													2018	Bolivia
														Bophuthatswana
									2010	2012	2014	2016		Botswana
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Brazil
1992	1994	1996	1998					2008	2010					Bulgaria
														Cameroon
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Canada
														Central African Republic
											2014	2016		Chad
1992	1994	1996	1998	2000	2002	2004	2006	2008		2012	2014	2016	2018	Chile
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	China
		1996	1998					2008						Colombia
														Congo
														Costa Rica
														Côte d'Ivoire
1992		1996	1998											Cuba
	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Czech Republic
														Czech and Slovak Rep.
1992		1996	1998			2004			2010	2012	2014	2016	2018	Denmark (Greenland)
														Dominican Republic
														Ecuador
1992	1994	1996	1998	2000		2004	2006	2008	2010					Egypt
														El Salvador
			1998			2004								Estonia
										2012				Ethiopia
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Finland
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	France
		1996	1998	2000	2002	2004	2006							Gabon
1992	1994	1996	1998	2000	2002		2006	2008	2010	2012	2014	2016	2018	Germany

Index of national reports in Red Books (*cont'd*)

	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990
Ghana							1977			1983			
Greece							1977	1979	1982	1983	1986	1988	1990
Guatemala											1986	1988	
Guyana								1979	1982	1983	1986		
Hungary													
India	1965	1967		1970	1973	1976	1977	1979	1982	1983	1986		1990
Indonesia							1977				1986	1988	1990
Iran, Islamic Republic of							1977						
Iraq													
Ireland								1979	1982	1983	1986		
Italy		1967		1970	1973	1976	1977	1979	1982	1983	1986	1988	
Jamaica									1982	1983			
Japan	1965	1967		1970	1973	1976	1977	1979	1982	1983	1986	1988	1990
Jordan							1977				1986	1988	1990
Kazakhstan													
Korea						1976	1977	1979	1982	1983	1986	1988	1990
Kyrgyzstan													
Lesotho												1988	
Liberia							1977			1983			
Libyan Arab Jamahiriya[3]										1983			
Lithuania													
Madagascar						1976	1977	1979	1982	1983	1986	1988	
Malawi													
Malaysia										1983	1986	1988	1990
Mali											1986	1988	
Mauritania													1990
Mexico				1970	1973	1976	1977	1979	1982		1986		1990
Mongolia													
Morocco	1965	1967				1976	1977	1979	1982	1983	1986	1988	1990
Namibia								1979	1982	1983	1986	1988	1990
Netherlands									1982	1983	1986		1990
New Zealand		1967					1977	1979					
Niger		1967		1970	1973		1977				1986	1988	1990
Nigeria								1979					
Norway								1979	1982	1983			
Pakistan		1967											
Panama										1983		1988	
Paraguay										1983	1986		
Peru							1977	1979		1983	1986	1988	1990
Philippines							1977		1982	1983	1986		1990
Poland													

3. Libya as of 2011.

Index of national reports in Red Books *(cont'd)*

1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	
														Ghana
1992	1994	1996	1998											Greece
														Guatemala
														Guyana
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Hungary
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	India
1992	1994	1996	1998	2000	2002	2004	2006		2010	2012	2014	2016	2018	Indonesia
			1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Iran, Islamic Republic of
												2016		Iraq
1992			1998											Ireland
1992	1994	1996	1998	2000						2012	2014	2016		Italy
														Jamaica
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Japan
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Jordan
	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Kazakhstan
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010					Korea
		1996			2002									Kyrgyzstan
														Lesotho
														Liberia
														Libyan Arab Jamahiriya
	1994	1996	1988	2000	2002	2004	2006	2008						Lithuania
														Madagascar
				2000				2008	2010	2012	2014	2016		Malawi
1992	1994	1996	1998	2000	2002									Malaysia
											2014	2016	2018	Mali
												2016		Mauritania
1992	1994	1996	1998	2000						2012		2016	2018	Mexico
	1994	1996	1998						2010	2012	2014	2016	2018	Mongolia
			1998											Morocco
	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Namibia
1992	1994	1996	1998	2000	2002									Netherlands
														New Zealand
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Niger
														Nigeria
1992		1996	1998											Norway
	1994		1998	2000										Pakistan
														Panama
													2018	Paraguay
1992	1994	1996	1998	2000		2004	2006	2008	2010	2012	2014	2016	2018	Peru
	1994	1996	1998	2000	2002	2004	2006							Philippines
				2000	2002			2008	2010	2012	2014	2016		Poland

Index of national reports in Red Books *(cont'd)*

	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990
Portugal	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990
Romania													
Russia													
Rwanda											1986		
Senegal									1982				
Slovak Republic													
Slovenia													
Somalia							1977	1979					
South Africa	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986		
Spain	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990
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
Switzerland						1976	1977	1979	1982	1983	1986	1988	1990
Syrian Arab Republic									1982	1983	1986	1988	1990
Tajikistan													
Tanzania													1990
Thailand							1977	1979	1982	1983	1986	1988	1990
Togo								1979					
Turkey					1973	1976	1977	1979	1982	1983	1986	1988	1990
Turkmenistan													
Ukraine													
United Kingdom						1976	1977	1979	1982	1983	1986	1988	1990
United States	1965	1967	1969	1970	1973	1976	1977	1979	1982	1983	1986	1988	1990
Uruguay							1977		1982	1983	1986	1988	1990
USSR (former)													
Uzbekistan													
Venezuela											1986	1988	
Viet Nam													
Yugoslavia					1973	1976	1977		1982				1990
Zaire[4]					1973		1977					1988	
Zambia											1986	1988	1990
Zimbabwe									1982			1988	

4. 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)*

1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016		Portugal
1992	1994	1996	1998	2000	2002									Romania
	1994		1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Russia
														Rwanda
													2018	Senegal
	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016		Slovak Republic
	1994	1996	1998		2002	2004	2006	2008	2010		2014	2016	2018	Slovenia
														Somalia
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016		South Africa
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Spain
														Sri Lanka
														Sudan
														Surinam
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016		Sweden
1992	1994	1996	1998	2000	2002	2004	2006	2008						Switzerland
	1994													Syrian Arab Republic
					2002									Tajikistan
									2010	2012	2014	2016	2018	Tanzania
1992	1994	1996	1998	2000	2002		2006				2014	2016	2018	Thailand
														Togo
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Turkey
						2004								Turkmenistan
	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	Ukraine
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010		2014	2016	2018	United Kingdom
1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	United States
														Uruguay
1992														USSR (former)
	1994	1996	1998	2000	2002	2004	2006			2012		2016	2018	Uzbekistan
														Venezuela
1992	1994	1996	1998	2000	2002	2004	2006	2008			2014	2016	2018	Viet Nam
1992														Yugoslavia
														Zaire
1992	1994	1996	1998							2012	2014	2016	2018	Zambia
1992	1994	1996	1998											Zimbabwe

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Uranium 2018: Resources, Production and Demand

Uranium is the raw material used to produce fuel for long-lived nuclear power facilities, necessary for the generation of significant amounts of baseload low-carbon electricity for decades to come. Although a valuable commodity, declining market prices for uranium in recent years, driven by uncertainties concerning the evolution in the use of nuclear power, have led to significant production cutbacks and the postponement of mine development plans in a number of countries and to some questions being raised about future uranium supply.

This 27th edition of the "Red Book", a recognised world reference on uranium jointly prepared by the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), provides analyses and information from 41 producing and consuming countries in order to address these and other questions. The present edition provides the most recent review of 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 2035, in order to address long-term uranium supply and demand issues.

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