



Uranium 2016: **Resources, Production and Demand**

Executive Summary

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

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NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Executive summary

In addition to updated resource figures, *Uranium 2016 – 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 as of 1 January 2015. It contains official data provided by 37 countries and 12 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.

Resources¹

Total identified uranium resources have increased by only 0.1% since 2013. The resource base has changed very little due to lower levels of investment and associated exploration efforts reflecting current, depressed uranium market conditions.

Total identified resources (reasonably assured and inferred) as of 1 January 2015 amounted to 5 718 400 tonnes of uranium metal (tU) in the <USD 130/kgU (<USD 50/lb U₃O₈) category, a decrease of 3.1% compared to 1 January 2013. In the highest cost category (<USD 260/kgU or <USD 100/lb U₃O₈), total identified resources amount to 7 641 600 tU, an increase of only 0.1% compared to the total reported for 2013.

A decrease in reasonably assured resources (RAR) was reported for this edition in all cost categories, with the exception of the <USD 80/kgU category (<USD 30/lb U₃O₈). The decrease in RAR was offset by increases in inferred resources reported for all cost categories. The most significant change is reported in the <USD 80/kgU category, with an increase of 20.9% in inferred resources, compared to values reported in 2013. This can be primarily attributed to the addition of 208 400 tU of inferred resources from China and Kazakhstan. At the 2014 level of uranium requirements, identified resources are sufficient for over 135 years of supply for the global nuclear power fleet. Moreover, an additional 72 700 tU of resources have been identified by the NEA/IAEA as resources reported by companies that are not yet included in national resource totals.

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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. For a more detailed description, see Appendix 3.

Total undiscovered resources (prognosticated resources and speculative resources) as of 1 January 2015 amounted to 7 422 700 tU, a minor decrease from the 7 697 700 tU in the previous edition (NEA/IAEA, 2014). 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 are either not reported or estimates 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 2015. Resource figures are dynamic and related to commodity prices. Identified resources have changed very little since the last reporting period because of lower levels of investment and associated exploration efforts reflecting current, depressed market conditions.

Exploration

Uranium exploration and mine development expenditures increased between 2013 and 2015. Nevertheless, no significant resources were added to the resource base during this reporting period as the expenditure increase can be largely attributed to the development of the Cigar Lake mine in Canada and the Husab mine in Namibia. Exploration expenditures continued to decrease because of low uranium prices.

Worldwide exploration and mine development expenditures as of 1 January 2015 totalled USD 2.9 billion, a 10% increase over 2013 figures. Over 38% of these exploration and development expenditures were devoted to non-domestic activities with the majority of expenditures made by China.

From 2012 to 2014, domestic exploration and mine development expenditures decreased in many countries, mainly as a result of the declining uranium price which slowed down many exploration and mine development projects, particularly in the junior uranium mining sector. Significant decreases are reported for Argentina, Australia, Canada, Finland, Kazakhstan, Russia, South Africa, Spain and the United States. In contrast, Brazil, China, the Czech Republic, Jordan, Mexico and Turkey reported increases in expenditures during this period. The most significant increases in domestic expenditures are reported by China with a steady increase in expenditures of USD 131 000 in 2012, USD 189 000 in 2013 and USD 197 000 in 2014. Despite a slowdown in the industry in more recent years, following peak levels of activity associated with high uranium prices in 2007-2008, the majority of reporting countries have maintained domestic exploration and mine development expenditures above pre-2007 levels.

Non-domestic exploration and development expenditures, although reported only by China, France, Japan and Russia, increased from USD 185 million in 2012 to more than USD 692 million in 2013 and USD 812 million in 2014. Non-domestic development expenses for China have been projected to reach over USD 777 million in 2015 principally because of investment in the Husab mine in Namibia, pushing non-domestic exploration and development expenditures to a total of more than USD 846 million in 2015.

For this reporting period, China accounts for the highest non-domestic and domestic exploration and development expenditures supporting reports of their strong commitment to growth in nuclear power.

Production

Global uranium mine production has decreased by 4% since 2013. However, production is still above 2011 levels, and Kazakhstan, currently the world's leading producer, continues to increase production, but at a slower pace.

Overall, world uranium production decreased by 4.1%, from 58 411 tU in 2012 to 55 975 tU as of 1 January 2015. The changes are principally the result of decreased production in Australia, and lower uranium mining output from Brazil, the Czech Republic, Malawi, Namibia and Niger. Within OECD countries, production decreased from 17 956 tU in 2012 to 16 185 tU in 2014, primarily as a result of decreased production in Australia and, to a smaller extent, in the

Czech Republic. From 2012 to 2014, uranium was produced in 21 different countries; the same number as in the last reporting period, with Germany, Hungary and France 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 22 781 tU in 2014 and 23 800 tU in 2015. Production in Kazakhstan in 2014 totalled more than the combined production that same year in Canada and Australia, the second and third largest producers of uranium, respectively.

In situ leaching (ISL, sometimes referred to as in situ recovery, or ISR) production continued to dominate uranium production accounting for 51% of world production as of 1 January 2015, largely as a result of continued production increases from Kazakhstan and other ISL projects in Australia, China, Russia, the United States and Uzbekistan. Underground mining (27%), open-pit mining (14%) and co-product and by-product recovery from copper and gold operations (7%), heap leaching (<1%) and other methods (<1%) accounted for the remaining uranium production shares.

Environmental and social aspects of uranium production

With uranium production projected to expand, efforts are being made to develop safe mining practices and to continue to minimise environmental impacts.

Although the focus of this publication remains uranium resources, production and demand, 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.

In Botswana, A-Cap Resources established the Safety, Health, Radiation, Environment and Community Group aimed at informing, educating and involving local communities through meetings held on a regular basis. An environmental and social impact assessment study of the Letlhakane Project was completed and submitted to the Department of Environmental Affairs (DEA) in 2015. Specialist studies have determined that with appropriate mitigation, all environmental and social aspects during the construction and planned operations will be addressed.

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 also engaged in social responsibility programmes, including committing itself to local procurement, recruitment and employment, training, education and responsible environmental management practices. To this end, projects were initiated to address research needs identified in the company's environmental management plan, including groundwater monitoring.

In several other countries with closed uranium production facilities (i.e. Brazil, Canada, the Czech Republic, France, Hungary, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Ukraine and the United States), updates of remedial and monitoring activities are provided in the respective country reports.

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.

Uranium demand

Demand for uranium is expected to continue to rise for the foreseeable future as nuclear power is projected to grow considerably in regulated electricity markets with increasing electricity demand and a growing need for clean air electricity generation.

As of 1 January 2015, a total of 437 commercial nuclear reactors were connected to the grid with a net generating capacity of 377 GWe requiring about 56 600 tU annually. Taking into account changes in policies announced in several countries and revised nuclear development plans, world nuclear capacity is projected to grow to between 418 GWe net in the low demand case and 683 GWe net in the high demand case by 2035, representing increases of 11% and 81%, respectively. Accordingly, world annual reactor-related uranium requirements (excluding mixed oxide fuel [MOX]) are projected to rise to between 66 995 tU and 104 740 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 48 GWe and 166 GWe of new capacity in the low and high cases, respectively, representing increases of more than 54% and 188% over 2014 capacity. Nuclear capacity in non-EU member countries on the European continent is also projected to increase significantly, with additions of between 21 and 45 GWe of capacity projected by 2035 (increases of about 49% and 105%, respectively). Other regions projected to experience significant nuclear capacity growth include the Middle East, Central and Southern Asia and South-East Asia, with more modest growth projected in Africa and the Central and South American regions. For North America, the low case projection sees nuclear generating capacity remaining about the same by 2035 and increasing by 11% in the high case, depending largely on future electricity demand, lifetime extension of existing reactors and government policies with respect to greenhouse gas emissions. In the European Union, nuclear capacity in 2035 is either projected to decrease by 48% in the low case scenario or increase by 2% in the high case.

These projections are subject to even greater uncertainty than usual following the Fukushima Daiichi accident, since the role that nuclear power will play in the future generation mix in some countries has not yet been determined and China did not report official targets for nuclear power capacity beyond 2020 for this edition. 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, non-proliferation concerns, proposed waste management strategies and public acceptance of nuclear energy, which is a particularly important factor in some countries after the Fukushima Daiichi accident. Concerns about longer-term security of fossil fuel supply and the extent to which nuclear energy is seen to be beneficial in meeting greenhouse gas reduction targets and enhancing security of energy supply could contribute to even greater projected growth in uranium demand.

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 increasing expectations of governments hosting uranium mining.

As of 1 January 2015, world uranium production (55 975 tU) provided about 99% of world reactor requirements (56 585 tU), with the remainder supplied by previously mined uranium (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 30% of the total 2015 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 factors, technical challenges and risks at some facilities, the potential development of ever more stringent regulatory requirements, and the heightened expectations of governments hosting uranium mining. 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 2015. However, available information indicates that there remains a significant amount of previously mined uranium (including material held by the military), some of which could feasibly be brought to the market in the coming years. With the successful transition from gas diffusion to centrifuge enrichment now complete and capacity at least temporarily in excess of requirements following the Fukushima Daiichi accident, enrichment providers are well-positioned to reduce tails assays below contractual requirements and in this way create additional uranium supply. In the longer term, alternative fuel cycles (e.g. 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 a delay in some mine development projects, other projects have advanced through regulatory and further stages of development. However, 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 a key facility be put out of operation. 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 demand is expected to continue to grow in the next several decades to meet the needs of a growing population, particularly in developing countries. Since nuclear power plant operation produces competitively priced, baseload electricity that is essentially free of greenhouse gas emissions, 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 considerably in regulated electricity markets with increasing electricity demand and a growing need for clean air electricity generation.

Regardless of the role that nuclear energy ultimately plays in meeting future electricity demand, the uranium resource base described in this publication is more than adequate to meet projected requirements for the foreseeable future. The challenge in the coming years is likely to be less one of adequacy of resources than adequacy of production capacity development due to poor uranium market conditions.

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Uranium 2016: 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 evolutions in the use of nuclear power, have led to the postponement of mine development plans in a number of countries and to some questions being raised about future uranium supply. This 26th 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 49 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.

