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

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Uranium 2014: Resources, Production and Demand

Executive Summary

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NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Executive summary

In addition to updated resource figures, *Uranium 2014: 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 2013. It contains official data provided by 36 countries and 9 national reports prepared by the joint NEA-IAEA Secretariat 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]

Total identified uranium resources have increased by more than 7% since 2011, adding almost ten years of global reactor requirements to the existing resource base, but the majority of the increases occurred in resource categories with higher production costs.

Total identified resources (reasonably assured and inferred) as of 1 January 2013 amounted to 5 902 900 tonnes of uranium metal (tU) in the <USD 130/kgU (<USD 50/lb U_3O_8) category, an increase of 10.8% compared to 1 January 2011. In the highest cost category (<USD 260/kgU or <USD 100/lb U_3O_8) which was reintroduced in 2009, total identified resources amount to 7 635 200 tU, an increase of 7.6% compared to the total reported in 2011.

Although the total identified resources have increased overall, since 2011 there has been a significant reduction of 36% in the <USD 80/kgU (or <USD 30/lb U_3O_8) cost category, owing principally to increased mining costs. The lowest cost category (<USD 40/kgU or <USD 15/lb U_3O_8) changed little, owing mainly to successful exploration efforts in Kazakhstan. The majority of the increases are a result of re-evaluations of previously identified resources and additions to known deposits, particularly in Australia, Canada, the Czech Republic, Greenland, Kazakhstan, Peoples' Republic of China and South Africa. At the 2012 level of uranium requirements, identified resources are sufficient for over 120 years of supply for the global nuclear power fleet. Moreover, an additional 119 100 tU

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.

of resources have been identified by the Secretariat as resources reported by companies that are not yet included in national resource totals.

Total undiscovered resources (prognosticated resources and speculative resources) as of 1 January 2013 amounted to 7 697 700 tU, a significant decrease from the 10 429 100 tU reported in 2011, principally because the United States did not report data for this edition as previous estimates completed in 1980 need re-evaluation to determine their accuracy.

It is important to note that in some cases, including those of major producing countries with large identified resource inventories (e.g. Australia, Canada), 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 2013. Resource figures are dynamic and related to commodity prices. The overall increase in identified resources (including high cost resources) from 2011 to 2013 have added over eight years of global supply based on 2012 uranium requirements, despite less favourable market conditions. Nonetheless, as in the case of past periods of increased exploration activity, continued high levels of investment and associated exploration efforts have resulted in the identification of additional resources of economic interest.

Exploration

The increased resource base described above has been identified thanks to a 23% increase in uranium exploration and mine development expenditures between 2010 and 2012.

Worldwide exploration and mine development expenditures in 2012 totalled USD 1.92 billion, a 22% increase over updated 2010 figures (reduced from over USD 2 billion to USD 1.56 billion). Despite a decline in market prices over the past few years, prices for uranium since 2003 have been generally higher compared to the preceding two decades and have stimulated increased exploration in regions known to have good potential based on past work and grass roots exploration in new areas. Concerted efforts also continue to be made to expand the resource base and develop deposits for projected future supply requirements. Over 95% of exploration and development expenditures in 2012 were devoted to domestic activities.

From 2011 to 2013, domestic exploration and mine development expenditures decreased in some countries, partly due to the declining uranium price which slowed down many exploration and mine development projects, particularly in the junior uranium mining sector. In Canada, although overall expenditures decreased, exploration expenditures increased by 3.5% from 2011 to 2012. In contrast, Australia reported a significant decrease in exploration expenditures from 2011 to 2012. This decrease was offset by increased total expenditures from 2011 to 2012 in a number of countries including Brazil, China, Ethiopia, Iran, Kazakhstan, Poland, Spain, Tanzania, Turkey, the Ukraine, the United States and Zambia. Worldwide expenditures are expected to remain the same or increase slightly in 2013 despite declining expenditures expected in China, Poland and Tanzania. Exploration expenditures in 2013 are projected to increase significantly in Kazakhstan.

Non-domestic exploration and development expenditures, although reported only by China, France, Japan and the Russian Federation, decreased from USD 371 million in 2009 to less than USD 200 million from 2010 through 2012, but remained significantly above the USD 70 million reported in 2004. Non-domestic development expenses in China are projected to reach over USD 560 million in 2013 principally due to investment in the Husab mine in Namibia, pushing expected non-domestic exploration and development expenditures to a total of more than USD 650 million in 2013.

Production

Global uranium mine production between 2010 and 2012 increased by 7.6%, which is a lower rate of growth compared to the last reporting period, but increases were again mainly the result of rising production in Kazakhstan, currently the world's leading producer.

Overall, world uranium production increased only 0.2% from 54 653 tU in 2010 to 54 740 tU in 2011. However, production in 2012 increased by 7.4% from 2011 to 58 816 tU and is projected to increase to over 59 500 tU in 2013. This recent growth is principally the result of increased production in Kazakhstan, with smaller additions in Australia, Brazil, China, Malawi, Namibia, Niger, the Ukraine and the United States. Within OECD countries, production increased slightly from 16 982 tU in 2011 to 17 956 tU in 2012 and is expected to remain relatively stable in 2013.

From 2011 to 2013, uranium was produced in 21 different countries; one less than in 2010 (Bulgaria did not report mine remediation recovery for this edition and France, Germany and Hungary continue to recover minor amounts of uranium only as the result of remediation activities). Kazakhstan's growing production continued to 21 240 tU in 2012 (with 22 500 tU expected in 2013). Although the rate of increase has been reduced from previous years it remains the world's largest producer by a large margin. Production in Kazakhstan in 2012 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 45% of world production in 2012, largely due to production increases in Kazakhstan and to other ISL projects in Australia, China, the Russian Federation, the United States and Uzbekistan. World uranium production by ISL is forecast to reach 47.5% of total production in 2013. In 2012, underground mining (26%), open-pit mining (20%) and co-product and by-product recovery from copper and gold operations (6%), heap leaching (2%) and other methods (1%) accounted for the remaining production shares.

Environmental and social aspects of uranium production

With uranium production poised to expand, in some cases to countries that have not previously hosted uranium mining, efforts are being made to develop operations similar to leading practice operations in more established uranium producing countries. These efforts aim to develop safe mining practices in communities well-informed of such activities and to continue to minimise environmental impacts.

Although the focus of this publication remains uranium resources, production and demand, environmental 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 national reports in the current edition. 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 January 2013, a number of agreements covering the Ranger Project Area were signed by the Australian government, Northern Land Council, the Mirarr traditional owners and the mine operator Energy Resources Australia. Such initiatives provide greater benefits to traditional owners, including intergenerational benefits, in this case through the establishment of the Kakadu West Arnhem Social Trust. Other key features include an agreed approach to increasing opportunities for local Aboriginal participation in business development, training and employment.

The Uranium Council (formerly the Uranium Industry Framework), established by the government in 2009 to develop a sustainable Australian uranium mining sector, initiated a project led by the Australian Radiation Protection and Nuclear Safety Agency on radiological protection of non-human biota and participated in the development and implementation of the Australian National Radiation Dose Register, a centralised database for the collection and long-term storage of radiation dose registers for uranium mine and mill workers.

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 submitted to the government of Botswana in 2011 and a detailed exploration programme was undertaken to identify sufficient water resources for the proposed Letlhakane Project.

In the Czech Republic, although environmental activities and actions attempting to resolve social issues arising from the closure of major mining activities were formally terminated in 2009, extensive environmental remediation projects and projects with a focus on associated social issues continue to be funded by the state budget and European Union (EU). These projects aim to develop alternative (mainly environmental) approaches to address social issues stemming from decreasing employment in uranium mining. This includes the development of projects and related environmental impact assessments, decommissioning activities, waste rock management, site rehabilitation and maintenance, water treatment and long-term monitoring.

Following the closure of all uranium mines in France in 2001, all facilities have been shut down, dismantled and the sites reclaimed. All sites (over 200), ranging from exploration camps to mines of various sizes, 8 mills and 17 tailings deposits (containing a total of 52 Mt of tailings) resulting from the production of over 80 000 tU, have been remediated. Monitoring continues at only the most affected sites and 14 water treatment plants have been installed to treat water at the remediated facilities.

In Kazakhstan, remediation of the west and central site of the Uvanas deposit has been completed and the second stage of remediation is being planned. Remediation of the Kanzhugan deposit is also scheduled to begin.

In Malawi, mine owner and operator Paladin Energy continues to fulfil its social development obligations under the terms of the Kayelekera mine development agreement. A programme to promote local involvement, economic growth and capacity building in communities is in progress and opportunities are being explored for the transfer of skills from Kayelekera's experienced workforce to local businesses. Additional projects include renovations to Karonga district hospital, the provision of medical equipment, implementation of a health awareness programme and the continuation of a weekly outpatient clinic.

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. Paladin Energy, owner and operator of the Langer Heinrich production centre, held numerous community meetings in 2011 and 2012 to update interested parties on mine development activities and to help identify an appropriate focus for the company's social development programme. One focus of site activities has been the reuse and recycling of water. 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 January 2013, the Geological Survey of Namibia released the first annual report produced under the Strategic Environmental Management Plan (SEMP) developed in response to the Strategic Environmental Assessment on the cumulative effects of uranium mine development.

One of the key points of interest of SEMP is water. Since 2010, water has been supplied to the Erongo region from a coastal desalination plant built by AREVA.

In Niger, *Somaïr* and *Cominak* maintained their ISO 14001 certification for environmental management and AREVA continues to manage environmental issues with a focus on water. Methods to conserve and reduce water consumption have successfully reduced water use despite increased production. The mining companies manage two hospitals and technical support centres in Arlit and Akokan. First created to provide medical care for miners and their families, the centres are now largely open to the public free of charge. A medical centre to treat local residents at no cost was also recently opened at Imouraren.

In several other countries with closed uranium production facilities (Brazil, Hungary, Poland, Portugal, the Slovak Republic, Slovenia, Spain and the Ukraine), 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 the joint NEA/IAEA Uranium Group publications *Environmental Remediation of Uranium Production Facilities* (OECD, 2002) and *Environmental Activities in Uranium Mining and Milling* (OECD, 1999). The OECD/NEA has also recently released a report, *Managing Environmental and Health Impacts of Uranium Mining* (OECD, 2014), outlining significant improvements in these areas that have been undertaken 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.

At the end of 2012, a total of 437 commercial nuclear reactors were connected to the grid with a net generating capacity of 372 GWe requiring some 61 980 tU, as measured by uranium acquisitions. Taking into account changes in policies announced in Belgium, France, Germany, Italy and Switzerland following the Fukushima Daiichi nuclear power plant accident, world nuclear capacity by the year 2035 is projected to grow to between about 400 GWe net in the low demand case and 680 GWe net in the high demand case, representing increases of 7% and 82% respectively. Accordingly, world annual reactor-related uranium requirements are projected to rise to between 72 000 tU and 122 000 tU by 2035. In addition to declining projections of nuclear generating capacity, uranium requirements have been reduced from 2011 on the assumption that tails assays at enrichment plants have been reduced, on average, from 0.30% to 0.25%.

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 57 GWe and 125 GWe of new capacity in the low and high cases respectively, representing increases of more than 65% and 150% over 2013 capacity. Nuclear capacity in non-EU member countries on the European continent is also projected to increase significantly, with additions of between 20 and 45 GWe of capacity projected by 2035 (increases of about 50% and 110% 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, nuclear generating capacity in 2035 is projected to either decrease by almost 30% in the low case or increase by over 15% in the high case by 2035. In the European Union the outlook is similar, with nuclear capacity in 2035 either projected to decrease by 45% in the low case scenario or increase by 20% in the high case scenario.

These projections are subject to even greater uncertainty than usual due to the Fukushima Daiichi accident, since Japan has not yet determined the role that nuclear power will play in its future generation mix 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 baseload 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 given the typically long lead times required to turn resources into refined uranium ready for nuclear fuel production. Other concerns in mine development include geopolitical factors, technical challenges, increasing expectations of governments hosting uranium mining and other issues facing producers in specific cases.

In 2012, world uranium production (58 816 tU) provided about 95% of world reactor requirements (61 980 tU), with the remainder supplied by previously mined uranium (so-called secondary sources) including excess government and commercial inventories, low-enriched uranium (LEU) produced by blending down highly enriched uranium (HEU) from the dismantling of nuclear warheads, re-enrichment of depleted uranium tails (DU) and spent fuel reprocessing.

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 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 development. Uranium miners have been hit harder by the Fukushima Daiichi accident than any other segment of the nuclear fuel cycle. The uranium market is currently well-supplied and projected primary uranium *production capabilities* including existing, committed, planned and prospective production centres would satisfy projected high case requirements through 2032 and low case requirements through 2035 if developments proceed as planned. Meeting high case demand requirements to 2035 would consume less than 40% of the total identified resource base. Nonetheless, significant investment and technical expertise will be required to bring these resources to the market, and 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. Sufficiently robust uranium market prices will be needed to support these activities, especially in light of the rising costs of production.

Although information on secondary sources is incomplete, the availability of these sources will at least temporarily decline somewhat after 2013 when the agreement between the United States and the Russian Federation to blend down HEU to LEU suitable for nuclear fuel comes to an end. Limited 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. Moreover, interest in the re-enrichment of DU is growing, and if a commercially viable means of re-enriching DU is developed a considerable source of secondary supply could become available. Developments in laser enrichment have the potential to accelerate secondary supply from DU, although considerable progress remains to be made to be successful in this regard. 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 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 timeframe 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 stemming from the global financial crisis in some developed countries, overall 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 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 in turn being reduced and subject to even greater uncertainty than usual. Additional safety measures required after reviews of all operating nuclear facilities have also driven operating costs upward. This, combined with the abundance of low-cost natural gas in North America and the risk-averse investment climate stemming from the global financial crisis, has 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, but it is not yet clear when and how widely such measures can be adopted. 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 is to continue developing safe and environmentally responsible mining operations to bring the required quantities of uranium to the market in a timely fashion.

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Uranium 2014: Resources, Production and Demand

Uranium is the raw material used to fuel over 400 operational nuclear reactors around the world that produce large amounts of electricity and benefit from life cycle carbon emissions as low as renewable energy sources. Although a valuable commodity, declining market prices for uranium since the Fukushima Daiichi nuclear power plant accident in 2011, driven by uncertainties concerning the future of nuclear power, have led to the postponement of mine development plans in a number of countries and raised questions about continued uranium supply. This 25th edition of the "Red Book", a recognised world reference on uranium jointly prepared by the OECD Nuclear Energy Agency and the International Atomic Energy Agency, provides analyses and information from 45 producing and consuming countries in order to address these and other questions. It includes 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, incorporating policy changes following the Fukushima accident, in order to address long-term uranium supply and demand issues.

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