

A Joint Report by the OECD Nuclear Energy Agency
and the International Atomic Energy Agency
2012



Uranium 2011: Resources, Production and Demand

Executive Summary



N U C L E A R E N E R G Y A G E N C Y

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NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Executive summary

Uranium 2011 – Resources, Production and Demand presents, in addition to updated resource figures, the results of the most recent review of world uranium market fundamentals and provides a statistical profile of the world uranium industry as of 1 January 2011. It contains official data provided by 34 countries and 8 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.

Resources¹

Total identified uranium resources have increased by over 12% since 2009, adding more than 12 years of global reactor requirements to the existing resource base, but costs of production have also increased.

Total identified resources (reasonably assured and inferred) as of 1 January 2011 declined slightly to 5 327 200 tonnes of uranium metal (tU) in the <USD 130/kgU (<USD 50/lb U₃O₈) category, a decrease of 1.4% compared to 1 January 2009. In the highest cost category (<USD 260/kgU or <USD 100/lb U₃O₈) which was reintroduced in 2009, total identified resources increased to 7 096 600 tU, an increase of 12.5% compared to the total reported in 2009.

Although total identified resources have increased overall, since 2009 there has been a significant reduction in lower cost resources owing principally to increased mining costs (a 14% reduction in the <USD 40/kgU cost category and an 18% reduction in the <USD 80/kgU cost category). Although a portion of the overall increases in the high cost category relate to new discoveries, the majority result from re-evaluations of previously identified resources and conservative Secretariat cost assessments of resources reported by exploration companies active in Africa, particularly in Namibia. At 2010 rates of consumption, identified resources are sufficient for over 100 years of supply for the global nuclear power fleet. An additional 124 100 tU of resources have been identified by the

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 RAR and *inferred*, see below) refer to uranium deposits delineated by sufficient direct measurement to conduct pre-feasibility and sometimes feasibility studies. For reasonably assured resources (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 a 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.

Secretariat as resources reported by companies but are not yet included in national resource totals.

Total undiscovered resources (prognosticated resources and speculative resources) as of 1 January 2011 amounted to 10 429 100 tU, a marginal increase from the 10 400 500 tU reported in 2009. It is important to note however that some countries, including major producing countries with large identified resource inventories (e.g. Australia, Namibia) do not report estimates of undiscovered resources.

The uranium resource figures presented in this volume are a “snapshot” of the situation as of 1 January 2011. Resource figures are dynamic and related to commodity prices. The overall increase in identified resources from 2009 to 2011, including in the high cost category, are equivalent to over 12 years of supply based on 2010 uranium requirements, demonstrating that new resources can be identified with appropriate market signals. Favourable market conditions will stimulate exploration and, as in the past, increased exploration will lead to the identification of additional resources through intensified efforts at existing deposits and the discovery of new deposits of economic interest.

Exploration

The increased resource base described above has been identified thanks to a 22% increase in uranium exploration and mine development expenditures between 2008 and 2010.

Worldwide exploration and mine development expenditures in 2010 totalled over USD 2 billion, a 22% increase over updated 2008 figures, as concerted efforts were made to develop deposits for projected future supply requirements. Most producing countries reported increasing expenditures, particularly in Africa, where significant mine development activities are underway. Although the majority of global exploration activities remain concentrated in areas with potential for hosting unconformity-related and ISL (*in situ* leach; sometimes referred to as *in situ* recovery, or ISR) amenable sandstone deposits, primarily in close proximity to known resources and existing production facilities, lower grade, high tonnage deposits became a focus of activity in Africa. Generally higher prices for uranium since 2003, compared to the preceding two decades, have stimulated increased exploration in regions known to have good potential based on past and “grass roots” exploration. Over 85% of exploration and development expenditures in 2010 were devoted to domestic activities. 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 USD 274 million in 2010 but remain significantly above the USD 71 million reported in 2004. Domestic exploration and development expenditures are expected to decline somewhat in 2011, amounting to about USD 1.8 billion.

Production

Global uranium mine production increased by over 25% between 2008 and 2010 because of significantly increased production in Kazakhstan, currently the world’s leading producer.

Uranium production amounted to 54 670 tU in 2010, a 6% increase from the 51 526 tU produced in 2009 and a 25% increase from the updated total of 43 758 tU produced in 2008. In all, 22 countries reported output in 2010, 2 more than in 2008 as production began in Malawi in 2009 and Germany resumed uranium recovery through mine remediation efforts. China reported uranium production figures for the first time and Uzbekistan reported production figures for the first time since 2005. Global production increases between 2008 and 2010 were driven principally by significantly increased output in Kazakhstan (109%). More modest increases were recorded in Canada, China, India, Namibia, Niger, the United States and Uzbekistan. Reduced production was recorded in a

number of countries between 2008 and 2010 (including Australia and Brazil) owing to a combination of lower than expected ore grades, technical difficulties and preparations for mine expansions, including regulatory approval processes. ISL mining accounted for 39% of global production in 2010, rising rapidly to become the most important mining method, principally because of significant ISL production increases in Kazakhstan. Underground mining (32%), open-pit mining (23%) and co-product and by-product recovery from copper and gold operations (6%) accounted for the remaining production shares. Global uranium production in 2011 was expected to increase by 5% to over 57 000 tU, with a continuing but less rapid ramp-up in Kazakhstan and expected increases in Australia and Uzbekistan.

Environmental aspects of uranium production

With uranium production ready to expand to new countries, efforts are being made to develop transparent and well-regulated operations similar to those used elsewhere in order to minimise local health and environmental impacts.

Although the focus of this publication remains uranium resources, production and demand, environmental aspects of the uranium production cycle are an important part of uranium production and updates on these activities are included in national reports in this edition. With uranium production ready to expand, in some cases to countries hosting uranium production for the first time, the continued development of transparent and well-regulated operations that minimise environmental impacts is crucial.

In Botswana, national policies regarding uranium production are under development, since no regulations for uranium mining and milling are in place and resources with potential for extraction have been identified. In Malawi, an atomic energy bill was passed in 2011, the first step towards development of comprehensive legislation on radioactive materials. Zambia and Finland signed co-operation agreements in 2011 to evaluate, update and review regulations regarding the safety of uranium mining. In Tanzania, the Parliamentary Committee for Energy stated that no uranium mining can take place until a policy and legislation on extraction are in place.

In South America, recognising the need to continually improve practices and to inform stakeholders of modern practices, the Argentinian Chamber of Uranium Companies was formed in 1999 to share best practices in uranium exploration and to co-operatively provide information on the industry. In Peru, the Peru-Canada Mineral Resources Reform Project (PERCAN) was established to provide the Ministry of Mines and Energy with input during development of an environmental guide for uranium exploration which is expected to be completed by the end of 2011. Local communities are participating in monitoring the activities of the exploration companies in Peru.

Countries with existing uranium production facilities are also strengthening aspects of health and safety practices at production facilities. In Iran, a comprehensive health, safety and environmental protection programme has been implemented at all production centres (an open-pit mine and mill near Bandar-Abbas, an underground Saghand mine and a uranium mill under construction in Ardakan). In late 2011, AREVA announced the creation of a Health Observatory for the Agadez region of Niger, one year after a similar institution was established in Gabon. These observatories are to monitor the health of former workers in uranium mines as well as the health of the local population. In cases of illness attributable to occupational causes, the cost of corresponding health care is to be covered by AREVA. Other such observatories around mining facilities operated by AREVA are planned.

Uranium mining companies actively contribute to improving social and cultural aspects of communities in the vicinity of operating facilities. For example, in Kazakhstan all contracts for uranium exploration and mining issued by the government require financial contributions (USD 30 000-100 000/yr during exploration and as much as

USD 50 000-350 000/yr during mining) to fund health care for employees and local citizens, education, sport, recreation and other facilities in accordance with national strategy. In 2010, Rössing and others provided financial and/or technical support to the Uranium Institute of Namibia, an organisation established to improve the quality of healthcare, environmental management and radiation safety in the industry, as well as educational and environmental programmes in local communities.

Planning and preparing for mine remediation well in advance of mine closure is one of the foundations of modern uranium mining. Along with planning for the life extension of the Rössing mine to 2023, the mine remediation plan was reviewed (including training requirements, demolition, tailings rehabilitation, long-term seepage control and monitoring costs) along with funding requirements to carry out the activities. Funds in the independent Rössing environmental rehabilitation trust fund amounted to USD 24.5 million at the end of 2010 and will be increased in the coming years to provide for the full range of planned closure and remediation activities of the mine and mill.

In countries with closed uranium production facilities that operated in the past without strict environmental regulations and where practices that would not be licensed today were used, remediation actions continue. In Brazil, a remediation/restoration study is being carried out on the Poços de Caldas uranium facility that was closed in 1997. In Hungary, after the closure of the mines in 1998, stabilisation and remediation work was finished successfully in 2008. The annual cost of the long-term activities (water treatment, environmental monitoring and maintenance of the remediated sites) amounts to USD 2-3.3 million/yr. Updates on similar activities in Poland, Portugal, the Slovak Republic and Spain are also included in this edition.

Additional information on environmental aspects of uranium production may be found in the joint NEA-IAEA Uranium Group publications entitled *Environmental Remediation of Uranium Production Facilities* (OECD, 2002) and *Environmental Activities in Uranium Mining and Milling* (OECD, 1999).

Uranium demand

Demand for uranium is expected to continue to rise for the foreseeable future.

At the end of 2010, a total of 440 commercial nuclear reactors were connected to the grid with a net generating capacity of 375 GWe requiring some 63 875 tU, as measured by uranium acquisitions. By the year 2035, world nuclear capacity, taking into account the current understanding of policies announced by some countries (e.g. Belgium, Germany, Italy and Switzerland) following the Fukushima accident, has been projected by the Secretariat to grow to between about 540 GWe net in the low demand case and 746 GWe net in the high demand case, increases of 44% and 99%, respectively. Accordingly, world annual reactor-related uranium requirements are projected to rise to between 97 645 tU and 136 385 tU by 2035.

Nuclear capacity projections vary considerably from region to region. The East Asia region is projected to experience the largest increase, which could result by the year 2035 in the installation of between 100 GWe and 150 GWe of new capacity, representing increases of over 125% to more than 185%, respectively. Nuclear capacity in non-European Union countries in Europe is also expected to increase considerably (between 55% and 125%). Other regions with projected growth include the Middle East and Southern Asia, Central and South America, Africa and South-eastern Asia. In North America, nuclear capacity is projected to grow by between 7% and 28% but in the European Union could either decrease by 11% or increase by 24%, depending principally on the implementation of nuclear phase-out policies. The high case assumes that at least some of the phase-out policies are eased.

There are uncertainties in these projections as debate continues on the role that nuclear energy will play in meeting future energy requirements. 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, a particularly important factor following 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 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 demand through 2035, but doing so will require timely investments in uranium production facilities given the long lead times required to turn resources into refined uranium ready for nuclear fuel production.

In 2010, world uranium production (54 670 tU) met about 85% of world reactor requirements (63 875 tU), with the remainder of supply coming from uranium already mined (so-called secondary sources) including excess government and commercial inventories, low-enriched uranium (LEU) produced by downblending highly enriched uranium (HEU) from the dismantling of nuclear warheads, re-enrichment of depleted uranium tails and spent fuel reprocessing.

Uranium mine development was responding to the market signal of increased prices and rising demand prior to the Fukushima accident. The drop in market prices following the accident and lingering uncertainty concerning nuclear power development in some countries has slowed the pace of mine development. Nonetheless, as currently projected, primary uranium *production capabilities* including existing, committed, planned and prospective production centres could satisfy projected high case requirements through 2030 and low case requirements through 2035. Meeting high case demand requirements would consume only 35% of the total identified resource base by 2035. Moreover, the entire *conventional resource base* documented in this edition is sufficient to fuel total lifetime requirements for all reactors built by 2035 in the low case scenario projection and over 90% of the requirements for the operational lifetime of all reactors built by 2035 in the high case scenario projection. Nonetheless, significant investment and technical expertise will be required to bring these resources to the market and to identify additional resources. Sufficiently high uranium market prices will be needed to fund these activities, especially in light of the rising costs of production. Secondary sources will continue to be required, complemented to the extent possible by uranium savings achieved by specifying low tails assays at enrichment facilities and developments in fuel cycle technology.

Although information on secondary sources is incomplete, their availability is expected to decline somewhat after 2013 when the agreement between the United States and the Russian Federation to downblend HEU to LEU suitable for nuclear fuel comes to an end. There remains however, a significant amount of previously mined uranium (including material held by the military), some of which could feasibly be brought to the market in a controlled fashion. Nonetheless, as secondary supplies are reduced in the coming years, reactor requirements will need to be increasingly met by mine production. The introduction of alternative fuel cycles, if successfully developed and implemented, could profoundly impact the market balance, but it is too early to say how cost-effective and widely implemented these proposed fuel cycles could be.

A strong market for uranium will be needed to bring about the timely development of production capability. Long lead times are required to identify new resources and to bring them into production, typically of the order of ten years or more in most producing countries. The global network of uranium mine facilities is relatively sparse and geopolitical uncertainties increase investment risks in some countries. The market will have to provide sufficient incentives for exploration and mine developments in order to continue to ensure that global nuclear fuel requirements will be met.

Conclusions

Despite recent declines in electricity demand stemming from the global financial crisis in some developed countries, demand is expected to continue to grow over the next several decades to meet the needs of a growing population, particularly in developing countries. Nuclear power produces competitively priced, baseload electricity that is essentially free of greenhouse gas emissions, and the deployment of nuclear power enhances security of energy supply. However, the Fukushima Daiichi accident has eroded public confidence in the technology in some countries and prospects for growth in nuclear generating capacity are in turn subject to greater uncertainty. Moreover, the abundance of low-cost natural gas, the risk-averse investment climate and the effects of the global financial crisis have made nuclear capacity growth more challenging, particularly in liberalised electricity markets.

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 environmentally sustainable mining operations to bring increasing quantities of uranium to the market in a timely fashion. Strengthened market conditions will be required for resources to be developed to meet projected uranium demand within the time frame required.

Uranium 2011: Resources, Production and Demand

In the wake of the Fukushima Daiichi nuclear power plant accident, questions are being raised about the future of the uranium market, including as regards the number of reactors expected to be built in the coming years, the amount of uranium required to meet forward demand, the adequacy of identified uranium resources to meet that demand and the ability of the sector to meet reactor requirements in a challenging investment climate. This 24th 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 42 producing and consuming countries in order to address these and other questions. It offers a comprehensive review of world uranium supply and demand as well as data on global uranium exploration, resources, production and reactor-related requirements. It also provides substantive new information on established uranium production centres around the world and in countries developing production centres for the first time. Projections of nuclear generating capacity and reactor-related requirements through 2035, incorporating policy changes following the Fukushima accident, are also featured, along with an analysis of long-term uranium supply and demand issues.



IAEA
International Atomic Energy Agency



NEA
Nuclear Energy Agency

OECD Nuclear Energy Agency
12, boulevard des Îles
92130 Issy-les-Moulineaux, France
Tel.: +33 (0)1 45 24 10 15
nea@oecd-nea.org www.oecd-nea.org

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www.oecdbookshop.org