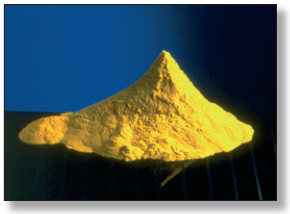
A Joint Report by the OECD Nuclear Energy Agency
and the International Atomic Energy Agency
2012

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# Uranium 2011: Resources, Production and Demand





AEN NEA

NUCLEAR ENERGY AGENCY

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

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# Uranium 2011: Resources, Production and Demand

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NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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*Cover photos: Uranium "yellow cake" (AREVA); Georges Besse II enrichment facility, France (AREVA).*

# 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. These updates have been published by the OECD/NEA in what is commonly known as the "Red Book". This 24th edition of the Red Book reflects information current as of 1 January 2011.

This edition features a comprehensive assessment of uranium supply and demand in 2011 and projections of supply and demand 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 projections of installed nuclear capacity. In cases where longer-term projections of installed nuclear capacity were not provided by national authorities, projected demand figures were developed with input from expert authorities. 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 production. In addition, individual country reports provide detailed information on recent developments in uranium exploration and production, updates on environmental activities and information on relevant national uranium policies.

This edition of the Red Book also includes a compilation and evaluation of previously published data on unconventional uranium resources. Available information on secondary sources of uranium is presented and their potential impact on the market is assessed.

This publication has been prepared on the basis of data obtained through questionnaires sent by the NEA to OECD member countries (18 countries responded and 1 country report was prepared by the Secretariat) and by the IAEA for those states that are not OECD member countries (24 countries responded and 7 country reports were prepared by the Secretariat). The opinions expressed in Chapters 1 and 2 do not necessarily reflect the position of the member countries or international organisations concerned. This report is published on the responsibility of the OECD Secretary-General.

# Acknowledgements

The OECD Nuclear Energy Agency (NEA), Paris, and the International Atomic Energy Agency (IAEA), Vienna, gratefully acknowledges the co-operation of those organisations (see Appendix 2) which replied to the questionnaire.

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# 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.

## Resources[1]

***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 $U_3O_8$) category, a decrease of 1.4% compared to 1 January 2009. In the highest cost category (<USD 260/kgU or <USD 100/lb $U_3O_8$) 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.

# *Chapter 1.* Uranium supply

This chapter summarises the current status of worldwide uranium resources, exploration and production. In addition, production capabilities in reporting countries for the period ending in the year 2035 are presented and discussed.

## 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 2009 edition of the "Red Book" are summarised in Table 1.1. The overall picture is one of resources shifting to higher cost categories and an increase in total reported identified resources. Resources recoverable at costs <USD 260/kgU increased by 790 300 tU (12.5%) to a total of 7 096 600 tU. This is equivalent to 12 years supply of 2011 uranium requirements. Some of these increases are the result of new discoveries, such as those in Botswana, but the majority relate to re-evaluations of known deposits and increased exploration efforts to extend the life-of-mine or expand production capacity at existing mining facilities. Australia, Canada, Greenland, Namibia, Niger, the Russian Federation and South Africa all made important contributions to the increases.

Identified resources recoverable at costs of <USD 130/kgU decreased by 1.4% from 5 404 000 tU to a total of 5 327 200 tU, as a result of substantial decreases in resources in India and Jordan combined with smaller reductions in Algeria, Australia, Canada, Kazakhstan, Namibia and Uzbekistan. These reductions were in part matched by substantial increases in Niger and Tanzania along with smaller increases in Mongolia, the Russian Federation, the Slovak Republic and Ukraine. Reduced resources in the lower cost categories, compared with 2009, were the result of increased mining costs.

The shift to higher cost categories is reflected in the decline in lower cost category resources. Identified resources in the <USD 80/kgU category dropped by 663 400 tU (17.7%) to 3 078 500 tU while the <USD 40/kgU dropped by 115 500 tU (14.5%) to 680 900 tU (Table 1.1). The smaller decline in the <USD40/kgU category resulted from Uzbekistan reporting significant new resources in this cost category. This combined with substantial reductions in Canada, Niger and South Africa caused the overall decline in both cost categories.

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 2009 and 2011 in selected countries.

### *Distribution of identified conventional resources by categories and cost ranges*

Australia still dominates the world's uranium resources with 31% of the total identified resources (<USD 130/kgU) and 25% of identified resources in the high cost category (<USD 260/kgU). Kazakhstan trails far behind with 12% in both cost categories, with all of the other countries having less than a 10% share. Only 13 countries around the world have more than a 1% share of the total world's identified resources available at costs <USD 130/kgU (Figure 1.1) and 15 countries in the high cost category.

The most significant changes between 2009 and 2011 are in the overall amount of identified resources (Table 1.2) with increases reported in Australia, Botswana, Canada, Greenland, India, Namibia, Niger, the Russian Federation and South Africa and decreases reported in Jordan and Uzbekistan. The distribution of identified resources (RAR and IR) among the countries with major resources is shown in Figures 1.2 and 1.3.

RAR recoverable at costs <USD 40/kgU, the most economically attractive category, decreased by 76 000 tU (13.3%). The drop would have been substantially more had Uzbekistan not reported significant new resources in this cost category. Resource figures in all RAR cost categories decreased from 2009, with the exception of the highest cost category. Changes were minimal in the <USD 130/kgU category with a 2.0% decrease while the largest fall in RAR was in the <USD 80/kgU, where the decrease amounted to 501 300 tU or 19.9% compared to 2009. The major increases in the overall total RAR were in Namibia and Niger with lesser contributions from Botswana, Canada, India, the Russian Federation and Tanzania. The only countries to report significant reductions were Jordan and Uzbekistan.

Lower cost inferred resources were reduced substantially with the <USD 40/kgU category decreasing by 17.5% and the <USD 80/kgU dropping by 13.2%. The <USD 260/kgU category increased by 18.1% while the <USD 130 category remained little changed. In keeping with the situation in previous years total IR amounted to more than half the total RAR.

**Table 1.1. Changes in identified resources 2009-2011**

(1 000 tU)

| Resource category | 2009 | 2011 | Change (1 000 tU)[a] | % change |
|---|---|---|---|---|
| Identified (total) | | | | |
| <USD 260/kgU | 6 306.3 | 7 096.6 | 790.3 | 12.5 |
| <USD 130/kgU | 5 404.0 | 5 327.2 | -76.8 | -1.4 |
| <USD 80/kgU | 3 741.9 | 3 078.5 | -663.4 | -17.7 |
| <USD 40/kgU[b] | 796.4 | 680.9 | -115.5 | -14.5 |
| RAR | | | | |
| <USD 260/kgU | 4 004.5 | 4 378.7 | 374.2 | 9.3 |
| <USD 130/kgU | 3 524.9 | 3 455.5 | -69.4 | -2.0 |
| <USD 80/kgU | 2 516.1 | 2 014.8 | -501.3 | -19.9 |
| <USD 40/kgU[b] | 569.9 | 493.9 | -76.0 | -13.3 |
| Inferred resources | | | | |
| <USD 260/kgU | 2 301.8 | 2 717.9 | 416.1 | 18.1 |
| <USD 130/kgU | 1 879.1 | 1 871.7 | -7.4 | -0.4 |
| <USD 80/kgU | 1 225.8 | 1 063.7 | -162.1 | -13.2 |
| <USD 40/kgU[b] | 226.6 | 187.0 | -39.6 | -17.5 |

(a) Changes might not equal differences between 2009 and 2011 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.

**Figure 1.1. Global distribution of identified resources**

(<USD 130/kgU)




The global distribution of identified resources among 13 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 13 countries are endowed with 96% of the identified global resource base in this cost category (the remaining 4% are distributed among another 20 countries). The widespread distribution of uranium resources is an important geographic aspect of nuclear energy in light of security of energy supply.

## Table 1.2. Identified resources (RAR and inferred)

(recoverable resources as of 1 January 2011, tonnes U, rounded to nearest 100 tonnes)

| Country | Cost ranges | | | |
|---|---|---|---|---|
| | <USD 40/kg U | <USD 80/kg U | <USD 130/kg U | <USD 260/kg U |
| Algeria[b, c] | 0 | 0 | 0 | 19 500 |
| Argentina | 2 400 | 9 000 | 18 500 | 19 600 |
| Australia | 0 | 1 349 400 | 1 661 600 | 1 738 800 |
| Botswana* | 0 | 0 | 0 | 82 200 |
| Brazil | 137 900 | 229 300 | 276 700 | 276 700 |
| Canada | 350 800 | 416 800 | 468 700 | 614 400 |
| Central African Republic[a, b, c] | 0* | 0* | 12 000* | 12 000* |
| Chile[d] | 0 | 0 | 0 | 1 900 |
| China[c] | 59 200 | 135 000 | 166 100 | 166 100 |
| Congo, Dem. Rep. of[a, b, c] | 0* | 0* | 0* | 2 700* |
| Czech Republic | 0 | 0 | 400 | 400 |
| Egypt[a] | 0 | 0 | 0 | 1 900 |
| Finland[b, c] | 0 | 0 | 1 100 | 1 100 |
| France | 0 | 0 | 0 | 11 600 |
| Gabon[a, b] | 0 | 0 | 4 800 | 5 800 |
| Germany[b, c] | 0 | 0 | 0 | 7 000 |
| Greece[a, b] | 0* | 0* | 0* | 7 000* |
| Greenland | 0 | 0 | 0 | 134 700 |
| Hungary | 0 | 0 | 0 | 8 600 |
| India[c, d] | 0 | 0 | 0 | 104 900 |
| Indonesia[c] | 0 | 2 000 | 8 400 | 10 600 |
| Iran, Islamic Republic of | 0 | 0 | 2 500 | 2 500 |
| Italy[a, b] | 0 | 0 | 6 100 | 6 100 |
| Japan[b] | 0 | 0 | 6 600 | 6 600 |
| Jordan[c] | 0 | 0 | 33 800 | 33 800 |
| Kazakhstan[c] | 47 400 | 485 800 | 629 100 | 819 700 |
| Malawi* | 0* | 0* | 12 300* | 17 000* |
| Mexico[c] | 0 | 0 | 2 800 | 2 800 |
| Mongolia[c] | 0 | 0 | 55 700 | 55 700 |
| Namibia* | 0* | 6 600* | 261 000* | 518 100* |
| Niger* | 5 500* | 5 500* | 421 000* | 445 500* |
| Peru[c] | 0 | 2 600 | 2 600 | 2 600 |
| Portugal[a, b] | 0 | 4 500 | 7 000 | 7 000 |
| Romania[a, b] | 0 | 0 | 6 700 | 6 700 |
| Russian Federation | 0 | 55 400 | 487 200 | 650 300 |
| Slovak Republic[c] | 0 | 5 900 | 9 000 | 9 000 |
| Slovenia[a, b, c] | 0 | 5 500* | 9 200 | 9 200 |
| Somalia[a, b, c] | 0* | 0* | 0* | 7 600* |
| South Africa* | 0 | 186 000 | 279 100 | 372 100 |
| Spain | 0 | 0 | 0 | 14 000 |
| Sweden* | 0 | 0 | 10 000 | 13 500 |
| Tanzania* | 0* | 0* | 36 700* | 45 700* |
| Turkey[b, c] | 0 | 7 300 | 7 300 | 7 300 |
| Ukraine | 6 400 | 61 500 | 119 600 | 224 600 |
| United States | 0 | 39 100 | 207 400 | 472 100 |
| Uzbekistan | 71 300 | 71 300 | 96 200 | 96 200 |
| Vietnam[a, b, c] | 0* | 0* | 0* | 6 400* |
| Zambia* | 0 | 0 | 0 | 15 600 |
| Zimbabwe[a, b, c] | 0* | 0* | 0* | 1 400* |
| Total[e] | 680 900 | 3 078 500 | 5 327 200 | 7 096 600 |

* Secretariat estimate; (a) Not reported in 2011 responses, data from previous Red Book; (b) Assessment not made within the last five years; (c) *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); (d) Cost data not provided, therefore resources are reported in the <USD 260/kgU category; (e) 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 1.3. Reasonably assured resources (RAR)

(recoverable resources as of 1 January 2011, tonnes U, rounded to nearest 100 tonnes)

| Country | Cost ranges | | | |
|---|---|---|---|---|
| | <USD 40/kg U | <USD 80/kg U | <USD 130/kg U | <USD 260/kg U |
| Algeria[b, c] | 0 | 0 | | 19 500 |
| Argentina | 0 | 5 000 | 8 600 | 8 600 |
| Australia | 0 | 961 500 | 1 158 000 | 1 180 100 |
| Botswana* | 0 | 0 | 0 | 23 100 |
| Brazil | 137 900 | 155 700 | 155 700 | 155 700 |
| Canada | 237 900 | 292 500 | 319 700 | 421 900 |
| Central African Republic[a, b, c] | 0 | 0 | 12 000 | 12 000 |
| Chile[d] | 0 | 0 | 0 | 700 |
| China[c] | 45 800 | 88 500 | 109 500 | 109 500 |
| Congo, Dem. Rep. of[a, b, c] | 0* | 0* | 0* | 1 400* |
| Czech Republic | 0 | 0 | 300 | 300 |
| Finland[b, c] | 0 | 0 | 1 100 | 1 100 |
| France | 0 | 0 | 0 | 11 500 |
| Gabon[a, b] | 0 | 0 | 4 800 | 4 800 |
| Germany[b, c] | 0 | 0 | 0 | 3 000 |
| Greece[a, b] | 0* | 0* | 0* | 1 000 |
| India[c, d] | 0 | 0 | 0 | 77 000 |
| Indonesia[c] | 0 | 2 000 | 8 400 | 8 400 |
| Iran, Islamic Republic of | 0 | 0 | 700 | 700 |
| Italy[a, b] | 0 | 0 | 4 800 | 4 800 |
| Japan[b] | 0 | 0 | 6 600 | 6 600 |
| Jordan[c] | 0 | 0 | 0 | 0 |
| Kazakhstan[c] | 17 400 | 244 900 | 319 900 | 402 400 |
| Malawi* | 0 | 0 | 10 000 | 11 300 |
| Mexico[c] | 0 | 0 | 2 800 | 2 800 |
| Mongolia[c] | 0 | 0 | 30 600 | 30 600 |
| Namibia* | 0* | 5 900* | 234 900* | 362 600* |
| Niger* | 5 500* | 5 500* | 339 000* | 340 600* |
| Peru[c] | 0 | 1 300 | 1 300 | 1 300 |
| Portugal[a, b] | 0 | 4 500 | 6 000 | 6 000 |
| Romania[a, b] | 0 | 0 | 3 100 | 3 100 |
| Russian Federation | 0 | 11 800 | 172 900 | 218 300 |
| Slovak Republic[c] | 0 | 0 | 0 | 0 |
| Slovenia[a, b, c] | 0 | 1 700 | 1 700 | 1 700 |
| Somalia[a, b, c] | 0* | 0* | 0* | 5 000* |
| South Africa* | 0 | 96 400 | 144 600 | 192 900 |
| Spain | 0 | 0 | 0 | 14 000 |
| Sweden* | 0 | 0 | 4 000 | 5 000 |
| Tanzania* | 0 | 0 | 28 700 | 30 100* |
| Turkey[b, c] | 0 | 7 300 | 7 300 | 7 300 |
| Ukraine | 2 800 | 44 600 | 86 800 | 143 300 |
| United States | 0 | 39 100 | 207 400 | 472 100 |
| Uzbekistan | 46 600 | 46 600 | 64 300 | 64 300 |
| Vietnam[a, b, c] | 0 | 0 | 0 | 1 000 |
| Zambia* | | | | 9 900 |
| Zimbabwe[a, b, c] | 0 | 0 | 0* | 1 400 |
| Total[e] | 493 900 | 2 014 800 | 3 455 500 | 4 378 700 |

* Secretariat estimate; (a) Not reported in 2011 responses, data from previous Red Book. (b) Assessment not made within the last five years. (c) *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). (d) Cost data not provided, therefore resources are reported in the <USD 260/kgU category. (e) 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 1.4. Inferred resources

(recoverable resources as of 1 January 2011, tonnes U, rounded to nearest 100 tonnes)

| Country | Cost ranges | | | |
|---|---|---|---|---|
| | <USD 40/kg U | <USD 80/kg U | <USD 130/kg U | <USD 260/kg U |
| Argentina | 2 400 | 4 000 | 9 900 | 11 000 |
| Australia | 0 | 387 900 | 503 600 | 558 700 |
| Botswana* | 0 | 0 | 0 | 59 100 |
| Brazil | 0 | 73 600 | 121 000 | 121 000 |
| Canada | 112 900 | 124 300 | 149 000 | 192 500 |
| Chile[b, d] | 0 | 0 | 0 | 1 200 |
| China[c] | 13 400 | 46 500 | 56 600 | 56 600 |
| Congo, Dem. Rep. of[a, b, c] | 0* | 0* | 0* | 1 300* |
| Czech Republic | 0 | 0 | 100 | 100 |
| Egypt | 0* | 0* | 0* | 1 900 |
| France | 0 | 0 | 0 | 100 |
| Gabon[a, b] | 0* | 0* | 0* | 1 000* |
| Germany[b, c] | 0 | 0 | 0 | 4 000 |
| Greece[a, b] | 0* | 0* | 0* | 6 000* |
| Greenland | 0 | 0 | 0 | 134 700 |
| Hungary | 0 | 0 | 0 | 8 600 |
| India[c, d] | 0 | 0 | 0 | 27 900 |
| Indonesia[c] | 0 | 0 | 0 | 2 200 |
| Iran, Islamic Republic of | 0 | 0 | 1 800 | 1 800 |
| Italy[a, b] | 0 | 0 | 1 300 | 1 300 |
| Jordan[c] | 0 | 0 | 33 800 | 33 800 |
| Kazakhstan[c] | 30 000 | 240 900 | 309 200 | 417 300 |
| Malawi* | 0 | 0 | 2 300 | 5 700 |
| Mexico[c] | 0 | 0 | 0 | 0 |
| Mongolia[c] | 0 | 0 | 25 100 | 25 100 |
| Namibia* | 0* | 700* | 26 100* | 155 500* |
| Niger* | 0* | 0* | 82 000* | 104 900* |
| Peru[c] | 0 | 1 300 | 1 300 | 1 300 |
| Portugal[a, b] | 0* | 0* | 1 000* | 1 000* |
| Romania[a, b] | 0* | 0* | 3 600* | 3 600* |
| Russian Federation | 0 | 43 600 | 314 300 | 432 000 |
| Slovak Republic[c] | 0 | 5 900 | 9 000 | 9 000 |
| Slovenia[a, b, c] | 0 | 3 800 | 7 500 | 7 500 |
| Somalia[a, b, c] | 0* | 0* | 0* | 2 600 |
| South Africa* | 0 | 89 600 | 134 400 | 179 200 |
| Spain | 0 | 0 | 0 | 0 |
| Sweden* | 0 | 0 | 6 000 | 8 500 |
| Tanzania* | 0* | 0* | 8 000* | 15 600* |
| Ukraine | 3 600 | 16 900 | 32 900 | 81 300 |
| Uzbekistan | 24 700 | 24 700 | 31 900 | 31 900 |
| Vietnam[a, b, c] | 0 | 0* | 0* | 5 400* |
| Zambia* | 0 | 0 | 0 | 5 700 |
| Total[e] | 187 000 | 1 063 700 | 1 871 700 | 2 717 900 |

* Secretariat estimate; (a) Not reported in 2011 responses, data from previous Red Book using inferred or EAR-I data. (b) Assessment not made within the last five years. (c) *In situ* resources were adjusted to estimate recoverable resources, using recovery factors provided by the countries or estimated by the Secretariat according to the expected production method. (d) Cost data not provided, therefore resources are reported in the <USD 260/kgU category. (e) Total related to cost range <USD 40/kgU is 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 | 2009 | 2011 | Changes | Reasons |
|---|---|---|---|---|---|
| Australia | RAR | | | | Resources moved into higher cost categories owing to increased mining costs. |
| | <USD 80/kg U | 1 163 | 961 | -202 | |
| | <USD 130/kg U | 1 176 | 1 158 | -18 | |
| | <USD 260/kg U | 1 179 | 1 180 | 1 | |
| | Inferred | | | | |
| | <USD 80/kg U | 449 | 388 | -61 | |
| | <USD 130/kg U | 497 | 504 | 7 | |
| | <USD 260/kg U | 500 | 559 | 59 | |
| Botswana | RAR | | | | Recent exploration activities identified substantial new low-grade deposits. |
| | <USD 260/kg U | 0 | 23 | 23 | |
| | Inferred | | | | |
| | <USD 260/kg U | 0 | 59 | 59 | |
| Canada | RAR | | | | RAR moved into higher cost categories owing to increased mining costs; increased IR results from the recent discovery of new deposits in the Athabasca Basin. |
| | <USD 40/kg U | 267 | 238 | -29 | |
| | <USD 80/kg U | 337 | 293 | -44 | |
| | <USD 130/kg U | 361 | 320 | -41 | |
| | <USD 260/kg U | 387 | 422 | 35 | |
| | Inferred | | | | |
| | <USD 40/kg U | 100 | 113 | 13 | |
| | <USD 80/kg U | 111 | 124 | 13 | |
| | <USD 130/kg U | 124 | 149 | 25 | |
| | <USD 260/kg U | 157 | 193 | 36 | |
| Greenland | Inferred | | | | Previously reported for Denmark. Intensive investigation of Kvanefjeld deposit. |
| | <USD 260/kg U | 86 | 135 | 49 | |
| India | RAR | | | | Extensions to known ore deposits in the Cuddapah basin. |
| | <USD 260/kg U | 55 | 77 | 22 | |
| | Inferred | | | | |
| | <USD 260/kg U | 25 | 28 | 3 | |
| Jordan | RAR | | | | Conservative re-evaluation of old resource estimates. |
| | <USD 130/kg U | 44 | 0 | -44 | |
| | <USD 260/kg U | 44 | 0 | -44 | |
| | Inferred | | | | |
| | <USD 130/kg U | 68 | 34 | -34 | |
| | <USD 260/kg U | 68 | 34 | -34 | |
| Kazakhstan | RAR | | | | Re-evaluation of resources into lower cost categories and mining has reduced total resources. A decrease in production costs for sandstone-hosted resources and the upgrading of resources from PR to RAR have contributed to an increase in low cost RAR. |
| | <USD 40/kg U | 15 | 17 | 2 | |
| | <USD 80/kg U | 234 | 245 | 11 | |
| | <USD 130/kg U | 336 | 320 | -16 | |
| | <USD 260/kg U | 414 | 402 | -12 | |
| | Inferred | | | | |
| | <USD 40/kg U | 30 | 30 | 0 | |
| | <USD 80/kg U | 242 | 241 | -1 | |
| | <USD 130/kg U | 316 | 309 | -7 | |
| | <USD 260/kg U | 418 | 417 | -1 | |
| Malawi | RAR | | | | Mining activities reduced RAR but exploration activities increased IR. |
| | <USD 130/kg U | 14 | 10 | -4 | |
| | <USD 260/kg U | 14 | 11 | -3 | |
| | Inferred | | | | |
| | <USD 130/kg U | 1 | 2 | 1 | |
| | <USD 260/kg U | 1 | 6 | 5 | |

**Table 1.5. Major identified resource changes by country** (*continued*)

(recoverable resources in 1 000 tonnes U)

| Country | Resource category | 2009 | 2011 | Changes | Reasons |
|---|---|---|---|---|---|
| Mongolia | RAR | | | | New deposits identified through exploration activities and re-evaluation of existing deposits increased resources and moved them into higher cost categories. |
| | <USD 80/kg U | 38 | 0 | -38 | |
| | <USD 130/kg U | 38 | 31 | -7 | |
| | <USD 260/kg U | 38 | 31 | -7 | |
| | Inferred | | | | |
| | <USD 80/kg U | 4 | 0 | -4 | |
| | <USD 130/kg U | 12 | 25 | 13 | |
| | <USD 260/kg U | 12 | 25 | 13 | |
| Namibia | RAR | | | | Extensive exploration leading to the discovery of large low-grade resources. |
| | <USD 80/kg U | 2 | 6 | 4 | |
| | <USD 130/kg U | 157 | 235 | 78 | |
| | <USD 260/kg U | 157 | 363 | 206 | |
| | Inferred | | | | |
| | <USD 80/kg U | 0 | 1 | 1 | |
| | <USD 130/kg U | 127 | 26 | -101 | |
| | <USD 260/kg U | 127 | 156 | 29 | |
| Niger | RAR | | | | Revitalised exploration activities have identified new resources, primarily in extensions to the Imouraren deposit. |
| | <USD 40/kg U | 17 | 6 | -11 | |
| | <USD 80/kg U | 43 | 6 | -37 | |
| | <USD 130/kg U | 242 | 339 | 97 | |
| | <USD 260/kg U | 245 | 341 | 96 | |
| | Inferred | | | | |
| | <USD 40/kg U | 0 | 0 | 0 | |
| | <USD 80/kg U | 31 | 0 | -31 | |
| | <USD 130/kg U | 31 | 82 | 51 | |
| | <USD 260/kg U | 31 | 105 | 74 | |
| Russian Federation | RAR | | | | New deposits identified through exploration and re-evaluation of existing deposits increased resources substantially and moved them into higher cost categories. |
| | <USD 80/kg U | 100 | 12 | -88 | |
| | <USD 130/kg U | 181 | 173 | -8 | |
| | <USD 260/kg U | 181 | 218 | 37 | |
| | Inferred | | | | |
| | <USD 80/kg U | 58 | 44 | -14 | |
| | <USD 130/kg U | 299 | 314 | 15 | |
| | <USD 260/kg U | 385 | 432 | 47 | |
| South Africa | RAR | | | | Increased resources through evaluation of uraniferous tailings dams and limited exploration but rising mining costs moved resources into higher cost categories. |
| | <USD 80/kg U | 142 | 96 | -46 | |
| | <USD 130/kg U | 195 | 145 | -50 | |
| | <USD 260/kg U | 195 | 193 | -2 | |
| | Inferred | | | | |
| | <USD 80/kg U | 91 | 90 | -1 | |
| | <USD 130/kg U | 100 | 134 | 34 | |
| | <USD 260/kg U | 100 | 179 | 79 | |
| Uzbekistan | RAR | | | | Previous resource figures are a Secretariat estimate. Current resources are reported by the country. |
| | <USD 40/kg U | 0 | 47 | 47 | |
| | <USD 80/kg U | 55 | 47 | -8 | |
| | <USD 130/kg U | 76 | 64 | -12 | |
| | <USD 260/kg U | 76 | 64 | -12 | |
| | Inferred | | | | |
| | <USD 40/kg U | 0 | 25 | 25 | |
| | <USD 80/kg U | 31 | 25 | -6 | |
| | <USD 130/kg U | 39 | 32 | -7 | |
| | <USD 260/kg U | 39 | 32 | -7 | |

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

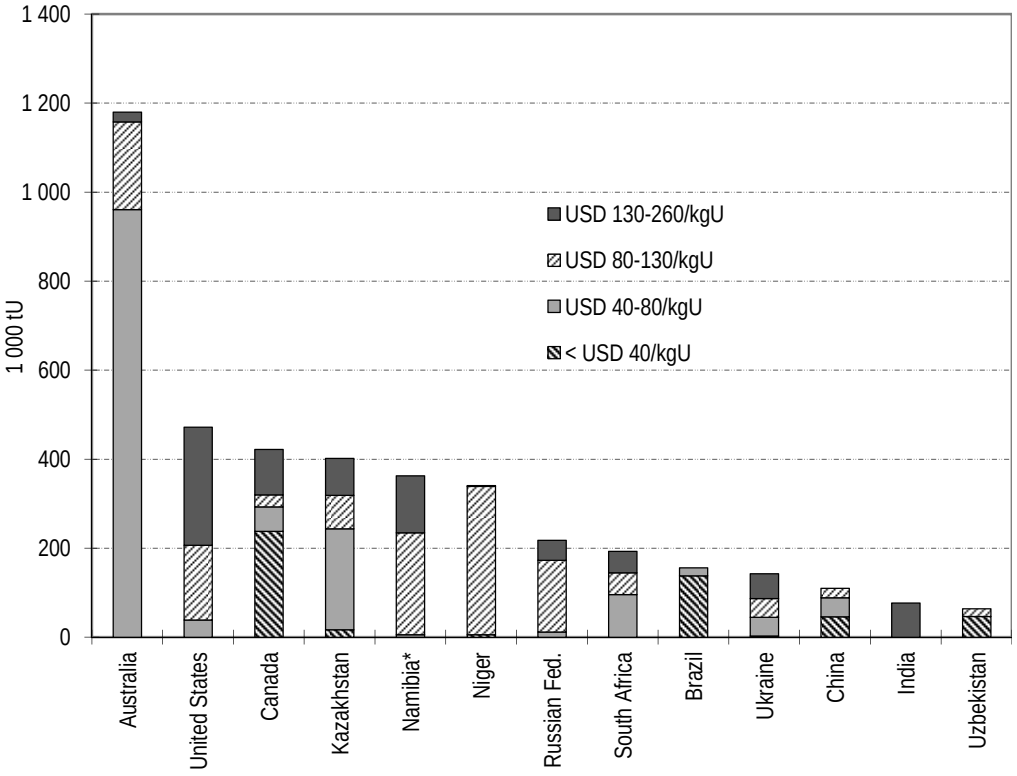
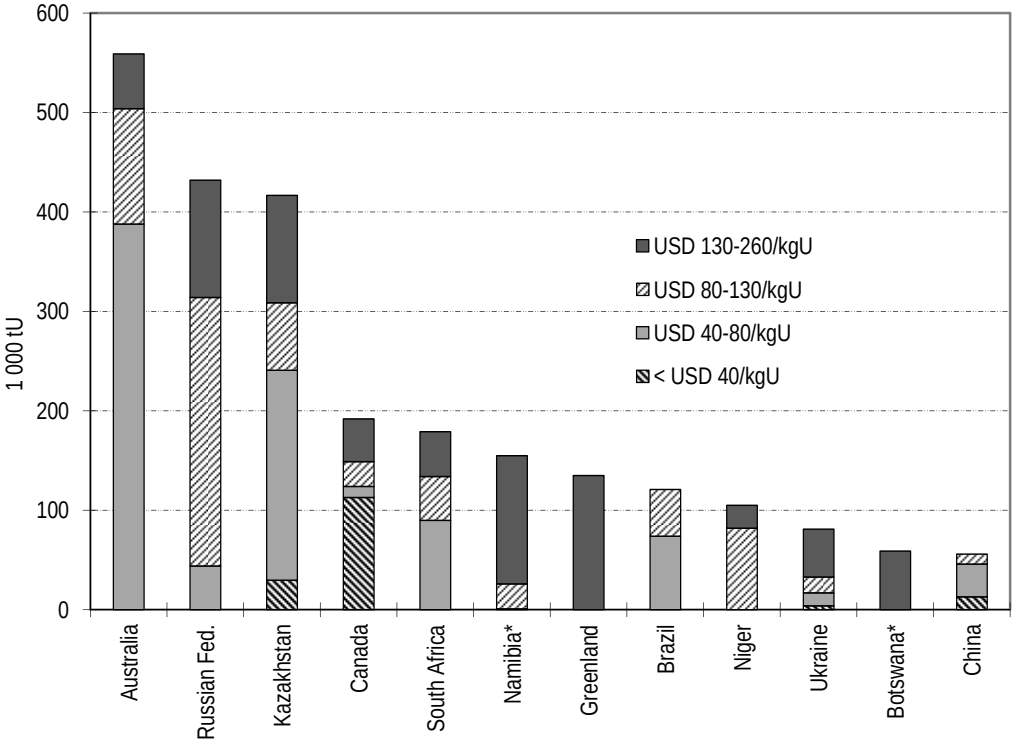



**Figure 1.3. Distribution of inferred resources (IR) among countries with a significant share of resources**




* Secretariat estimate.

### *Distribution of resources by production method*

In 2011, countries reported identified resources by cost categories and by the expected production method, i.e., open-pit or underground mining, *in situ* leaching, heap leaching or in-place leaching, co-product/by-product or as unspecified (Tables 1.6 and 1.7).

In the lowest cost category, <USD 40/kgU, underground mining is the predominant production method for RAR (Table 1.6), mainly from Canada. Resources in the by/co-product category make a significant contribution, mainly from Brazil, with ISL from China and Kazakhstan making up most of the rest. The total is likely underestimated because of the difficulty in assigning mining costs accurately in the by/co-product category, particularly in Australia. In the <USD 80/kgU category, resources in the by/co-product category become dominant with Australia (Olympic Dam) being the single largest contributor. It is only in the highest cost category that underground and open-pit mining again surpasses the by/co-product category. Canada holds the largest resource total for underground mining while Namibia and Niger make the largest contribution to open-pit production. Olympic Dam is responsible for the majority of the by-product category with South Africa and Brazil making significant contributions. ISL makes an important contribution in all cost categories with Kazakhstan being the major player.

The pattern of production capacity through the IR cost categories (Table 1.7) is very similar to that for RAR with Australia, the Russian Federation and Kazakhstan being responsible for 52% of total production method resources, followed by Canada, South Africa and Namibia. The United States does not report IR by production method, leading to under-representation in the ISL alkaline category.

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

(recoverable resources as of 1 January 2011, tonnes U)

| Production method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU |
|---|---|---|---|---|
| Open-pit mining | 28 600 | 99 600 | 868 700 | 1 286 000 |
| Underground mining | 313 800 | 428 900 | 875 800 | 1 272 000 |
| *In situ* leaching acid | 80 400 | 347 400 | 438 700 | 426 700 |
| *In situ* leaching alkaline | 0 | 36 600 | 88 500 | 111 000 |
| Co-product/by-product | 71 100 | 1 102 300 | 1 150 700 | 1 198 900 |
| Unspecified | 0 | 0 | 33 100 | 84 100 |
| Total | 493 900 | 2 014 800 | 3 455 500 | 4 378 700 |

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

(recoverable resources as of 1 January 2011, tonnes U)

| Production method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU |
|---|---|---|---|---|
| Open-pit mining | 120 500 | 180 800 | 606 400 | 873 700 |
| Underground mining | 13 300 | 24 600 | 194 900 | 496 900 |
| *In situ* leaching acid | 53 100 | 314 900 | 388 000 | 395 000 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 |
| Co-product/by-product | 0 | 503 500 | 595 700 | 648 000 |
| Unspecified | 0 | 40 000 | 86 700 | 304 300 |
| Total | 186 900 | 1 063 800 | 1 871 700 | 2 717 900 |

### *Distribution of resources by processing method*

In 2011, countries were 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, *in situ* leaching, in-place leaching, heap leaching from open-pit or heap leaching from underground or as unspecified. It should be noted that not all countries reported their resources according to processing method.

In all cost categories for RAR (Table 1.8) and IR (Table 1.9), conventional processing from underground mining is the major contributor, with Australia dominating because of Olympic Dam. Into the higher cost categories conventional processing from open-pit and ISL make increasing contributions, but even when combined do not surpass the underground resources. However, if expansion plans for Olympic Dam come to full fruition there will be a strong shift towards open-pit production. The amount of IR 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 production 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 2011, tonnes U)

| Processing method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU |
|---|---|---|---|---|
| Conventional from OP | 6 800 | 59 500 | 798 300 | 1 186 500 |
| Conventional from UG | 313 800 | 1 446 900 | 1 920 500 | 2 377 400 |
| *In situ* leaching acid | 80 400 | 347 400 | 438 700 | 426 700 |
| *In situ* leaching alkaline | 0 | 36 600 | 88 500 | 111 000 |
| In-place leaching* | 0 | 0 | 500 | 500 |
| Heap leaching** from OP | 21 800 | 35 500 | 72 700 | 100 400 |
| Heap leaching** from UG | 0 | 0 | 13 100 | 13 100 |
| Unspecified | 71 100 | 88 900 | 123 200 | 163 100 |
| Total | 493 900 | 2 014 800 | 3 455 500 | 4 378 700 |

* Also known as stope leaching or block leaching.

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

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

(recoverable resources as of 1 January 2011, tonnes U)

| Processing method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU |
|---|---|---|---|---|
| Conventional from OP | 2 500 | 12 300 | 143 300 | 349 600 |
| Conventional from UG | 120 400 | 653 200 | 1 122 900 | 1 450 400 |
| *In situ* leaching acid | 53 100 | 314 900 | 388 000 | 395 000 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 |
| In-place leaching* | 0 | 0 | 2 100 | 2 100 |
| Heap leaching** from OP | 10 900 | 12 200 | 12 500 | 105 400 |
| Heap leaching** from UG | 0 | 0 | 3 800 | 7 500 |
| Unspecified | 0 | 71 200 | 199 100 | 407 900 |
| Total | 186 900 | 1 063 800 | 1 871 700 | 2 717 900 |

* 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 2011, countries also reported identified resources by cost categories and by geological types of deposits, i.e., *unconformity-related, sandstone, hematite breccia complex, quartz-pebble conglomerate, vein, intrusive, volcanic and caldera-related, metasomatite* or *other* (Tables 1.10 and 1.11). Deposit type definitions can be found in Appendix 3.

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

(recoverable resources as of 1 January 2011, tonnes U)

| Deposit type | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU |
|---|---|---|---|---|
| Unconformity-related | 237 900 | 336 900 | 446 600 | 538 800 |
| Sandstone | 55 200 | 349 000 | 985 200 | 1 247 100 |
| Hematite breccia complex | 0 | 917 100 | 918 500 | 919 300 |
| Quartz pebble conglomerate | 0 | 43 600 | 65 400 | 110 500 |
| Vein | 0 | 7 900 | 36 500 | 145 800 |
| Intrusive | 0 | 5 900 | 152 000 | 273 200 |
| Volcanic caldera-related | 0 | 3 500 | 128 100 | 152 700 |
| Metasomatite | 87 100 | 140 000 | 262 000 | 375 100 |
| Other | 67 900 | 120 700 | 331 400 | 381 700 |
| Unspecified | 45 800 | 90 200 | 129 800 | 234 500 |
| Total | 493 900 | 2 014 800 | 3 455 500 | 4 378 700 |

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

(recoverable resources as of 1 January 2011, tonnes U)

| Deposit type | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU |
|---|---|---|---|---|
| Unconformity-related | 112 800 | 129 500 | 184 500 | 195 600 |
| Sandstone | 45 700 | 312 800 | 519 100 | 667 600 |
| Hematite breccia complex | 0 | 382 700 | 397 100 | 402 500 |
| Quartz pebble conglomerate | 0 | 55 900 | 79 400 | 122 000 |
| Vein | 0 | 600 | 21 500 | 146 200 |
| Intrusive | 0 | 700 | 17 800 | 233 500 |
| Volcanic caldera-related | 500 | 9 000 | 79 200 | 123 700 |
| Metasomatite | 3 600 | 22 000 | 321 500 | 441 700 |
| Other | 10 900 | 104 100 | 184 100 | 298 100 |
| Unspecified | 13 400 | 46 500 | 67 500 | 87 000 |
| Total | 186 900 | 1 063 800 | 1 871 700 | 2 717 900 |

In the lowest cost RAR (<USD 40/kgU) category, unconformity-related deposits in Canada dominate, with small contributions from sandstone, metasomatite, unspecified and other type deposits (Table 1.10). Hematite breccia complex deposits come to the forefront in the <USD 80/kgU category with unconformity-related and sandstone deposits making relatively smaller contributions. In the <USD 130/kgU category, sandstone-related resources (in Kazakhstan, Niger and the United States) just surpass resources in the hematite breccia complex category, with unconformity-related resources still making an important contribution while metasomatite, intrusive, other and volcanic-related resources lag behind. Vein and quartz pebble deposit types only become comparable to other deposit types in terms of total resources in the <USD 260/kgU category, while

sandstone deposits rank highest, followed closely by hematite breccia complex resources. In declining importance are metasomatite, intrusive, volcanic, vein and quartz-pebble conglomerate-hosted resources.

Similar observations can be made in the IR category (Table 1.11). In the <USD 260/kgU and <USD 130/kgU category sandstone-hosted resources dominate with metasomatite and hematite breccia complex resources the next most important. Hematite breccia complex deposits dominate the <USD 80/kgU cost category, followed by sandstone and unconformity deposits. IR for metasomatite deposits drop significantly within the lowest cost categories while unconformity-related deposits again dominate the reported IR within the lowest cost category (<USD 40/kgU).

### *Proximity of resources to production centres*

A total of nine countries provided estimates of the availability of resources for near-term production by reporting the percentage of identified resources (RAR and inferred resources) recoverable at costs of <USD 80/kgU and <USD 130/kgU that are tributary to existing and committed production centres (Table 1.12). Resources tributary to existing and committed production centres in the nine countries listed total 2 575 786 tU at <USD 80/kgU (about 86% of the total resources reported in this cost category). This is 3.6% higher than the 2009 value of 2 486 752 tU, but still less than the 2 757 590 tU reported in 2007. Resources tributary to existing and committed production centres in the nine countries listed total 2 906 468 tU at <USD 130/kgU (about 70% of the total resources reported in this cost category).

**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 production centres | | |
|---|---|---|---|---|---|---|
| | Total resources (tU) | % | Proximate resources (tU) | Total resources (tU) | % | Proximate resources (tU) |
| Australia | 1 349 400 | 100 | 1 349 400 | 1 661 600 | 80 | 1 329 280 |
| Brazil | 229 300 | 66 | 151 338 | 276 700 | 66 | 182 622 |
| Canada | 416 800 | 81 | 337 608 | 468 600 | 75 | 351 450 |
| China | 135 000 | 65 | 87 750 | 166 100 | 65 | 107 965 |
| Czech Republic | 0 | 100 | 0 | 374 | 100 | 374 |
| Kazakhstan | 553 200 | 93 | 514 476 | 716 500 | 82 | 587 530 |
| Russian Fed. | 55 400 | 7 | 3 878 | 487 200 | 23 | 109 620 |
| South Africa | 186 000 | 62 | 115 320 | 279 100 | 65 | 181 415 |
| Ukraine | 61 600 | 26 | 16 016 | 119 600 | 47 | 56 212 |
| Total | 2 986 700 | 86 | 2 575 786 | 4 175 774 | 70 | 2 906 468 |

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

### *Additional conventional resources*

The Secretariat identified additional identified resources (Table 1.13) for inclusion in the Red Book for the first time. Some countries do not include resource determinations by junior exploration companies until additional information is provided to the pertinent agencies or until a mining licence application is filed (e.g. Argentina, Peru and the Slovak Republic). Other countries do not always have sufficient human resources to provide detailed information and evaluation as requested in the questionnaire. The table represents a Secretariat estimate based on technical reports of resources that have been classified either as JORC, NI 43-101 or SAMREC compliant.

These additional resources amount to a total of 124 100 tU classified as RAR and IR in several countries that are not included in Tables 1.2, 1.3 and 1.4. The most significant "additional resources" occur in the Central African Republic (36 500 tU), Peru (22 400 tU), Mauritania (20 100 tU) and Spain (18 000 tU).

**Table 1.13. Additional identified resources**

(rounded to nearest 100 tU)

| Country | Deposit/project | RAR and inferred resources |
|---|---|---|
| Central African Republic | Bakouma | 36 500 |
| Egypt | Gabal Gutter | 2 000 |
| | Abu Zenima | 100 |
| Mali | Falea | 8 600 |
| Mauritania | Bin En Nar | 800 |
| | Reguibat | 19 300 |
| Paraguay | Yuty | 4 300 |
| Peru | Macusani | 12 600 |
| | Corachapi | 1 900 |
| | Colibri 2 and 3 | 7 900 |
| Slovak Republic[a] | Kosice (Kurishkova) | 9 300 |
| | Novoveska Huta | 2 800 |
| Spain[b] | Berkeley/Enusa (owners) | 18 000 |
| Total | | 124 100 |

(a) Amount not reported in RAR and IR national totals. Note, however, that this may include amounts reported as undiscovered resources.

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

### *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* refer to those expected to occur in known uranium provinces, generally supported by some direct evidence. *Speculative resources* 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 prognosticated resources (PR) and speculative resources (SR) are reported as *in situ* resources (Table 1.14).

Worldwide, reporting of PR and SR is incomplete, as only 26 countries have historically reported resources in this category. A total of 23 countries reported undiscovered resources for this edition, compared to the 27 that reported RAR. Only 13 countries of those reporting provided updated undiscovered resource figures for this edition. For the countries that reported PR, 15 also reported SR while 3 countries reported only SR and 5 only PR. Chile reported SR and PR as one combined figure. Some of the countries that do not report undiscovered resources, such as Australia, Gabon and Namibia, are considered to have significant resource potential in as yet sparsely explored areas.

## Table 1.14. Reported undiscovered resources*

(in 1 000 tU as of 1 January 2011)

| 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[a] | NA | 1.4 | 1.4 | NA | NA | NA | NA |
| Brazil[a] | 300.0 | 300.0 | 300.0 | NA | NA | 500.0 | 500.0 |
| Bulgaria[b] | NA | NA | 25.0 | NA | NA | NA | NA |
| Canada[a] | 50.0 | 150.0 | 150.0 | 700.0 | 700.0 | NA | 700.0 |
| Chile[c] | NA | NA | 2.3 | NA | NA | 2.3 | 2.3 |
| China[a] | 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[a] | NA | 0.2 | 0.2 | NA | NA | 179.0 | 179.0 |
| Germany[a] | NA | NA | NA | NA | NA | 74.0 | 74.0 |
| Greece[b] | 6.0 | 6.0 | 6.0 | NA | NA | NA | NA |
| Hungary | NA | NA | 12.8 | NA | NA | NA | NA |
| India[a] | NA | NA | 63.6 | NA | NA | 17.0 | 17.0 |
| Indonesia | NA | NA | 23.5 | NA | NA | 22.0 | 22.0 |
| Iran, Islamic Republic of[a] | 0.0 | 4.2 | 4.2 | 0.0 | 14.0 | 14.0 | 28.0 |
| Italy[a] | NA | NA | NA | NA | 10.0 | NA | 10.0 |
| Jordan | 0.0 | 15.0 | 15.0 | 0.0 | 50.0 | NA | 50.0 |
| Kazakhstan | 335.0 | 498.0 | 500.0 | 227.0 | 300.0 | NA | 300.0 |
| Mexico[b] | NA | 3.0 | 3.0 | NA | NA | 10.0 | 10.0 |
| Mongolia | 21.0 | 21.0 | 21.0 | 1 390.0 | 1 390.0 | NA | 1 390.0 |
| Niger[d] | 0.0 | 13.6 | 13.6 | 0.0 | 51.3 | NA | 51.3 |
| Peru | 6.6 | 20.0 | 20.0 | 19.7 | 19.7 | NA | 19.7 |
| Portugal[a] | 1.0 | 1.5 | 1.5 | NA | NA | NA | NA |
| Romania[b] | NA | 3.0 | 3.0 | 3.0 | 3.0 | NA | 3.0 |
| Russian Federation | 0.0 | 191.8 | 191.8 | NA | NA | 772.0 | 772.0 |
| Slovak Republic | 2.2 | 7.2 | 7.2 | NA | NA | NA | NA |
| Slovenia[b] | 0.0 | 1.1 | 1.1 | NA | NA | NA | NA |
| South Africa[a] | 34.9 | 110.3 | 110.3 | NA | NA | 1 112.9 | 1 112.9 |
| Ukraine | 0.0 | 8.4 | 22.5 | 0.0 | 120.0 | 255.0 | 375.0 |
| United States[b] | 839.0 | 1 273.0 | 1 273.0 | 858.0 | 858.0 | 482.0 | 1 340.0 |
| Uzbekistan | 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 |
| Vietnam[b] | 0.0 | 7.9 | 7.9 | 100.0 | 100.0 | 130.0 | 230.0 |
| Zambia[b] | 0.0 | 22.0 | 22.0 | NA | NA | NA | NA |
| Zimbabwe[b] | 0.0 | 0.0 | 0.0 | 25.0 | 25.0 | NA | 25.0 |
| Total | 1 624.1 | 2 698.0 | 2 841.3 | 3 543.8 | 3 862.1 | 3 733.2 | 7 595.3 |

NA = Data not available.

* Undiscovered resources are reported as *in situ* resources.

(a) Reported in 2011 responses, but values have not been updated since 2009 Red Book.

(b) Not reported in 2011 response, data from previous Red Book.

(c) National report combines PR and SR.

(d) Secretariat estimate.

Total PR in the highest cost category (<USD 260/kgU) amounted to 2.84 million tU, a decrease of 2%, compared to 2009. The major changes were declines in Hungary, Indonesia, Jordan, and Ukraine along with increases in some other countries, such as Mongolia, Peru, the Russian Federation and the Slovak Republic. In parallel with the trends observed in the RAR and IR, the lower cost categories (i.e. <USD 130/kgU and <USD 80/kgU) dropped by 4% and 5% respectively, reflecting the influence of increasing mining costs.

Total SR in the <USD 260/kgU cost category declined slightly by 1% compared to 2009, but the unassigned cost range increased by about 4%, compared to 2009. The <USD 130/kgU cost category dropped by 6% from 2009, matching the trends shown in identified resources. The reasons for the changes in SR are similar to those in PR, but in the <USD 130/kgU cost category the Russian Federation also made a significant contribution. High cost (<USD 260/kgU) PR and total SR amount to a combined total of 10 436 600 tU, a marginal increase of 36 100 tU compared to the total of 10 400 500 tU reported in 2009.

### *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 phosphate rocks, but other potential sources exist (e.g. black shale and seawater).

An IAEA Technical Meeting convened in November 2009 addressed activities in this area, covering a range of issues relating to the potential of unconventional resources, along with research, technological developments and related environmental aspects (IAEA, 2009). It is clear that stronger uranium prices and expectations of rising demand in recent years have stimulated investigation of a variety of projects and technologies by both governments and commercial entities in this area. In particular, an interest in recovery of uranium from phosphates was highlighted prompting a series of IAEA supported consultancies and technical meetings in 2010 and 2011, as well as a workshop in Morocco in 2011.

Since few countries reported updated information a comprehensive compilation of unconventional uranium resources and other potential nuclear fuel materials is not possible. Instead, a summary of information documented over recent years and data reported in this edition is provided. 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 edition in order to illustrate the evolution of these resource estimates.

Unconventional uranium resources were reported occasionally by countries in Red Books beginning in 1965. Earlier estimates for Jordan appear to have overestimated contained U in phosphate, whereas estimates of U contained in black schists (shales) in Finland and Sweden appear to have underestimated contained U (Table 1.15). Other estimates of uranium resources associated with marine and organic phosphorite deposits point to the existence of almost 9 million tU in Jordan, Mexico, Morocco and the United States alone (IAEA, 2001). Others have estimated the global total to amount to 22 million tU (De Voto and Stevens, 1979). Recent data from the International Fertilizer Development Centre (IFDC) indicates that the latter figure is probably a very conservative estimate of total resources, but is likely to be a reasonably accurate reflection of commercially exploitable resources (Hilton *et al.*, 2012).

The figures presented in Table 1.15 can be expected to continue to evolve and are clearly incomplete, since large uranium resources associated with the Chattanooga

(United States) and Ronneburg (Germany) black shales, which combined contain a total of 4.2 million tU, are not listed. Neither are large uranium resources associated with monazite-bearing coastal sands in Brazil, India, Egypt, Malaysia, Sri Lanka and the United States. Unconventional resources are also not regularly reported in former USSR countries. The total uranium reported in previous Red Books as unconventional resources, dominated by phosphorite deposits in Morocco (>85%), were conservatively estimated to amount to about 7.0-7.3 million tU. Comparing these past totals with the updated information in Table 1.15, the estimated total unconventional U resources is 7.3 to 8.0 million tU, which is an approximately 10% increase. The potential to expand the unconventional uranium resource base is clear but will likely not be fully realised until market conditions strengthen considerably.

**Table 1.15. Unconventional uranium resources (1 000 tU) reported in 1965-2003 Red Books with updated figures from 2011 edition in brackets**

| Country | Phosphate rocks | Non-ferrous ores | Carbonatite | Black schist/shales, lignite |
|---|---|---|---|---|
| Brazil* | 28.0-70.0 (76) | 2 | 13 | |
| Chile | 0.6-2.8 (7.2) | 4.5-5.2 | | |
| Columbia | 20.0-60.0 | | | |
| Egypt** | 35.0-100.0 | | | |
| Finland | 1 (1) | | 2.5 (2.5) | 3.0-9.0 (26) |
| Greece | 0.5 | | | |
| India | 1.7-2.5 | 6.6-22.9 | | 4 |
| Jordan | 100-123.4 (60) | | | |
| Kazakhstan | 58 | | | |
| Mexico | 100-151 (240) | 1 | | |
| Morocco | 6 526 | | | |
| Peru | 20 (21.6) | 0.14-1.41 | | |
| South Africa*** | | | | 77 |
| Sweden | | | | 300 (600) |
| Syria | 60.0-80.0 | | | |
| Thailand | 0.5-1.5 | | | |
| United States | 14.0-33.0 | 1.8 | | |
| Venezuela | 42 | | | |
| Vietnam | | | | 0.5 |

* Considered a conventional resource in Brazil and is thus included in conventional resource figures (Table 1.4).

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

*** Also reports resources in phosphorite but does not provide tonnage estimates.

In 2011, only a few countries (Chile, Finland, Jordan, Mexico, Peru, South Africa and Sweden) mentioned or reported unconventional uranium resources (Table 1.15). Chile reports a total of 7 200 tU as unconventional resources in a variety of host rocks including 1 300 tU at the Mejillnes and 638 tU at the Bahi Inglesa phosphorite deposits.

Finland reports a substantial increase in unconventional U resources which is primarily due to recent evaluations of the polymetallic Talvivaara black shales at the Sotkamo nickel mine. Previous estimates of resources associated with black shales in Finland ranged from 3 000 to 9 000 tU and this has been updated to around 26 000 tU. Mawson Resources and Namura Finland are also working towards development of the Nuottijärvi deposit which contains U associated with phosphates in black shales. This deposit has a historic resource estimate of 1 000 tU (>USD 130/kgU). In 2007, the Ministry

of Employment and the Economy in Finland granted a two-year extension of the Sokli mining concession for carbonatites containing niobium, thorium and uranium. The environmental assessment delivered in support of its development includes an option for uranium production.

Jordan has downgraded the amount of U that was previously reported in phosphate rocks from 100 000-123 000 to 60 000 tU with grades remaining the same as originally reported in 2007, ranging between 20 and 70 ppm (0.002 and 0.007% U).

Mexico provided a significant update to its unconventional resource estimates to 240 000 tU in phosphate rocks including the San Juan de la Costa deposit which is estimated to contain a total of about 80 million tonnes with a uranium content of about 0.004% $U_3O_8$ (0.003% U).

Peru notes in the 2009 edition of the Red Book the potential of the Bayovar deposit in Piura, estimated to contain as much as 16 000 tU at an average grade of 60 ppm (0.006% U).

Egypt previously reported (i.e. in 2008) an estimate of 42 000 tU contained in upper Cretaceous phosphate deposits, with U content ranging between 50 and 200 ppm (0.005 and 0.02% U). Although not reported in this edition of the Red Book, other countries, such as Morocco and Tunisia, have also expressed an interest in recovering uranium from phosphate rocks during fertiliser production.

South Africa notes the potential in the long term for recovery of uranium from phosphate deposits off its west coast with uranium grades as high as 430 ppm (0.043% U).

If uranium prices reach levels in excess of USD 260/kgU (USD 100/lb $U_3O_8$), and/or improvements are made in reducing mining and processing costs, by-product recovery of uranium from unconventional resources, and in particular from phosphate processing facilities, could once again become a viable source of uranium. Doing so will require overcoming potential barriers such as regulatory requirements and development of qualified personnel. In this way, uranium that is now being dispersed in very low concentrations on the land surface in fertiliser or stored in tailings facilities could be recovered and used in the nuclear fuel cycle. In recent years, interest in by-product U extraction has been revived and a few projects are moving towards production.

*Recent developments in uranium extraction from phosphate rocks*

Historically phosphate deposits (Barthel, 2005) are the only unconventional resource from which a significant amount of uranium has been recovered. Processing of Moroccan phosphate rock in Belgium produced 686 tU between 1975 and 1999. During 1954 to 1962 about 17 150 tU were recovered in the United States from phosphate rocks in Florida with production focused on military needs, but a second wave of US production (1970s to 1990s) was largely for civil nuclear power production. As much as 40 000 tU were also recovered from processing marine organic deposits (essentially concentrations of ancient fish bones) in Kazakhstan. In the 1990s, the price of uranium dropped to a level that made these operations uneconomic and most of these plants were shut down. Those that were operating in the United States were decommissioned and demolished.

Past uranium production from phosphate rocks relied on solvent extraction processes. The cost of solvents and the volume of waste generated prompted development of an ion exchange process by Urtek, an alliance between Australia's Uranium Equities and Cameco. Purported advantages of ion exchange include lower costs, the ability to recover lower concentrations of uranium and the avoidance of possible organic solvent contamination in the phosphoric acid product stream. Uranium Equities is continuing development of this process and anticipates having a commercial process completed by 2015.

The global maximum of production at existing phosphoric acid production centres using solvent extraction processes is estimated to amount to a maximum of about

11 000 tU/yr (Hilton *et al.*, 2012). All production would be as a by-product of phosphoric acid production as estimated costs of a dedicated U production facility are too high to be economic. Important variables include the process employed to produce phosphoric acid at the existing plants, the wide variability of U content in phosphoric acid at each production facility and the wide range in size of the existing plants.

In the 1980s, estimated production costs for a 50 tU/yr uranium by-product solvent extraction recovery project in the United States, including capital investment, ranged between USD 40/kgU and USD 115/kgU (USD 15/lb $U_3O_8$ and USD 45/lb $U_3O_8$; McCarn, 1998). More recently, ion exchange production costs of between USD 50/kgU and USD 65/kgU (USD 20/lb $U_3O_8$ and USD 25/lb $U_3O_8$) have been put forward by Australia's Uranium Equities (www.uel.com.au/discover/phosenergy-technology/process.html), although supporting feasibility study results have not been produced. In November 2009, Cameco invested USD 16.5 million in Uranium Equities to develop and commercialise the company's PhosEnergy process and a demonstration plant is scheduled to commence operation in 2012, along with development of a prefeasibility study.

While evaluation of production possibilities in a number of countries continues, Brazil is the only country with firm plans to produce uranium from phosphate rocks. Resources at Santa Quitéria amount to over 76 000 tU at a relatively high grade of 800 ppm (0.08% U). The government of Brazil reports that development of the St. Quitéria Project is ongoing, with production of uranium from phosphoric acid produced from the Itataia phosphate/uranium deposit expected to begin in 2015 with a capacity of 970 tU/yr.

*Recent developments in uranium extraction from black shales*

In Finland, low-grade polymetallic (nickel, zinc, copper and cobalt) sulphide ores in the Talvivaara black shales with an average grade of 0.0017% U have been in commercial production at the Sotkamo nickel mine since October 2008 using bio-heap leaching. Although uranium recovery is not included in the extraction process at present, advances have been made to begin by-product U extraction as early as 2012. The company is proceeding with applications for the necessary licences and is expected to begin uranium production in 2012 using a solvent extraction circuit added to the main production process, recovering what is currently a waste product. At full production, the operation is expected to produce a maximum of 350 tU/yr. The current extraction licence is valid until the end of 2054.

In Sweden, exploration of the Alum Shale has led to significant resource determinations of low-grade uranium occurrences (0.014-0.002% U) by Continental Resources and Aura Energy, with inferred resources totalling over 600 000 tU in two projects alone which is double the amount previously reported (Table 1.15). Aura Energy is currently investigating the use of bio-heap leaching to recover these resources.

*Other potential sources*

Efforts to recover uranium from tailings deposits in South Africa have also been advanced recently. Rand Uranium, recently bought out by Gold One, has been investigating the potential of recovering uranium from 11 tailings dumps south-west of Johannesburg, where the Cooke dump near Doornkop alone contains an estimated 9 500 tU, as well as gold. Gold Fields is also investigating the potential of 14 tailings dumps and gold–uranium quartz–pebble conglomerates at their Far West Wits Line mines near Carletonville, containing an estimated 40 900 tU and 75 tAu. In addition, First Uranium is working towards uranium production from 14 old tailings dams included in the Mine Waste Solutions (MWS) tailings reclamation project. Harmony Gold is examining its existing gold operations and tailings dams in the Welkom area to assess the viability of extracting uranium from resources amounting to 31 600 tU on surface and 29 700 tU underground.

Canadian based Sparton Resources has been developing technology to recover uranium from coal ash, focusing efforts on a Chinese coal-fired power station, but is also

considering other potentially suitable ash disposal sites in China, South Africa and Eastern Europe. Although the process has been conducted on a limited scale in the past, as with other unconventional sources of uranium, strong uranium prices will be necessary for such extraction technologies to be commercially viable.

Holgoun, through its subsidiary Holgoun Uranium and Power, had been investigating uranium recovery from the Springbok Flats coal field, estimated to contain 84 000 tU at grades of 0.06 to 0.1% U. The project is investigating the feasibility of mining the low-grade coal, using it to fire a conventional electricity generation plant and extracting the uranium from the residual ash. However, developing a cost effective, environmentally acceptable means of uranium extraction from this potential source remains a challenge.

Although uranium recovery from tailings and coal ash would be a welcome addition, these projects, as currently outlined, would contribute annually only small amounts of material, likely on the order of a few hundred tU/yr from each operation.

*Uranium from seawater*

Seawater has long been regarded as a possible source of uranium due to the large amount of contained uranium (over 4 billion tU) and its almost inexhaustible nature. However, because of the low concentration of uranium in seawater (3-4 parts per billion), developing a cost-effective method of extraction remains a challenge.

Research on uranium recovery from seawater was carried out in Germany, Italy, Japan, the United Kingdom and the United States from the 1950s through the 1980s, but until recent years was only known to be continuing in Japan. The most recently reported Japanese trials of a recovery system, based on a new type of polymer braid that enhanced U recovery by three times, recovered about 1.5 gU/kg adsorbent over a 30-day period (Tamada, 2009). Directly mooring 60 m long adsorbent braids to the sea floor significantly reduced costs compared to an earlier system where the braids were suspended from a floating frame. From these tests and trials the potential cost of U recovery including adsorbent production, U collection and purification considering a scaled-up annual recovery of about 1 200 tU/yr using braids with 18 repeated soaking cycles, amounted to just over USD 250/kgU (USD 96/lb $U_3O_8$). However, if other expected costs are included, such as capital equipment and more frequent braid replacement (a repetition of only eight times was demonstrated in the trials), the costs associated with commercialising sea-bed uranium production including potential maritime legal constraints and disposal of a significant quantity of adsorbent material used during large-scale production, total costs can be expected to rise considerably. Nonetheless, research and development into more effective and durable braid collection systems could eventually bring costs down. In 2011, the United States began a research effort to evaluate the Japanese results and define the potential for seawater uranium to be an economic fuel resource.

### *Thorium*

Thorium is a naturally occurring, silvery white, slightly radioactive metal found in small quantities in most rocks and soils. Its global abundance is between three and five times that of uranium. It occurs as oxides, silicates and phosphates, often with rare earth elements (REE). A common REE/thorium mineral is monazite in which the thorium content can reach 26%, but commonly is 10% or less. Various classification schemes have been proposed for thorium-bearing deposits. At the simplest level thorium is found in four distinct types of deposit. In decreasing order of importance they are carbonatite-hosted, placer, vein-type and alkaline rock-hosted (Table 1.16). Other, less important deposit types are also known.

**Table 1.16. Major thorium deposit types and resources (NEA, 2006)**

| Deposit type | Resources (1 000 t Th) |
|---|---|
| Carbonatite | 1 900 |
| Placer | 1 500 |
| Vein-type | 1 300 |
| Alkaline rocks | 1 120 |
| Other | 258 |
| Total | 6 078 |

Carbonatite-hosted thorium deposits are common around the world and are documented in Argentina, Brazil, Canada, the Russian Federation, Scandinavia, South Africa and the United States. Placer-type deposits range in age from the Archean, such as those in the Witwatersrand Basin, to recent in the heavy mineral beach sands on the coasts of Australia, Brazil, India, Mozambique and South Africa. Vein-type and alkaline-hosted deposits are equally widespread, occurring on all continents. Some deposits such as the enormous Bayan Obo deposit in China are difficult to assign to a specific deposit type category since they display characteristics of carbonatite, alkaline and vein-type deposits and several genetic theories have been proposed. Currently, beach sand deposits in Brazil and India are the only sources of thorium, and this type of deposit is likely to remain an important source of thorium production.

There are a few REE projects which have possible Th by-product and Th containing residues that have the potential to come into production in the near term. One such project is Nolans Bore in Australia that contains about 81 810 tonnes of Th in 30.3 Mt of measured, indicated and inferred resources as 2.8% rare-earth oxides (REO), 12.9% $P_2O_5$, 0.02% $U_3O_8$ and 0.27% Th. Currently proponents are considering establishing processing facilities at Whyalla in South Australia. The thorium content in the concentrate will be separated as an iron thorium precipitate and transported back to the Nolans Bore mine site in NT for long-term storage as a possible future energy source.

At Steenkampskraal, South Africa during the 1950s and 1960s about 50 000 tonnes of monazite concentrates were extracted which had between 3.3 and 7.6% Th. Operation of the mine was halted in 1963. Historical reserve estimates for this deposit are 15 000 tTh. Rare-earth oxide production is scheduled for 2013 and thorium will be extracted from the mixed rare-earth chloride concentrate, then mixed with concrete and stored in designated areas. Thorium hydroxide will be stockpiled at a rate of about 360t/yr.

In 2011, the government of Greenland agreed to include radioactive materials in an exploration licence covering the Kvanefjeld rare-earth element project and a pre-feasibility report was released in 2012. The REE, uranium and zinc resources were re-evaluated by Greenland Minerals and Energy and in 2011 a JORC compliant, indicated and inferred resource was announced consisting of 134 654 tU, 6.5 Mt HREE (heavy rare earth elements) and Y at 1.07%, and 1.36 Mt Zn at 0.22%. Using the chondritic ratio Th/U of three, the deposit could contain about 400 000 tTh. However, it should be noted that a licence to complete such assessments does not give rights to explore for or exploit radioactive elements. If the deposit were to be exploited, uranium 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.

Like uranium, thorium can be used as a nuclear fuel. Although not fissile itself, $^{232}$Th when loaded into a nuclear reactor absorbs neutrons to produce $^{233}$U, which is fissile (and long-lived). Much of the $^{233}$U will then fission in the reactor. The used fuel can then be unloaded from the reactor and the remaining $^{233}$U can be chemically separated from the thorium and used as fuel for another reactor.

A recent report by the Nuclear Energy Agency (2011), notes an interest in several countries to use thorium as a nuclear fuel over the last few decades. Basic research and development as well as operation of reactors with thorium fuel has been conducted in Canada, Germany, India, Japan, the Russian Federation, the United Kingdom and the United States. Some examples include:

- Germany: The 15 MWe AVR (*Arbeitsgemeinschaft Versuchsreaktor*) experimental pebble bed reactor at Jülich operated between 1967-1988 partly as a test bed for various fuel pebbles, including thorium. The 300 MWe THTR (thorium high temperature reactor), developed from the AVR, operated between 1983 and 1989 with 674 000 pebbles, over half containing Th/HEU fuel. In addition to these high temperature reactors, thorium fuel was tested at the 60 MWe BWR in Lingen.
- United Kingdom: Thorium fuel elements with a 10:1 Th/U (HEU) ratio were irradiated in the 20 MWth Dragon reactor at Winfrith, for 741 full power days. Dragon was run between 1964 and 1973 as an OECD/Euratom co-operation project, involving Austria, Denmark, Sweden, Norway and Switzerland in addition to the United Kingdom.
- United States: Fuel was tested in one light water reactor (Shippingport) and two gas-cooled reactors. Shippingport operated as a light water breeding reactor between August 1977 and October 1982. General Atomics' Peach Bottom high-temperature, graphite-moderated, helium-cooled reactor operated between 1967 and 1974 at 110 MWth, using high-enriched uranium with thorium. The Fort St Vrain reactor, the only commercial thorium-fuelled nuclear plant in the United States, was a high-temperature (700°C), graphite-moderated, helium-cooled reactor with a Th/HEU fuel designed to operate at 842 MWth (330 MWe). The fuel was arranged in hexagonal columns ("prisms") rather than as pebbles. Almost 25 tonnes of thorium were used as fuel for the reactor, and this achieved 170 GWd/t burn-up.
- Canada: Atomic Energy Canada Limited has more than 50 years of experience with thorium-based fuels, including burn-up to 47 GWd/t. Some 25 tests have been performed in three research reactors and one pre-commercial reactor.
- India: The Kamini 30 kWth experimental neutron-source research reactor using $^{233}U$ started up in 1996 near Kalpakkam. The $^{233}U$ was recovered from $ThO_2$ fuel irradiated in another reactor. The Kamini reactor was built adjacent to the 40 MWt fast breeder test reactor, in which the $ThO_2$ is irradiated.

Current research and development is being carried out on several concepts for advanced reactors including: high temperature gas-cooled reactor (HTGR); molten salt reactor (MSR); Candu-type reactor; advanced heavy water reactor (AHWR); and fast breeder reactor (FBR).

In India, during mid-2010 a pre-licensing safety appraisal of the planned experimental thorium-fuelled 300 MW(e) AHWR had been completed by the Atomic Energy Regulatory Board. The site-selection process started in 2011 and the reactor is expected to become operational by 2020. However, full commercialisation of the AHWR is not expected before 2030.

In January 2011, the China Academy of Sciences launched a research and development programme on a liquid fluoride thorium reactor, known at the academy as the thorium-breeding molten salt reactor (Th-MSR or TMSR).

Despite these tests using thorium as reactor fuel, it has yet to be fully commercialised in a modern power reactor. As a result of the low demand for thorium, it has never been a primary exploration target. Its common association with uranium and/or REE has the consequence that thorium resources have been identified as a spin-off of exploration activities aimed at those commodities. In current market conditions, primary production of thorium is not economically viable.

## Table 1.17. Identified[1] thorium resources

| Region | Country | Total thorium resources, t Th (*in situ*) |
|---|---|---|
| Europe | Turkey* | 744 000-880 000 |
| | Norway | 320 000 |
| | Greenland (Denmark) | 86 000-93 000 |
| | Finland* | 60 000 |
| | Russian Federation, European part | 55 000 |
| | Sweden | 50 000 |
| | France | 1 000 |
| | Total | 1 316 000-1 459 000 |
| Americas | Brazil* | 606 000 – 1 300 000 |
| | United States | 434 000 |
| | Venezuela* | 300 000 |
| | Canada | 172 000 |
| | Peru | 20 000 |
| | Uruguay* | 3 000 |
| | Argentina | 1 300 |
| | Total | 1 536 300-2 230 300 |
| Africa | Egypt* | 380 000 |
| | South Africa | 148 000 |
| | Morocco* | 30 000 |
| | Nigeria* | 29 000 |
| | Madagascar* | 22 000 |
| | Angola* | 10 000-20 000 |
| | Mozambique | 10 000 |
| | Malawi* | 9 000 |
| | Kenya* | 8 000 |
| | DRC* | 2 500 |
| | Others* | 1 000 |
| | Total | 649 500-659 500 |
| Asia | CIS* (excluding Russian Federation, European part) | 1 500 000 |
| | - Kazakhstan, estimated | >50 000 |
| | - Russian Federation, Asian part, estimated | >100 000 |
| | - Uzbekistan, estimated | 5 000-10 000 |
| | - others | Unknown |
| | India | 846 500 |
| | China, estimated | >100 000 (and 9 000* Chinese Taipei) |
| | Iran* | 30 000 |
| | Malaysia | 18 000 |
| | Bangladesh* estimated | 17 000 |
| | Thailand* estimated | 10 000 |
| | Vietnam* estimated | 5 000-10 000 |
| | Korea, Rep. of* | 4 500-7 500 |
| | Sri Lanka* estimated | 4 000 |
| | Total | 2 708 000-2 721 000 |
| Australia | | 521 000 |
| | | |
| World total | | 6 730 000-7 590 800 |

1. Currently there is no international or standard classification for thorium resources and identified Th resources do not have the same meaning in terms of classification as identified U resources.

* Data not updated.

Extraction of thorium as a by-product of REE from monazite seems to be the most feasible source of thorium production at present. The recovery of monazite from crushed ore is possible by physical separation techniques involving gravity and electrostatic methods. The monazite is then dissolved in either sodium hydroxide or sulphuric acid. The resulting solutions contain REE, uranium and thorium. This is followed by a multistage process using organic phases to achieve separation with a final product of $ThO_2$. Brazil and India are the only two countries currently producing thorium from monazite. The Brazilian production is used to make mantles for gas lanterns and the Indian production for their nuclear programme.

The by-product nature of the occurrence of thorium and a lack of economic interest has meant that thorium resources have seldom, if ever, been accurately defined. Information on thorium resources was published in Red Books between 1965 and 1981, typically using the same terminology as for uranium resources at that time (e.g. reasonably assured resources and estimated additional resources I and II, which are now termed inferred and prognosticated resources, respectively). No further information was published until 2003 when a global estimate of thorium resources of 4.5 million tTh was presented in the 2003 Red Book. A more comprehensive report was presented in the 2007 Red Book where resource estimates were given by deposit type and by countries and this was updated in the 2009 edition. Worldwide thorium resources by major deposit types are estimated to total about 6.08 million tTh including undiscovered resources (Table 1.16).

The IAEA, in co-operation with Indian Rare Earths Limited organised an international Technical Meeting on "World Thorium Resources" on 17-21 October 2011, in Thiruvananthapuram, India. The meeting was supported by the Atomic Minerals Directorate for Exploration and Research, Hyderabad, and the University of Kerala, Thiruvananthapuram. Over 50 experts from 20 IAEA member states including India participated in the meeting. Based on the inputs given in the meeting and other details available in other open sources, total thorium resources, regardless of resource category or cost category, have been updated for 16 of the 35 countries listed (Table 1.17). The world total Th resources reported in Table 1.17 ranges from 6 730 000 to 7 590 800 tTh which is approximately 9 to 24% higher compared to the total Th reported by deposit type in Table 1.16.

### Uranium exploration

Only four countries, China, France, Japan and the Russian Federation reported non-domestic exploration and development expenditures since 2008 (Table 1.18). The Russian Federation reported exploration expenditures in 2008 and 2009 as 65% and 61%, respectively of total expenditures. China reported the development portion of total expenditures as 97% and 91% in 2009 and 2010, respectively. This is expected to continue into 2011 with 86% of total expenditures listed as development related. France and Japan reported only exploration expenditures. Total expenditures jumped upwards in 2007 and continued to increase through 2009, despite generally declining prices since 2007. Total expenditures dropped sharply in 2010 and are expected to decline even further in 2011 to an amount similar to 2006. For individual countries, expenditures are estimated to be highest in the Russian Federation in 2010, amounting to over USD 114 million. However, the data are incomplete. Canada reported the highest expenditures (e.g. 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.

Despite a slowdown in the industry in the past few 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 (Table 1.19). Expenditures in Australia, Kazakhstan, Mongolia and the United States somewhat mirrored the fluctuation in the spot and long-term average uranium prices, with the highest domestic expenditures in 2008 followed by a decline in 2009 and a recovery to higher levels of expenditure in 2010. In comparison, several countries, including Argentina, Botswana, Chile, China, Finland, India, Iran, Jordan, the Russian Federation, and Spain, have shown a steady increase in exploration expenditures from 2008 to the present indicating a strong commitment to exploration and development of uranium resources. In contrast, Ukraine and the Czech and Slovak Republics reported a decline in domestic expenditures, with this trend expected to continue in the near future. Niger reported a large increase in expenditures from 2009 to 2010 but in 2011 they are expected to return to amounts closer to that reported in 2009. Increased 2010 expenditures can be attributed to the development of the Azelik and Imouraren mines. Brazil reported exploration expenditures for 2010 for the first time since 2004, while the government of Poland reported figures for the first time.

The declining uranium price slowed down many exploration and mine development projects in the short term, particularly in the junior uranium mining sector. However, many major uranium companies made concerted efforts to secure uranium deposits suitable for projected future supply requirements, pushing exploration and development expenditures to an all-time reported high of USD 2.07 billion in 2010 (Table 1.19). A notable increase in exploration in Africa and South America occurred during this time frame primarily due to a change in focus to other deposit models. That is, while unconformity-type deposits with their high grades are still the most desired target for exploration companies, there has been a marked trend in the past few years towards targeting lower-grade, higher tonnage deposits and diversification to distribute risks associated with mining of only one deposit style (i.e. unconformity-type). With this change in focus in uranium deposit model types, the distribution of uranium exploration activities geographically has become more diverse, with a particular emphasis on the most economical of the alternative models to the high-grade unconformity-type, namely surficial (i.e. calcrete) and sandstone-type deposits. Exploration efforts on the later type of deposits have been particularly important in Africa, with total reported domestic exploration and development expenditures of about USD 515 million for 2010. Figure 1.4 depicts trends in domestic and non-domestic uranium exploration and development expenditures from 1998 to 2011.

The delay in production from Cigar Lake also influenced some exploration activities as companies sought alternative deposits to fill the potential supply gap if attempts to seal the second breach at Cigar Lake mine were unsuccessful. The events also made the industry more aware of the potential for higher risks with the development of some of the deeper and more technologically challenging high-grade uranium deposits in the Athabasca basin. This in turn contributed to the diversification of exploration efforts to target deposit models other than the classical high-grade unconformity-type deposit.

For 2008 to 2010, of the countries that reported exploration and development expenditures separately, Canada, Kazakhstan and Namibia reported more exploration than development expenditures (59-75%, 54-95% and 59-82% of total exploration and development expenditures, respectively). In contrast, Niger, the Russian Federation, South Africa and the United States reported higher percentages of development expenditures (52-68%, 73-79%, 68-84%, and 76-83%, respectively). Finland reported expenditures separately in 2010 only, with exploration accounting for 95% of the total. Exploration expenditures in Iran were 67% of the reported total in 2008 but the proportion of development expenditures increased in 2009 and 2010 to 58% and 56% of the total, respectively. Expected exploration expenditures will again predominate in 2011 at about 57%. For other countries, expenditures in 2011 are expected to follow a similar trend to the previous few years with Canada, Namibia and Kazakhstan expecting a higher percentage of exploration expenditures (75%, 53% and 85%, respectively). In South Africa, 2011 exploration expenditures are projected to be 60% of total expenditures.

Based on the information provided in national reports, 16 countries reported exploration and development drilling activities for this edition. In terms of drilling, the majority of countries reported an increase in total m/yr drilled from 2008-2010. However, decreased efforts during this period are noted for Canada, Mongolia, Namibia, Slovak Republic, Ukraine, the United States and Indonesia, with the latter expecting a modest increase for 2011. In the United States, although total metres drilled have been declining, the proportion of development drilling has been steadily increasing. Kazakhstan is expecting a slightly lower total drilling length in 2011 but also expects an increase in the amount of development drilling. For the countries reporting in this edition, total drilling in 2008 amounted to 4 456 898 m (3 315 570 m exploration; 1 141 328 m development), 4 006 202 m (2 603 001 m exploration; 1 403 201 m development) in 2009 and 4 928 945 m (3 253 442 m exploration; 1 675 503 m development) in 2010. Development totals exclude some of the activities being undertaken by the Russian Federation as the government reports the number of development holes but not the actual length drilled.

**Table 1.18. Non-domestic uranium exploration and development expenditures**

(USD thousands in year of expenditures)

| Country | Pre-2004 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|---|---|---|
| Australia | NA | 1 571 | 8 855 | 4 580 | NA | NA | NA | NA | NA |
| Belgium | 4 500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Canada | 27 916 | 9 559 | 53 968p | 124 546p | 139 655 | NA | NA | NA | NA |
| China | 0 | 0 | NA | NA | 160 000[1] | 220 000[1] | 193 020[2] | 94 610[2] | 94 190[2] |
| France | 753 694 | 59 701 | 127 500 | 85 000 | 53 985 | 87 092 | 77 356 | 61 652 | NA |
| Germany | 403 158 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Japan | 418 331 | NA | NA | NA | 1 570[2] | 3 810[2] | 4 779[2] | 3 020[2] | 2 976[2] |
| Korea, Republic of | 24 049 | NA | NA | NA | NA | NA | NA | NA | NA |
| Russian Federation | NA | NA | NA | NA | NA | 49 724 | 95 613 | 114 379* | 115 321* |
| Spain | 20 400 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Switzerland | 29 657 | 3 | 0 | 3 | 16 | 0 | 0 | 0 | 0 |
| United Kingdom | 61 263 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| United States | 260 598 | NA | NA | NA | NA | NA | NA | NA | NA |
| Total | 2 003 566 | 70 834 | 190 323 | 214 129 | 355 226 | 360 625 | 370 769 | 273 662 | 212 487 |

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.

p = Provisional data.

1. Government development expenditures only.

2. Government expenditures only.

* Secretariat estimate.

## Table 1.19. Industry and government uranium exploration expenditures – domestic in countries listed

(USD thousands in year of expenditures)

| Country | Pre-2004 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|---|---|---|
| Argentina | 51 914 | 701 | 966 | 649 | 439 | 7 153 | 6 854 | 12 222 | 15 353 |
| Australia | 508 949 | 9 971 | 31 366 | 61 603 | 149 917 | 211 612 | 144 605 | 166 084 | 192 698 |
| 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* | 825 | NA | NA | NA | NA | 377 | 3 727 | 5 421 | 7 273 |
| Brazil | 186 128 | 449 | 0 | 0 | 0 | 0 | 0 | 223 | 237 |
| Cameroon | 1 282 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Canada | 1 288 477 | 78 676 | 184 921 | 316 364 | 532 710 | 514 751 | 457 936 | 585 106 | 511 000 |
| Central African Rep. | 21 800 | NA | NA | NA | NA | NA | NA | NA | NA |
| Chile | 6 896 | 133 | 84 | 100 | 113 | 480 | 540 | 1 272 | 1 067 |
| China | 25 000 | 9 500 | 13 500 | 28 000 | 38 000 | 44 000 | 55 000 | 77 000 | 77 000 |
| Colombia | 19 946 | 0 | 0 | 0 | 6 000 | 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] | 314 076 | 23 | 53 | 132 | 33 | 373 | 114 | 5 | 5 |
| Denmark | 4 140 | 0 | 0 | NA | NA | NA | NA | NA | NA |
| Ecuador | 1 945 | NA | NA | NA | NA | NA | NA | NA | NA |
| Egypt | 108 807 | 2 589 | 1 730 | 1 736 | 1 761 | 2 378 | NA | NA | NA |
| Ethiopia | NA | NA | NA | NA | NA | 22 | NA | NA | 15 |
| Finland | 13 984 | 210 | 803 | 1 798 | 1 511 | 2 449 | 506 | 2 367 | NA |
| France | 907 240 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gabon | 102 433 | 0 | 0 | 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 |
| Guatemala | 610 | NA | NA | NA | NA | NA | NA | NA | NA |
| Hungary | 3 700 | 0 | 0 | NA | 112 | 239 | NA | NA | NA |
| India | 315 228 | 14 333 | 16 588 | 16 422 | 19 793 | 25 093 | 39 905 | 55 778 | 55 616 |
| Indonesia | 15 878 | 31 | NA | 120 | 122 | 74 | 266 | 327 | 877 |
| Iran, Islamic Rep. of | 9 731 | 3 751 | 3 723 | 4 826 | 3 930 | 8 047 | 23 084 | 32 165 | 77 384 |
| Ireland | 6 200 | NA | NA | NA | NA | NA | NA | NA | NA |
| Italy | 75 060 | NA | NA | NA | NA | NA | NA | NA | NA |
| Jamaica | 30 | NA | NA | NA | NA | NA | NA | NA | NA |
| Japan | 19 697 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jordan | 920 | 0 | 0 | 0 | 0 | 419 | 5 166 | 5 731 | 5 370 |
| Kazakhstan | 47 248 | 723 | 1 169 | 8 500 | 34 318 | 78 155 | 59 740 | 57 584 | 73 376 |
| Korea, Republic of | 17 886 | 0 | 0 | 0 | 0 | 0 | NA | NA | NA |
| Lesotho | 21 | NA | NA | NA | NA | NA | NA | NA | NA |
| Madagascar | 5 293 | NA | NA | NA | NA | NA | NA | NA | NA |

See notes on page 42.

**Table 1.19. Industry and government uranium exploration expenditures – domestic in countries listed** (*continued*)

(USD thousands in year of expenditures)

| Country | Pre-2004 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|---|---|---|
| Malaysia | 10 478 | NA | NA | NA | NA | NA | NA | NA | NA |
| Mali | 58 693 | NA | NA | NA | NA | NA | NA | NA | NA |
| Mexico[(b)] | 30 306 | NA | NA | NA | NA | 50 | 100 | 150 | 500 |
| Mongolia | 8 153 | NA | NA | 12 527 | 26 138 | 29 156 | 11 332 | 18 284 | NA |
| Morocco | 2 752 | NA | NA | NA | NA | NA | NA | NA | NA |
| Namibia | 25 741 | 1 747 | 2 000* | 2 000* | 8 000* | 46 560* | 44 911* | 32 984* | 39 121* |
| Niger | 216 121 | 4 222 | 6 400* | 12 453 | 152 984 | 207 173 | 306 828 | 458 000 | 319 760 |
| Nigeria | 6 950 | NA | NA | NA | NA | NA | NA | NA | NA |
| Norway | 3 180 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 0 |
| Paraguay | 26 360 | NA | NA | NA | NA | NA | NA | NA | NA |
| Peru | 4 776 | 0 | 0 | NA | NA | NA | NA | NA | NA |
| Philippines | 3 462 | NA | NA | NA | NA | NA | NA | NA | NA |
| Poland | NA | NA | NA | NA | NA | 0 | 0 | 90 | 20 |
| Portugal | 17 637 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Romania | 10 060 | NA | NA | NA | NA | NA | NA | NA | NA |
| Russian Federation | 94 600 | 10 597 | 24 946 | 33 496 | 64 218 | 221 783 | 233 998 | 383 154 | 436 567 |
| Rwanda | 1 505 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Slovak Republic | NA | NA | NA | NA | NA | 7 465 | 7 454 | 5 302 | 3 811 |
| Slovenia[(d)] | 1 581 | NA | NA | 0 | 0 | 0 | NA | NA | NA |
| Somalia | 10 000 | NA | NA | NA | NA | NA | NA | NA | NA |
| South Africa | 140 919 | 886 | 1 593 | 24 698 | 14 972 | 11 386 | 14 552 | 18 761 | 5 638 |
| Spain | 140 455 | 0 | NA | 427 | 3 887 | 4 552 | 3 354 | 10 223 | 14 096 |
| Sri Lanka | 43 | NA | NA | NA | NA | NA | NA | NA | NA |
| Sudan | 200 | 0 | 0 | 0 | 0 | 0 | 0 0 | 0 | 0 |
| Sweden | 47 900 | 0 | 0 | NA | NA | NA | NA | NA | NA |
| Switzerland | 3 359 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Syria | 1 151 | NA | NA | NA | NA | NA | NA | NA | NA |
| Thailand | 11 299 | NA | NA | NA | NA | NA | NA | NA | NA |
| Turkey | 21 981 | 7 | 23 | 56 | 50 | 74 | 66 | 91 | 195 |
| Ukraine | 15 654 | 4 259 | 4 801 | 6 168 | 6 560 | 7 548 | 3 362 | 3 207 | 2 963 |
| United Kingdom | 3 815 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| United States[(e)] | 2 538 413 | 59 000 | 77 800 | 155 300 | 245 700 | 246 400 | 139 300 | 144 000 | NA |
| Uruguay | 231 | NA | NA | NA | NA | NA | NA | NA | NA |
| USSR | 3 692 350 | NA | NA | NA | NA | NA | NA | NA | NA |
| Uzbekistan | 139 580 | 16 995 | 21 230* | 21 230* | 21 230* | 23 798 | 25 652 | NA | NA |
| Vietnam | 3 684 | 45 | NA | NA | NA | NA | NA | NA | NA |
| Zambia | 25 | NA | NA | NA | NA | NA | NA | NA | NA |
| Zimbabwe | 6 902 | NA | NA | NA | NA | NA | NA | NA | NA |
| Total | 13 415 705 | 218 848 | 393 696 | 708 605 | 1 332 497 | 1 701 568 | 1 588 353 | 2 075 531 | 1 839 943 |

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).

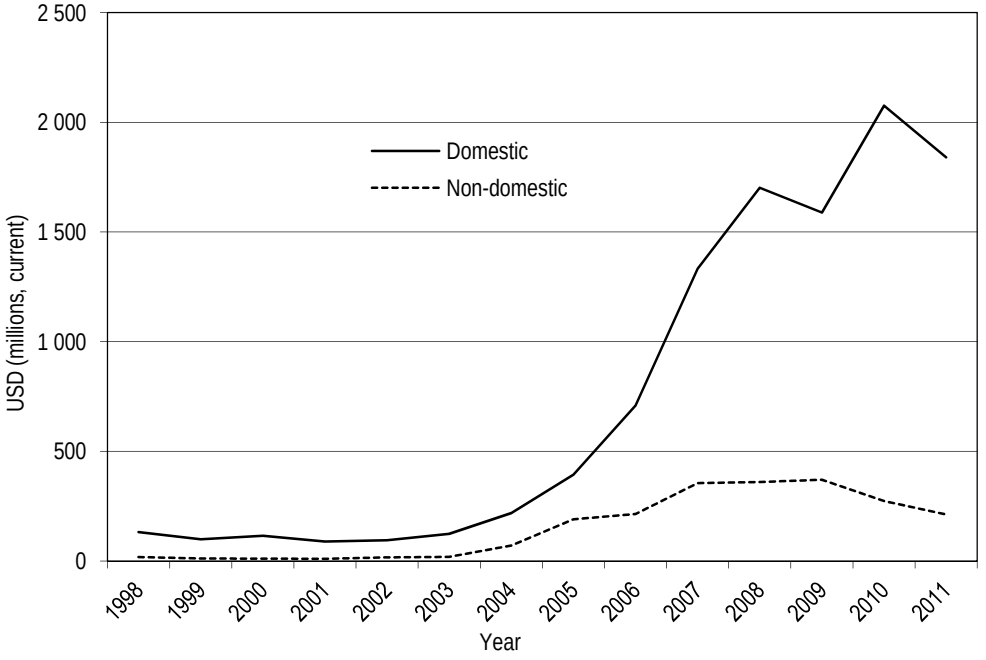
(b) Government exploration expenditures only.

(c) Includes USD 1 905 920, spent in GDR between 1946 and 1990.

(d) Includes expenditures in other parts of the former Yugoslavia.

(e) Includes reclamation and restoration expenditures from 2004 to 2010. Reclamation expenditures amounted to USD 49.1 million, 62.4 million and 44.7 million in 2008, 2009 and 2010, respectively.

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




### *Current activities and recent developments*

*North America*

In **Canada**, overall uranium exploration and development expenditures amounted to USD 585 million in 2010 and are expected to decrease to USD 511 million in 2011. However, exploration expenditures, considered separately, are expected to increase from USD 355 million in 2010 to USD 387 million in 2011. Less than one-third of overall exploration and development expenditures in 2010 can be attributed to advanced underground exploration, deposit appraisal activities, and care and maintenance expenditures associated with projects awaiting production approvals.

Exploration efforts have continued to focus on areas favourable for the occurrence of deposits associated with Proterozoic unconformities in the Athabasca basin of Saskatchewan, and to a lesser extent, similar geologic settings in the Thelon basin of Nunavut. In particular, a proposal by AREVA to develop the Kiggavik and Sissons deposits in Nunavut is currently undergoing an environmental assessment as well as a feasibility study.

Uranium exploration has also remained active in the Otish Mountains of Québec where Strateco Resources Inc. has applied for a licence to conduct underground exploration on the Matoush deposit. Mineralisation at Matoush occurs in mafic dykes associated with Proterozoic sandstones.

A three-year moratorium in Labrador that was enacted in 2008 by the Nunatsiavut Assembly, the legislative branch of Labrador's regional aboriginal government, was lifted in December 2011. There are two main uranium projects in Labrador, the Michelin and Jacques Lake deposits. Paladin Energy, which owns the Michelin project, plans to restart exploration in mid-2012, with drilling foreseen in the third quarter.

Recent exploration activity has led to new uranium discoveries in the Athabasca basin in Saskatchewan. Significant, high-grade uranium mineralisation discoveries in the Athabasca basin include: Centennial (UEM Inc.), Shea Creek (AREVA Resources Canada Inc.), Wheeler River (Denison Mines Inc.), Midwest A (AREVA Resources Canada Inc.) and

Roughrider (Rio Tinto). The Roughrider deposit was discovered by Hathor Exploration and in 2011 both Cameco and Rio Tinto pursued a takeover of this Canadian junior. Anglo-Australian miner Rio Tinto succeeded in its USD 654 million takeover bid.

There has been a notable decrease in total (exploration and development) drilling from 821 200 m in 2008 to 447 300 m in 2009 and 373 900 m in 2010. The decline initially started gradually in 2008 after the record year of drilling reported in 2007. Approximately 85-90% of the total drilling in Canada is attributed to exploration efforts with over 70% of the combined exploration and development drilling in 2010 taking place in Saskatchewan.

A renewed interest in nuclear power has resulted in renewed exploration activities in **Mexico** and a corresponding increase in expenditures of USD 50 000 in 2008 to USD 150 000 in 2010, with estimated expenditures of USD 500 000 in 2011. Exploration activities, by law conducted only by the Mexican Geological Survey, have been focused on selecting prospective areas through examination of the available technical information and field visits to the most favourable areas (i.e. Chihuahua, Nuevo León, Sonora and Oaxaca y Puebla).

In the **United States**, private industry expenditures for exploration and mine development activities in 2009 amounted to USD 139.3 million, a 43% decrease from 2008 expenditures of USD 246.4 million. In 2010, expenditures increased slightly by 3% to USD 144 million.

Expenditures for uranium surface drilling during 2009 were USD 35.4 million, down USD 46.5 million from 2008 expenditures of USD 81.9 million. This 67% decrease halted an upward trend from 2004 to 2008, during which there was an overall 673% increase in expenditures. The upward trend was re-established in 2010, with USD 44.6 million in expenditures, a 21% increase from 2009. Development drilling has increased from 777 547 m drilled in 2008 to 1 049 735 m in 2010. Exploration drilling in 2008 amounted to 775 109 m and decreased substantially to 320 346 m in 2009 and increased somewhat in 2010 to 445 009 m.

The number of holes and total meters drilled decreased from 2008 to 2009, from 9 355 and 1 552 656 m to 5 679 and 1 140 565 m, respectively. In 2010, the number of holes and total meters drilled increased to 7 209 and 1 495 000 m. The increases in 2010 brought total meters drilled to within 96% of the 2008 figure. Regardless of these recent fluctuations, the number of holes drilled more than tripled between 2004 and 2010, from 2 185 to 7 209, and the total meters drilled quadrupled, from 381 to 1 495 m.

Exploration continued in the main established uranium districts in the US including the Tertiary basins of Wyoming and Nebraska; the Colorado Plateau; Texas and New Mexico. There is a strong focus on *in situ* leach (ISL, sometimes referred to as *in situ* recovery, or ISR) projects because these generally take less time to develop and license, particularly in terms of regulatory aspects. Other projects will require conventional mills of which there is only one currently in operation, the White Mesa mill in Utah. The White Mesa mill presently processes "alternate feed material" (uranium-contaminated soils and other materials) while the Shootaring Canyon mill, also in Utah has a reclamation licence. Converting a reclamation licence to an operating licence is a lengthy process that might take years.

*Central and South America*

**Argentina** reported a significant increase in domestic exploration and development expenditures over the past few years. 2010 expenditures amounted to USD 12.2 million with a forecast of USD 15.4 million in 2011, which is over twice the amount reported in 2008 (USD 7.1 million). It is worth noting that exploration and development expenditures and drilling totals, as reported by the government, may not reflect all activity within the private sector as there is no requirement for private industry to report these items. From 2009 to April 2011, the number of exploration permit areas studied by the National

Atomic Energy Commission (CNEA) increased from 50 to 76 as a consequence of the reactivation of the nuclear programme and uranium mining activity by the government of Argentina. In the past five years, there has also been an increase in exploration activity by the private sector in Argentina. In particular, Calypso, UrAmerica and Blue Sky Uranium have been actively exploring in the country and more recently within partnerships with major companies such as Cameco and AREVA.

Calypso, through its subsidiaries Energía Mineral and Pampa Amarilla has over 5 000 $km^2$ of prospective uranium properties located in the provinces of Chubut, Mendoza and Neuquén. In September 2010, Calypso signed an Option Agreement with Cameco for a joint venture on the majority of Calypso projects in Argentina through Energía Mineral. Projects covered in the joint venture include: the Sierra Pintada uranium district in Mendoza, where the country's largest uranium deposit and historically producing mine is located; the Neuquen Basin projects, including Ranquil-Co in Mendoza, and the Campesino Norte and Central Block projects in Neuquen, with Central Block the first potential ISR uranium project being explored in Argentina; and projects in Chubut concentrated in the uraniferous San Jorge Basin, where the Cerro Solo uranium deposit is located.

In 2010, Calypso created Pampa Amarilla to focus on the Huemul Project which was not included in the joint venture agreement with Cameco. Pampa Amarilla projects in Argentina include past uranium producers Huemul, Arroyo Seco and Agua Botada in Mendoza Province.

Blue Sky Uranium Corp has more than 5 000 $km^2$ of tenements and recently entered into a MoU with AREVA to jointly explore for uranium deposits. The company has three projects in the Rio Negro province: the Anit, Santa Barbara and Ivana projects as well as the Sierra Colonia and Tierras Colorados projects in the Chubut province.

Blue Sky has completed more than 20 000 $km^2$ of radiometric and magnetic surveys, the first survey of its kind ever conducted in the region. This has resulted in the discovery of several large new mineralised systems that are associated with the radiometric anomalies. Surface follow-up by Blue Sky of "Santa Barbara" and "ANIT" systems has discovered abundant uranium-bearing petrified wood and visible yellow coloured uranium mineralisation on and near surface.

UrAmerica, a UK-based junior uranium exploration company, owns concessions in Argentina covering 229 000 ha in the San Jorge Basin, Chubut province and is currently conducting exploration drilling. A portion of the licence area surrounds the National Atomic Energy Commission CNEA's Cerro Solo deposit. UrAmerica has entered into a strategic alliance with Cameco to advance exploration in the Chubut province.

One of the main uranium exploration projects in Argentina is the Cerro Solo deposit in the Pichiñan district. From 2007 to April 2011 a total of 28 431 m had been drilled by CNEA.

In the east slope of Velasco Hill, La Rioja province, detailed exploration is being carried out on surface and a drilling campaign was initiated in 2009 in order to study uranium mineralisation which occurs at the contact between granite and metamorphic rocks.

Other areas considered to have potential for uranium mineralisation were selected for more detailed geological studies. These include an examination of the potential of some ISL-amenable sandstone occurrences and favourability studies in vein and episyenite type granitic environments.

The **Bolivian** government has not reported any exploration expenditures since 1986 and there is little indication that any significant exploration activities are currently being carried out. There is limited indication that there may be some renewed interest with a government announcement in 2010 that a preliminary study for a programme of uranium

exploration in the southern department of Potosí would be initiated. The programme is expected to be financed by the Potosí departmental government and carried out by the National Mineral Geological and Technical Service (Sergeotecmin). There has also been some speculation that production may resume at the volcanic associated Cotaje deposit if the remaining uranium resources are confirmed.

In **Brazil**, USD 0.22 million was reportedly spent on domestic exploration and development activities in 2010 and a similar level of expenditure is expected in 2011. Prior expenditures of this type have not been reported since 2004 (USD 0.44 million). Limited exploration work was completed in 2009 and 2010 as work scheduled for the Cachoeira deposit was suspended following interruptions in the ramp-up of construction activities due to regulatory requirements. Planned exploration in the Rio Cristalino area was also postponed. However, geological mapping of new targets in the north area of the Caetité province has begun.

In **Colombia**, exploration activities have focused on sedimentary-hosted uranium. A total area of 267 $km^2$ is being currently explored for uranium and 14 licences were issued (Muriel, 2010). Active companies include U3O8 Corp. and URACOL S.A with exploration activities focusing on the Caldas, Santandar, North Santander and Cundinamarca regions. There are others conducting exploration in these regions but for which very limited information is available.

Of main interest is the work being carried out by U3O8 Corp., a Canadian uranium exploration company that has been conducting exploration at the Berlin Project in Caldas Province. The company reported an exploration budget of USD 7 million in 2011 and in January 2012 announced a NI 43-101 resource of 1.5 million lbs indicated (577 tU), at 0.11% $U_3O_8$ (0.09% U) and 19.9 million lbs inferred (7 655 tU), at 0.11% $U_3O_8$ (0.09% U).

**Chile** reported a significant increase in domestic exploration expenditures, amounting to USD 480 000 in 2008 and USD 1.27 million in 2010. Projected expenditures for 2011 are USD 1.07 million. The exploration focus appears to be in multi-commodity projects (i.e. Cu, Au, Mo, Co, U) in hematite breccia type complexes and to a lesser extent Cu-porphyry systems (i.e. intrusive type).

Hot Chili Limited, an ASX-listed Australian company, operates three uranium projects in Chile: Productora, Los Mantos and Chile Norte. The most advanced of these projects is Productora where uranium occurs as part of a multi-commodity target within a hematite breccia type complex. Approximately 2 400 m of diamond drilling and 16 000 m of RC drilling was completed in 2010. In 2011, JORC code resources of copper, molybdenum and gold were reported but no equivalent classification of uranium resources has been made. The company's other projects, Los Mantos and Chile Norte are at a much earlier stage of exploration.

In 2008, Comisión Chilena de Energía Nuclear (CCHEN) signed a broad scope co-operation agreement with the National Copper Corporation (CODELCO Norte) for geological and metallurgical investigation of natural atomic material occurrences and in 2009 a second agreement to carry out a programme of activities aimed at extracting uranium and molybdenum.

There has been some uranium exploration in **Guyana** where unconformity-type and volcanic-associated deposits are being targeted. Canadian U3O8 Corp. obtained uranium exploration rights from the Guyana Geology and Mines Commission (GGMC) for two areas in western Guyana: the Roraima basin and the Kurupung batholith. Exploration focused initially on the Roraima basin, however, recently reported NI 43-101 uranium resources are from the Kurupung Batholith of 5.8 Mlb at an average grade of 0.10% $U_3O_8$ (2 200 tU at 0.084% U), indicated and 1.3 Mlb at an average grade of 0.09% $U_3O_8$ (500 at 0.076% U), inferred.

AZIMUTH Resources is an Australian-based junior explorer that has an ongoing uranium exploration project in the Amakura region of north-western Guyana. It is an early stage exploration project which was previously explored in the 1980s by COGEMA who had concluded that uranium mineralisation in Amakura was likely similar to Kurupung (where U3O8 Corp. currently conducts exploration).

Argus Metals Corp. is a Canadian-based mineral exploration company which holds the Kaituma east uranium-gold project in Guyana, reportedly a low-grade, large tonnage uranium target modelled on the Rössing mine and the Husab deposit in Namibia, as well as the Lago Real mine in Brazil. Historically, the Kaituma project has been explored by various companies including COGEMA and BHP. The company plans to execute a drill programme in early 2012 or as soon as it is technically and financially feasible.

The government of **Paraguay** did not report domestic exploration or development expenditures for 2010. However, there have been recent exploration activities in the country including the Yuty project in the Paraná basin that was originally held by Cue Resources. In 2012, a US based exploration company, Uranium Energy Corp. (UEC), acquired the rights to the project through a takeover agreement. A NI 43-101 compliant measured, indicated and inferred resource for the project was updated in 2011 to 9.98 Mt at 507 ppm $eU_3O_8$ for 11.1 Mlbs $eU_3O_8$ (4 300 tU). UEC also holds approximately 399 425 ha in the Coronel Oviedo region in central Paraguay, and 10 000 m of exploration drilling was expected to be undertaken in 2011.

UrAmerica is reportedly conducting exploration in Paraguay on three exploration permits, covering 229 205 ha, located approximately 300 km south-east of the capital city of Asunción. The three exploration permits lie within the departments of Guaira, Caazapá, and Itapua.

**Peru** does not report exploration and development expenditures and industry is not required to report this to the government. There are currently six active Canadian exploration companies involved in exploration activities: Vena Resources, Cameco, Southern Andes Energy Inc., Macusani Yellowcake, Fission Energy Corp. and Wealth Minerals Ltd.

As of November 2010, Vena Resources had spent more than USD 9.0 million exploring concessions which make up the mineral holdings of the Minergia joint venture (Vena/Cameco). Of this, the bulk of the funds were spent exploring the Macusani project area (Vena Resources, 2010). An *in situ* indicated resource estimate of 3 200 tU and an additional inferred tonnage estimate of 5 467 tU have been calculated for the five prospects which make up the Macusani project area.

Macusani Yellowcake was successful in confirming the previous drilling at the Corachapi project during 2010. Based on these drilling results Macusani was able to upgrade the resource into a NI 43-101 estimate with measured resources of 115 tU at 0.011% U, indicated resources of 1 808 tU at 0.016% U, and inferred resources of 730 tU at 0.019% U. Macusani also has reported NI 43-101 resources for its Colibri 2 and 3 projects with indicated resources of 2 077 tU at 0.022% U and inferred resources of 5 808 tU at 0.016% U.

A new IAEA initiative (2012-2013), within the technical co-operation project (TC) PER/2/016 "Evaluating the uraniferous potential in the magmatic environments in the eastern Andes region", is aimed at supporting uranium exploration in volcanic and intrusive granite environments in the Macusani Uranium District. The project plans to prioritise some areas with uranium mineralisation in granitic rocks for detailed exploration in a strategic alliance with the companies involved in uranium exploration.

In **Uruguay**, the government is developing a law that will give Administración Nacional de Combustibles, Alcoholes y Portland (ANCAP) facilities for uranium prospection, exploration and exploitation. ANCAP governs the state oil company which is

responsible for supervising energy initiatives. However, the entity has not announced any plans for uranium development.

The IAEA is supporting uranium exploration and development efforts in **Venezuela** through the TC project VEN 3/007 (2009-2011). The geological conditions and records of uranium exploration show that uranium mining may be possible although at present it is unknown whether there are adequate uranium reserves. The project involves co-ordination with relevant government institutions, formation of a team of trained professionals, enhancement of the existing laboratory infrastructure by the acquisition of equipment, collection and centralisation of existing uranium exploration data, review of existing anomalies and generation of new information through detailed exploration of known anomalies. This project is in line with the strategies and the priorities set out by the Venezuelan government in its Economic and Social Development Plan 2007-2013, which is to research and promote alternative energies.

*European Union*

In the **Czech Republic**, exploration and development expenditures have decreased dramatically from USD 373 000 in 2008 to USD 114 000 in 2009 and only negligible amounts of USD 5 000 are reported for 2010 and the same amount is forecasted for 2011.

**Greenland** does not report uranium exploration and development expenditures as currently uranium exploration and mining is not allowed under home state rule. However, the government does allow companies which have found and demarcated mineral resources containing radioactive elements to apply for a licence to prepare assessments of the environmental impact and social sustainability to better inform government. However, it should be noted that a licence to complete such assessments does not give rights to explore for or exploit radioactive elements.

A renewed interest in REE (rare earth element) deposits spurred Greenland Minerals and Energy Limited, an ASX-listed company, to acquire the Kvanefjeld deposit in 2007. Kvanefjeld is part of the Ilimaussaq complex, a peralkaline igneous complex which contains elevated concentrations of rare earth elements, uranium, and zinc. The REE, uranium and zinc resources were re-evaluated by Greenland Minerals and Energy and in 2011 a JORC compliant, indicated and inferred resource was announced consisting of 134 654 tU, 6.5 Mt heavy REE and Y at 1.07% and 1.36 Mt Zn at 0.22%.

Exploration and development expenditures in **Finland** have fluctuated in the past few years but there was a significant change and increase in expenditures from USD 506 000 in 2009 to USD 2.37 million in 2010.

A notable development in Finland was the acceptance by the parliament in March 2011 of a new Mining Act (superseding the 1965 Mining Act), with amendments to the Nuclear Act. This legislation entered into force on 1 July 2011. Among other changes, the new act extends the validity of a mineral exploration permit up to 15 years and increases land owner compensation with an annual mineral exploration payment of EUR 20/ha in the first four years that increases incrementally in following years.

Only minor field activities were carried out by companies in 2009. Namura Finland relinquished uranium exploration in Finland and cancelled all its licences and applications at the end of 2009. AREVA NC decided to sell its Finnish uranium exploration portfolio and a database to Vancouver-based Mawson Resources Ltd in April 2010 and became a significant Mawson shareholder (11%). Currently, Mawson Energi AB, the Swedish subsidiary of Mawson Resources Ltd, is the only active uranium exploration company in Finland. The Rompas Au-U prospect in northern Finland, discovered in 2008, is Mawson Energi's main target and is likely one of the main reasons for an increase in reported exploration expenditures in 2010.

The government of **Hungary** did not report any exploration or development expenditures. Exploration activities appear to be limited to activities conducted by

Wildhorse Energy in four uranium exploration project areas: Mecsek, Bátaszék, Dinnyeberki and Máriakéménd which are covered by seven exploration licences.

In 2009-2010, a total of five holes were drilled, logged and core samples were tested on non-mined portions of the Mecsek deposit. The Mecsek Hills project spans Wild Horse Energy's 42.9 $km^2$ Pécs and Mecsek-Öko's neighbouring 19.6 $km^2$ MML-E licence areas. MML-E is held by Hungarian state-owned entity Mecsek-Öko, which is an unconnected third party of the Wildhorse Group.

In 2009, the government of **Poland** decided to introduce nuclear energy and the possibility of mining uranium resources in Poland is being studied. Exploration expenditures of USD 90 000 in 2010 were reported for the first time and expected expenditures for 2011 are USD 20 000. There are no current (up-to-date) documented uranium deposits in Poland and no concessions for uranium granted. However, there are some perspective regions based on past work.

In the **Slovak Republic**, recent resource estimates are not yet included in the national resource totals. The exploration data are typically assessed by the Commission for Reserves Classification at the time that the company developing the resource makes a decision to mine the deposit. Exploration and development expenditures were steady in 2008 and 2009 at around USD 7.5 million each year but dropped to USD 5.3 million in 2010 and are expected to decrease further to USD 3.8 million in 2011.

Ludovika Energy Ltd (a subsidiary of Tournigan recently taken over by European Uranium Resources) is continuing exploration in six eastern prospecting areas. European Uranium Resources provided updated 43-101 compliant resources for their Kurishkova (Kosice 1) and Novoveska Huta projects in 2011. For Kurishkova, using a 0.05% U cut-off grade, the updated resources are 10 957 tU indicated and 4 871 tU inferred amounting to a total of 15 828 tU, which is 9 267 tU more than what is reported in the national resources. These resources may be included as part of the prognosticated resources in the national report.

The Novoveska Huta project contains 1 442 tU as measured and indicated resources and 4 889 tU as inferred resources at a cut-off grade of 0.06% U. The total measured, indicated and referred resources amounts to 6 331 tU, nearly twice the national resource totals.

**Spain** reported an increase in domestic expenditures from USD 3.35 million in 2009 to USD 10.22 million in 2010, with projected expenditures of USD 14.10 million in 2011. This reflects uranium exploration and development activities by Berkeley Resources and Enusa Industrias Avanzadas, S.A. (ENUSA). ENUSA is a publicly traded company that is 60% owned by Sociedad Estatal de Participaciones Industriales (SEPI) which reports to the Ministry of Finance and Public Administration, and 40% by the Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), which in turn belongs to the Ministry of Economy and Competitiveness.

Shortly after the Ministerial Cabinet approval of an agreement between Berkeley and ENUSA in April 2009, the mining domain feasibility study (MDFS) on state reserves in Salamanca province commenced on the Aguila, Alameda and Villar deposits. In addition to the MDFS, Berkeley has also been prospecting its permits and has increased its mineral resource inventory to a total of 32 000 tU.

The government of **Sweden** did not report exploration and development expenditures but a number of exploration programmes are ongoing in the country. Exploration companies active in the region include Mawson Resources of Canada that has reported a number of small deposits in the Hotagen district of central Sweden and elsewhere. The Hotagen district uranium deposits are located in the north-eastern portion of a geological province known as the Olden Window, which is an isolated area of Proterozoic basement exposed within younger late Precambrian-early Paleozoic sequences that form the

Caledonide mountain range that straddles the border of Sweden and Norway. Uranium mineralisation occurs as vein and breccia deposits developed within uranium rich granite. Mawson is also conducting exploration on the Duobblon project which is part of the acid volcanic-related uranium deposit type. Three near surface sandstone-hosted uranium prospects in central Sweden that Mawson is exploring are known as the Kapell project. Lastly, Mawson's Harrejokk project is comprised of uranium prospects which occur as mineralisation disseminated within a granitic syenite where Mawson reports that high uranium grades are common.

Canadian explorer Continental Precious Minerals has 72 mineral exploration licences throughout Sweden. The company has been focusing on their Viken licence in central Sweden, which contains the Lill-Juthatten deposit, a black shale deposit with elevated concentrations of uranium, nickel, molybdenum and vanadium.

In addition, ASX-listed Aura Energy is actively targeting aluminium shales where uranium can be recovered as a by-product. In August 2011, Aura reported an updated JORC compliant inferred resource for their Häggån Project of 242 714 tU at an average grade of 136 ppm U (0.0136% U) plus credits from co-products: molybdenum, vanadium, nickel and zinc. A scoping study has been completed and pre-feasibility planning is underway. Aura is also exploring for a similar style of mineralisation at their Kallsedet Project close to the Norwegian border. Additionally, Aura is following up a historical occurrence at the Virka Project, which was discovered by the Swedish Geological Survey (SGU) during the 1970s.

No domestic uranium activities have been carried out in **France** since 1999. During 2009 and 2010, AREVA and its subsidiaries have been active abroad, focusing on targets aimed at the discovery of exploitable resources in Australia, Canada, the Central African Republic, Finland, Gabon, Jordan, Kazakhstan, Mongolia, Namibia, Niger and South Africa. Total non-domestic exploration expenditures reported by the government decreased from USD 87.1 million in 2008 to USD 61.7 million in 2010. No development expenditures were reported.

*Europe (non EU)*

An **Armenian**-Russian joint venture CJ-SC "Armenian-Russian Mining Company" was established in April 2008 for geological exploration, mining and processing of uranium. The document "Geologic Exploration Activity for 2009-2010" aimed at the uranium ore exploration in the Republic of Armenia was developed and approved. According to this document, in the spring of 2009 field work related to uranium ore exploration was started near Lernadzor, in the province of Syunik and was ongoing as of mid-2011.

The **Russian Federation** reports increases in both non-domestic and domestic exploration and development expenditures. Non-domestic expenditures increased from USD 49.7 million in 2008 to USD 114 million in 2010 and are estimated to remain steady at USD 115 million in 2011 (values for 2010 and 2011 are Secretariat estimates). In 2009-2010, ARMZ through its joint ventures with Kazatomprom (Akbastau and Zarechnoye in Kazakhstan) performed exploration in areas three and four of the Budennovskoye and the South Zarechnoye deposits, respectively, which resulted in updated resource figures. In Namibia, SWA Uranium Mines, an ARMZ joint venture with VTB Capital Namibia (Pty) Ltd. and Arlan, performed exploration for calcrete-type uranium mineralisation. In Armenia, an Armenian-Russian Mining Co. joint venture performed uranium exploration in licensed areas.

Domestic expenditures rose from USD 221.8 million in 2008 to USD 383 million in 2010, with forecasted expenditures of USD 436.6 million in 2011. The increases were primarily by industry as government exploration expenditures have decreased somewhat over the past few years. In 2009-2010, the majority of uranium prospecting in the Russian Federation was in the Republics of Kalmykia and Buryatia, with the aim of identifying sandstone-type uranium mineralisation amenable for ISL. Prospecting in

Trans-Baikal district was aimed at the identification of uranium deposits suitable for underground mining. The executing organisations were the territorial subsidiaries of the Urangeo, as well as Sosnovgeo, Koltsovgeology and Chitageologorazvedka.

Exploration and development expenditures in **Turkey** increased from USD 74 000 in 2008 to USD 91 000 in 2010 while projected expenditures are expected to be around USD 1.9 million in 2011. Exploration for radioactive materials from 2009 to 2011 was focused on granite and acidic intrusive rocks and sedimentary rocks in the Kütahya-Uşak-Manisa region. In addition, prospecting of a 75 $km^2$ area was made on a licensed area owned by ETI MINE in 2010.

There has been an overall decline in exploration and development expenditures in **Ukraine** from USD 7.55 million in 2008 to USD 3.21 million in 2010 and a decline to USD 2.96 million is expected in 2011. Despite these decreases, prospecting studies for discovery of deposits of different geological/economic types continue. This included prospecting for vein-type uranium deposits in the Rozanovskaya and Khmelnisckoy areas and evaluation of the Zhdanovskoy, Sokolovskoy and other occurrences; exploration for unconformity-type uranium deposits in the Drukhovskoy area; and continued exploration for metasomatite-type deposits, beginning within the areas of currently operating mines.

*Africa*

The IAEA TC programme Regional Africa Project, RAF/3/007 "Strengthening Regional Capabilities for Uranium Mining, Milling and Regulation of Related Activities" is being carried out from 2009 to 2012. The objectives are to address common regional priority needs in uranium exploration, mining, milling and regulation using the available infrastructure and expertise, including regional designated centres and specialised teams. Regional workshops, training courses and technical meetings in **Egypt**, **Gabon**, **Ghana**, **Madagascar**, **Malawi**, **Morocco**, **Mozambique**, **Namibia**, **Tanzania** and **Uganda** (planned for 2012) provided opportunities for experts to receive updated information on technology, operations and environmental aspects of uranium production, leading to improved understanding of regulatory requirements for mining and processing.

A number of IAEA technical co-operation projects have provided ongoing support to develop uranium exploration and production capacities in **Algeria**. Most recently, TC project ALG 3/006 "Supporting Uranium Ore Processing and Purification of Concentrates" has improved workers' skills by placing some Algerians in educational, research or government institutions in countries with more experience in the field for a few weeks or months. Additionally, external expert missions to assess and assist local development facilities took place.

Although the government of **Botswana** has not reported exploration expenditures, a Secretariat estimate indicates that expenditures have increased to USD 5.4 million in 2010, with USD 7.3 million expected in 2011.

Exploration activities have focused on uranium occurrences in the Karoo Group, targeting similar deposits to those currently being mined by Paladin Energy in Malawi (i.e. the sandstone-type Kayelekera deposit). Surficial calcrete-type mineralisation is a secondary target.

A-Cap, an Australian based junior, has been the most active, reporting Botswana's first JORC compliant uranium resource in 2008 and working since to substantially increase these resources. In 2011, a JORC compliant indicated and inferred *in situ* resources totalling just over 100 000 tU at an average grade of 129 ppm U with an 85 ppm U cut-off grade (0.0085% U).

Impact Minerals, another Australian junior company, began work around A-Cap's areas in early 2008. Exploration activities in 2009 began with airborne radiometric surveys, followed by field reconnaissance, mapping and drilling, which led to the discovery of four

prospects in Karoo siltstones and sandstones. Additional work is needed before resource estimates can be reported.

Australia-based Bannerman Resources also held three prospecting licences for uranium exploration in the Foley and Sua Pan regions but is no longer active in Botswana.

**Ethiopia** reports government expenditures of USD 22 000 in 2008, no values are reported for 2009 and 2010 and expenditures for 2011 are expected to decline to USD 15 000.

In 2007, Aura Energy commenced exploration on the Reguibat Craton in northern **Mauritania**, a region with strong uranium radiometric anomalies recorded in airborne geophysical data. Aura has eight wholly owned permits and two permits in joint venture with Ghazal Minerals Limited.

Aura drilled 2 022 holes (9 100 m) at the Reguibat Project in 2011 and 392 holes in January 2010. Drilling confirmed the presence of widespread calcrete uranium mineralisation and in July 2011, Aura established JORC inferred resources of 19 300 tU at 280 ppm U (0.028% U), based on a cut-off grade of 85 ppm U (0.0085% U).

Aura's activities to date have focused on calcrete-type mineralisation; however, the area also has potential for vein style mineralisation, as demonstrated by Forte Energy in Bir En Nar. Aura has not yet tested for this style of mineralisation on their tenements.

The Bir En Nar project, 180 km south-east of Bir Moghrein, is the most advanced project in terms of historic drilling completed by AREVA. The uranium mineralisation is comprised of shallow, narrow vein, high-grade deposits. In July 2010, Forte Energy announced an initial estimate of indicated and inferred resources totalling 792 tU. The project is a 900 m long radioactive zone averaging 50-70 m in width that follows a tectonic structure in a NW-SE direction where uranium occurs in narrow, high-grade veins. Future work is being planned to include additional drilling and testing to further substantiate existing data and expand resources.

The Bakouma deposit in the **Central African Republic** was discovered in the 1960s. It is small, but has a relatively high uranium content of approximately 2 700 ppm U (0.27% U). In August 2008, AREVA and the Central African government signed an agreement which stipulates that the country will receive financial support of 18 billion CFA francs over five years. It also provides for the construction of infrastructure and employment of 900 people (primarily from the region) once the mine is operating at full capacity. Following a test phase, the Bakouma project was originally planned to gradually ramp up to full production by 2014-2015. However, AREVA suspended investment in the development of the Bakouma mine in 2011 due to current market conditions, even though inferred resources at Bakouma were raised from 32 224 tU to 36 475 tU.

The government of **Namibia** did not report exploration and development expenditures, but the Secretariat estimates that, on average, USD 41 million per year was spent between 2008 and 2011. This is a significant increase over expenditures of USD 2 million and USD 8 million in 2006 and 2007, respectively. Exploration expenditures alone are decreasing overall but this is balanced by an increase in development expenditures which is expected to be approximately 40% of the 2011 total. Two major types of deposits are currently being targeted; the intrusive type associated with alaskites, as at Rössing, and the surficial, calcrete type, as at Langer Heinrich and Trekkopje.

The state-owned Epangelo Mining Company, created by the Namibian government in 2008, was given exclusive rights to all future uranium exploration and mining licences in April 2011. Existing licences held by private companies are not affected.

In 2010, the Namibian and Russian governments signed a memorandum on co-operation for the exploration and development of Namibian uranium deposits. The

head of the Russian State Atomic Energy Corporation reportedly stated that the Russian Federation would be prepared to invest up to USD 1 billion in joint venture deposit development.

An updated mine plan to extend operations at the Rössing mine to 2023 was released in 2009. This calls for the development of two open-pit mines and associated support facilities. Exploration in 2009 and 2010 focused on the SJ and SK pit areas, the former to better understand the geology of the current open-pit and the latter to define the ore body and plan future mining. Additional areas of interest in the southern parts of the lease area also received attention.

The Rössing South deposit, located 6-7 km south of the Rössing mine, combined with Ida Dome in the Husab project, is under development by Perth-based Extract Resources. Intensive exploration activities led to a 33% increase in identified resources to 187 705 tU in 2011. Early that year, Extract announced that it was in discussions with Rio Tinto regarding the possible combination of the Husab deposit with the Rössing mine. About the same time, CGNPC Uranium Resources made a cash offer for a significant shareholding in the project that was later withdrawn, but negotiations are continuing.

The Ministry of Mines and Energy (MME) granted an exclusive exploration licence (EPL) to Langer Heinrich Uranium (Pty) Ltd in October 2006. Drilling for the Stage Four mineral resource update was completed in 2010 and a new resource estimate was announced in early 2011.

Trekkopje, acquired by UraMin Inc in 1999, is comprised of the Klein Trekkopje and Trekkopje ore bodies. UraMin was then taken over by AREVA to become AREVA Resources Southern Africa who, with subsidiary AREVA Resources Namibia, is now developing the mine. China Guangdong Nuclear Power Company (CGNPC) reportedly acquired 49% of the company with take-off rights of 35% of mine production.

In **Niger**, exploration and development expenditures increased from 2008 to 2010 with the highest expenditures of USD 458 million reported in 2010. Expenditures for 2011 are expected to drop to USD 319 million.

Since 2006, uranium exploration in Niger has been revitalised. A total of six new exploration permits were granted in that year and by 2011 uranium exploration activities were being carried out on 160 concessions by foreign companies.

A new company Société des Mines d'Azelik (SOMINA) was created in 2007 to mine the Azelik/Teguidda deposit. First production from this deposit was announced at the end of December 2010. Total RAR and inferred recoverable resources at the Azelik/Tequidda deposit amount to 15 900 tU.

The Imouraren mine (AREVA/Kepco/SOPAMIN) is scheduled to begin production in 2014. The mine has a forecasted production of 5 000 tU/yr for more than 35 years after an initial investment of more than EUR 1.2 billion (CFA 800 billion). It is expected to create nearly 1 400 direct jobs.

GoviEx holds exploration properties of 2 300 $km^2$ near the Arlit mine, as well as 2 000 $km^2$ near Agadez. This includes the Marianne/Marilyn deposits and MAD South area, which as of January 2011, have reported NI 43-101 compliant identified resources of nearly 40 000 tU.

URU Metals Limited (previously Niger Uranium Limited) reported a SAMREC compliant inferred resource of 1 654 tU. Exploration drilling of approximately 5 600 m was completed in 2010 and an additional 7 000 m as a follow-up of prospective areas was planned.

In December 2010, Paladin completed the takeover of NGM Resources Ltd (NGM), the owner of the local company, Indo Energy Ltd, which held concessions in the Agadez region. NGM Resources had announced an inferred mineral resource of 4 320 tU. Paladin

indicates that they have developed an exploration programme to identify higher grade uranium mineralisation in the Lower Carboniferous stratigraphies of the area.

**Egypt** last reported exploration expenditures in 2008. It has had ongoing support over the last several years in developing uranium exploration and production capacities through IAEA TC projects. Previous TC activities including EGY/3/014 "Uranium Resources Development in the Eastern Desert" and EGY/3/015 "Uranium Resources Development" have assisted in identifying the most prospective regions in the country. From 2006 to 2008, the Nuclear Materials Authority of Egypt concentrated on four prospects in the southern and northern parts of the Eastern Desert and south-west Sinai Peninsula. These activities included exploratory deep trenching and shallow drilling works supported by ground integrated geophysical and geochemical investigations to follow-up subsurface extensions of the tectonic structures and geologic formations hosting the uranium mineralisation. In more recent years (2009 to 2011), the exploration and development of uranium resources and production facilities has been supported by IAEA-TC project EGY/3/019. One of the objectives of this project was to expand on previous work with the aim of eventually having private industry assist the government by investing in identified advanced uranium projects.

At the Gabal Gatter project, uranium mineralisation occurs in the Precambrian calc-alkaline granites. Ore grades are between 0.19-0.24% U and inferred uranium resources of 2 000 tU have been previously reported. A smaller resource of about 100 tU inferred, has been reported for the Abu Zenima prospect which is hosted primarily by Carboniferous sandstones.

The upper Cretaceous phosphate deposits represent one of the more promising unconventional uranium resources in Egypt. Estimates of these phosphate ores reach about 700 million tU with uranium content ranging between 50-200 ppm (0.005-0.02% U) with an average value of 60 ppm U (0.006% U). No reliable estimate of the uranium resources in Egyptian phosphate ores has been made although a speculative resource estimate of 47 000 tU was reported by the government in 2008.

In the Abu Rushied-Seikat area uranium mineralisation associated with REE was discovered in the para-geneises and metamorphosed sandstones of Precambrian age, whereas in the Sella area structurally-controlled uranium mineralisation has been discovered along the shear structures cutting across the Precambrian granitic masses. In these two areas some subsurface exploratory works (deep trenching and shallow drilling) have been undertaken to follow-up potential subsurface extensions and configuration of the discovered surface mineralisation. So far no resource estimates have been made.

The Ministry of Mines of **Gabon** authorised AREVA to resume uranium prospecting activities in late 2006. After some initial success AREVA founded AREVA Gabon SA in 2008, a 100% owned subsidiary of AREVA with headquarters in Franceville. AREVA is currently leading uranium exploration activities in Gabon with four exploration permits (each 2 000 $km^2$) for Mopia (South of Franceville), Andjogo (North of Franceville), Lekabi and N'Goutou. At the same time, COMUF and AREVA Gabon signed an agreement authorising exploration work in the Francevillian mining concession held by the CEA and leased to COMUF (i.e. the Mounana district). AREVA stated that it invested EUR 3.3 million in prospecting activities in Gabon from 2006 to 2008.

In 2006, Motapa Diamonds Inc. (which was taken over by Lucara Diamond Corp) formed a joint venture with Pitchstone Exploration Ltd. and Cameco for a number of permits in the Franceville Basin of east-central Gabon. Cameco and Pitchstone funded exploration for uranium on Motapa's permits while the work was carried out by Motapa under the technical direction of Cameco and Pitchstone. The Proterozoic Franceville basin is geologically similar to the Athabasca basin in Canada and exploration focused on unconformity-type and sandstone-type mineralisation. However, only limited exploration on the leases occurred in 2008-2009 and in 2009 Pitchstone withdrew from

the project. There is no mention in public sources of Cameco's continued involvement or withdrawal from the project before the end of their four-year vesting period.

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, Zambia, Malawi, South Africa and Tanzania. These similarities have prompted some interest in exploration for potentially economic deposits of this type. UMC Energy PLC dominates the majority of prospective holdings through its 80% equity interest in URAMAD S.A, holder of a number of exploration permits including the Folakara deposit which has a historical resource estimate of 500 tU at 0.01% U. The deposit is hosted by the Triassic to Jurassic Isalo I and Isalo II formations of the Karoo Group. Exploration permits in Madagascar are normally granted for ten years and UMC's current holdings expire in 2015 and 2016. There appears to have been very little exploration activity by UMC on these permits since their acquisition. A few other less extensive areas with uranium exploration permits have been held by various companies over the past few years that also do not show any exploration activity in recent years.

Uranium exploration activities have increased in recent years in **Malawi** due to the interest in expanding resources at the currently producing Kayelekera mine operated by Paladin Energy and the potential for discovery of additional deposits in a similar geological setting in the Karoo Group sedimentary rocks. In 2010, Paladin Energy completed 3 084 m of drilling in exploration areas to the north-west and south of the mine area. Ongoing exploration is aimed at extending the existing orebody as well as identifying and evaluating new ore bodies.

The Livingstonia uranium project is a joint venture between Resource Star and Globe Metals and Mining. The geologic setting is very similar to that of Kayelekera. In 2006, Globe drilled 94 holes totalling 11 533 m. In July 2010, Resource Star did an additional 1 502 m of drilling in 13 holes to prove up a JORC compliant inferred resource of 7.7 million tonnes ore at 229 ppm U (0.0229% U). Given the potential for additional resources, follow-up drilling was expected to continue through 2011.

Another potential resource may become available through the Kanyika niobium project held by Globe Metals and Mining. Uranium is an important by-product in the complex polymetallic ore. A bankable feasibility study was initiated in mid-2009 with completion scheduled for mid-2012.

According to the Ministry of Mines in **Mali**, uranium potential occurs in three main regions. The best 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. Two companies are reporting uranium exploration activities in Mali, Oklo Resources Limited, an ASX-listed Australian company and Rockgate Capital Corp. (formerly Delta Exploration), a TSX-listed Canadian exploration company.

Oklo Resources operates the Kidal uranium project in north-east Mali with two mining conventions but no work occurred in the last quarter of 2011 due to political unrest. However the company intends to continue work by undertaking a drilling programme in May 2012.

Rockgate Capital has rights to the Falea uranium project and in 2011 reported 43-101 compliant indicated resources of 2 307 tU and inferred resources of 8 346 tU at a cut-off grade of 0.025% U. Despite political unrest, Rockgate's exploration and development work at the Falea uranium, silver and copper project is expected to continue without interruption. The geological setting is reportedly similar in age and style to the Athabasca basin, with the equivalent in Mali being represented by Birimian stratigraphy intruded by uraninite bearing Sarayagranites and additionally uraninite which overprints native

silver and copper mineralisation near the basal unconformity in the sandstone unit. The company completed 20 000 m of core and reverse circulation drilling from October 2009 to December 2010. Exploration in 2010 focused on the north zone expansion with reported intersections of 6 m at 1.13% U, including 1 m at 5.47% U. In addition, two new areas were discovered, both of which are considered to have the potential to be mined by open-pit with grades reportedly up to 0.23% U.

Exploration and development expenditures in **South Africa** decreased from USD 15.0 million in 2007 to USD 11.4 million in 2008 and rebounded to USD 14.5 and 18.8 million in 2009 and 2010, respectively. Expenditures are expected to decrease substantially to USD 5.6 million in 2011 as some projects have already been evaluated (e.g. Anglo Ashanti Gold) and in other cases companies had difficulties in obtaining financing due to political instability (e.g. Witsgold). AREVA initially carried out investigations on Rystkuil uranium mineralisation hosted by the Karoo Group, but when the price declined activities ceased without any reportable resources being demonstrated. Holgoun Energy carried out an extensive feasibility study on the Springbok Flats deposits and reported about 84 000 tU of inferred resources, reportedly proceeding with a bankable feasibility study in 2011.

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.

The government has issued over 70 licences to foreign companies. In 2007, British-based Uranium Resources and Australia's Western Metals undertook joint exploratory drilling that revealed evidence of uranium mineralisation, particularly in the Lindi and Ruvuma regions. Uranium Resources acquired Western Metals in 2009 and continued with exploration on their Mtonya, Rumvuma and Ruhuhu projects. Drilling on the first two projects produced encouraging results. At Mtonya, a two-phase programme comprising 4 170 m of diamond drilling identified favourable geological environments to facilitate target selection. A 19 hole, 1 382 m reverse circulation drill programme intersected low to medium grade uranium mineralisation at shallow depths. The Ruhuhu project is in the early stages of target identification for sandstone hosted type deposits.

Mantra Resources completed an environmental and social impact assessment in 2011 and submitted the reports to the Tanzanian National Environmental Management Council in support of an application for a mining licence for the Mkuju River project. The project lies within the Selous Game Reserve and is opposed by local and international conservation bodies. In the interim, Mantra Resources was acquired by Atomredmetzoloto (ARMZ) and an operating agreement with Uranium One (51% owned by ARMZ) has given Uranium One operational control of the project. An updated resource estimate in September 2011, based on a total of 82 400 m of reverse circulation drilling in 2 976 holes, 9 020 m of diamond drilling in 173 holes and sampling from 400 trenches, boosted total resources by over 40%. This will form the basis of a definitive feasibility study to be completed in 2012.

Uranex is currently active in Tanzania with its Manyoni, Mkuju, Bahi and Itigi projects which includes both Karoo-hosted sandstone-type prospects and calcrete prospects. An earlier 2009 resource estimate for the Manyoni project was boosted in May 2010 by 53% to a total of 92 Mt of ore containing 11 155 tU at a grade of 0.01% U. Drilling has identified sandstone-hosted mineralisation with multiple intersections of up to 0.3% U.

East African Resources is conducting initial work on sandstone-type prospects on their Madaba-Mkuju properties and their Eastern Rift property, targeting calcrete-style mineralisation. Syrah Resources has recently acquired three uranium projects (Nondwa, Wembere and Tanga) in Tanzania through the acquisition of Jacana Resources.

In **Zambia**, exploration activities are focused on identifying sandstone-type deposits in the Karoo Group. Denison Mines have concentrated on the Mutanga deposit in the

south-east of the country. Initial plans called for production to commence in 2012 but the company subsequently indicated that further studies, drilling and a stronger uranium price are required before further development can take place.

African Energy is also undertaking extensive exploration activities on a variety of projects in Zambia, including the Chirundu and Northern Luangwa Valley projects. The most advanced is the Chirundu project adjacent to Denison's Mutanga project.

*Middle East, Central and Southern Asia*

In **India**, government exploration expenditures have increased from USD 25.1 million for 2008 to USD 55.8 million in 2010 with USD 55.6 million expected in 2011. Expenditures parallel the exploration drilling efforts with just over 117 000 m drilled in 2008 and 217 548 m drilled in 2010. In recent years, exploration activities have been concentrated in the following areas: Meso-Neo-Proterozoic Cuddapah basin of Andhra Pradesh; Meso-Proterozoic Delhi basin of Rajasthan and Haryana; Neo-Proterozoic Bhima – Kaladgi basins of Karnataka; and Cretaceous sedimentary basin of Meghalaya. Although there are currently significant development activities in India the government does not report such expenditures.

The **Islamic Republic of Iran** reported an increase in exploration and development expenditures from USD 8 million in 2008 to USD 32.2 million in 2010 with a forecasted high of USD 77.4 million expected in 2011. Exploration drilling has also increased substantially from 16 645 m in 2008 to 45 230 m in 2010. Although government development expenditures have increased, no development drilling was reported. Exploration has been conducted in the Kerman, Sistan-va-Baluchstan, South Khorasan and Razavi Khorasan provinces, in the south-east, east and central regions of Iran, in addition to regional structural studies covering almost the entire eastern portion of Iran. Reconnaissance for sedimentary-type uranium deposits by various procedures over the entire country has also been undertaken in order to evaluate potential in favourable sedimentary basins.

Exploration expenditures by government and industry in **Jordan** increased significantly from 2008 (USD 419 000) to USD 5.2 and USD 5.7 million, for 2009 and 2010, respectively. Expenditures of USD 5.4 million are expected in 2011. Industry expenditures make up greater than 90% of the total reported. The interest of companies such as AREVA, Rio Tinto and SinoU, combined with the commitment of Jordan to try to meet its own energy needs with plans for building up to four NPPs has fuelled this increase in expenditures. These companies are all working in co-operation with the Jordan Atomic Energy Commission (JAEC), established in 2008 and entrusted with the development and execution of the nuclear power programme. The exploration, extraction and mining of all nuclear materials including uranium, thorium, zirconium and vanadium is now under the authority of JAEC.

Decreased expenditures are reported by **Kazakhstan** from a high of USD 78.1 million in 2008 to USD 59.7 and USD 57.6 million in 2009 and 2010. However, expenditures are expected to rise to USD 73.4 million in 2011. In 2009, Kazakhstan became the largest uranium miner worldwide and mine development could explain the high expenditures in the preceding years as projects were advanced to production. During 2009 and 2010, exploration of sandstone-type deposits was performed at Kanzhugan, Moinkum, Inkai, Mynkuduk and Budenovskoye in the Shu-Sarysu Uranium Province and at Northern Kharassan in the Syrdaria Uranium Province. Re-estimation of uranium resources in vein-type deposits was also undertaken in the Northern Kazakhstan Uranium Province. During 2011, renewed geological exploration of sandstone-type deposits amenable for ISL mining in new perspective areas of the Shu-Sarysu and Syrdaria uranium provinces is planned. Projected estimates for exploration and development expenditures for 2011 support Kazakhstan remaining the top global producer of uranium in the near future with estimated total production of 19 968 tU for 2011.

Domestic exploration and development expenditures in **Uzbekistan** have increased steadily from Secretariat estimates in 2007 of USD 21.2 million to government reported numbers of USD 23.8 million in 2008 to USD 25.7 million in 2009. This trend in increasing expenditures is likely to continue in the near future as both exploration and development drilling is expected to increase in 2011. The national report indicates that in 2010, 155 364 m of exploration and 685 100 m of development drilling were completed and 578 600 m of exploration and 822 000 m of development drilling are expected in 2011.

*South-eastern Asia*

Exploration expenditures in **Indonesia** have shown a steady increase since 2008 with USD 266 000 spent in 2009, USD 327 000 in 2010 and a large increase to USD 877 000 is expected in 2011. There are currently no prospects under development, but continued exploration drilling (600 m) is planned at Sarana in the Kalan sector as well as general prospection in Ketapang, Bangka Belitung province and Papua.

*East Asia*

Total non-domestic development expenditures reported by **China** declined significantly from USD 193 million in 2009 to 94.6 million in 2010. The majority of the expenditures, i.e. greater than 80% of the total can be attributed to development spending and the sharp decline reflects progress in the completion of construction of mines abroad. Though overall non-domestic expenditures are decreasing, the national report indicates that the amount spent for exploration has increased from USD 5.4 million in 2009 to USD 8.8 million in 2010 with the trend expected to continue into 2011 with expected expenditures of USD 13.5 million.

Domestic exploration and development expenditures have continued to increase since 2004 with an all-time high of USD 77 million in 2010 and a similar amount forecasted for 2011. The scope of work has been expanded to potential prospects selected after regional prognosis and assessment, in addition to continued prospecting and exploration on the mineralised areas and belts related to previously discovered deposits. Exploration efforts are focused on the sedimentary basin in northern China and granite and volcanic metallogenetic belts in southern China.

Drilling completed in the last two years amounted to 1 150 000 m and resources in northern China, such as those contained in the Yili, Erlian, Turpan-Hami, Erdos, Songliao basins and the Guyuan uranium field have been increased. In addition, some potential areas and prospects were identified such as the Badanjili, Bayingebin and north Erdos basins. Meanwhile, important progress has been achieved in old mining areas of southern China, such as the Taoshan, Zhuguangnanbu, Heyuan, Lujing and Dazhou fields.

Non-domestic government exploration expenditures from **Japan** remained relatively steady over the past few years with a high of USD 4.8 million reported in 2009 and an expected expenditure of USD 3.0 million in 2011. Japan-Canada Uranium Co. Ltd is carrying out exploration activities in Canada. In addition, Japanese private companies hold shares in developing and mining operations in Canada, Niger, Kazakhstan and Australia. Japan does not report any non-domestic development expenditures.

Reported domestic exploration and development expenditures in **Mongolia** fluctuated over the past few years from a high in 2008 of USD 29.2 million to USD 11.3 and USD 18.3 million in 2009 and 2010, respectively. The main areas of exploration during 2008 and 2009 were the Dornod district of north-east Mongolia for volcanic and caldera-related uranium bearing rocks, the Ulziit basin in Tamsag Province of south-east Mongolia for sandstone-hosted uranium deposits and the Sainshand, Airag and central Gobi Provinces of south Mongolia for sandstone-type uranium deposits. In 2009 and 2010, 18 foreign companies carried out exploration. Recent activity has led to discoveries in the Matad Province, the Engershand, Ugtam, Ulziit uul, Dund-Gobi districts and the Ulziit, Nylga, Choir, Gurvansaikhan, Zuun bayan and Sainshand basins.

*Pacific*

Domestic exploration expenditures were variable over the past few years in **Australia**. The highest expenditures were in 2008 (USD 211.6 million), followed by a decline in 2009 (USD 144.6 million) and an increase (USD 166 million) in 2010, with projected expenditures of USD 192.7 million in 2011. The main areas of exploration were the Gawler Craton/Stuart Shelf region for hematite breccia complex deposits, the Frome Embayment for sandstone-type deposits in South Australia, the Alligator Rivers region of the Northern Territory for unconformity-related deposits, the Mount Isa region in Queensland for extensions of metasomatite-type deposits and Cenozoic palaeochannel sands in Western Australia for calcrete deposits.

In 2009, Heathgate Resources announced the discovery of the Pepegoona and Yadglin sandstone-hosted uranium deposits in the Frome Embayment, some 12 km north and 16 km north-northeast (respectively) of Beverley mine, collectively referred to as Beverley North Project. Australia does not collect information on non-domestic uranium exploration and development expenditures. However, during 2009 and 2010, several Australian companies explored for uranium in Namibia and other African countries.

## Uranium production

In 2010, uranium was produced in 22 different countries; two more than in 2008, with Malawi producing uranium for the first time in 2009 and Germany once again recovering small amounts of uranium in mine water treatment operations at decommissioned mines. Four other countries, Bulgaria, France, Germany and Hungary produced uranium as the result of mine remediation activities. Kazakhstan's growth in production continued unabated and in 2009 it became the largest producer in the world, far outstripping Canada and Australia. Growth increased in 2010 by 27% but is expected to slow to just above 10% in 2011. This decline in growth is probably related to market and other considerations more than resource availability as Kazakhstan still has large resources. Table 1.20 summarises major changes in uranium production in a number of countries and Table 1.21 shows production in all producing countries from 2008 to 2010, with expected production in 2011. Figure 1.5 shows 2010 production shares and Figure 1.6 illustrates the evolution of production shares from 2004 to 2010.

**Table 1.20. Production in selected countries and reasons for major changes**

(tonnes U)

| Country | Production 2008 | Production 2010 | Difference | Reason for changes in production |
|---|---|---|---|---|
| Australia | 8 433 | 5 918 | -2 515 | Flooding at Ranger, shaft damage at Olympic Dam and ore shortage at Beverley. |
| Brazil | 330 | 148 | -182 | Reduced due to need to address regulatory requirements related to tailings ponds. |
| Canada | 9 000 | 9 775 | 775 | Higher grade ore from McClean Lake and MacArthur River mines. |
| China | 770 | 1 350 | 580 | Expansions at the Qinglong, Yining and Fuzhou mines. |
| India | 250 | 400 | 150 | Commissioning of the Jaduguda mill. |
| Kazakhstan | 8 512 | 17 803 | 9 291 | Five new deposits came on stream and a new processing plant was commissioned. |
| Malawi | 0 | 681 | 681 | Kayelekera mine started production in 2009 and an expansion plan was announced in 2010. |
| Niger | 2 993 | 4 197 | 1 204 | Arlit expansion (2009) and limited production at Azelik (2010) mine. |
| United States | 1 492 | 1 630 | 138 | La Palangana and Christensen Ranch ISL mining operations started production in 2010. |
| Uzbekistan | 2 283 | 2 874 | 591 | Increased production at existing ISL facilities and more being brought into production. |

## Table 1.21. Historical uranium production

(tonnes U)

| Country | Pre-2008 | 2008 | 2009 | 2010 | Total to 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Argentina | 2 582 | 0 | 0 | 0 | 2 582 | 0 |
| Australia | 147 996 | 8 433 | 7 934 | 5 918 | 170 281 | 7 300 |
| Belgium | 686 | 0 | 0 | 0 | 686 | 0 |
| Brazil | 2 509 | 330 | 347 | 148 | 3 334 | 360 |
| Bulgaria | 16 361 | 1(c) | 1(c) | 1(c) | 16 364 | 1(c) |
| Canada | 417 670 | 9 000 | 10 174 | 9 775 | 446 619 | 8 600 |
| China | 30 629* | 770* | 1 200 | 1 350 | 33 949 | 1 500 |
| Congo, Democratic Republic of | 25 600* | 0 | 0 | 0 | 25 600 | 0 |
| Czech Republic(a) | 110 152 | 275 | 258 | 254 | 110 939 | 226 |
| Finland | 30 | 0 | 0 | 0 | 30 | 0 |
| France | 75 980 | 5(c) | 8(c) | 9(c) | 76 002 | 5*(c) |
| Gabon | 25 403 | 0 | 0 | 0 | 25 403 | |
| Germany(b) | 219 517 | 0(c) | 0(c) | 8(c) | 219 525 | 80(c) |
| Hungary | 21 051 | 1(c) | 1(c) | 6(c) | 21 059 | 2(c) |
| India* | 8 903 | 250* | 290* | 400* | 9 843 | 400* |
| Iran, Islamic Rep of | 11 | 6 | 8 | 7 | 32 | 9 |
| Japan | 84 | 0 | 0 | 0 | 84 | 0 |
| Kazakhstan | 118 388 | 8 512 | 14 020 | 17 803 | 158 723 | 19 968 |
| Madagascar | 785 | 0 | 0 | 0 | 785 | 0 |
| Malawi | 0 | 0 | 90 | 681 | 771 | 850 |
| Mexico | 49 | 0 | 0 | 0 | 49 | 0 |
| Mongolia | 535 | 0 | 0 | 0 | 535 | 0 |
| Namibia | 91 098 | 4 365* | 4 626* | 4 503* | 104 592* | 3 781* |
| Niger | 103 911 | 2 993 | 3 245 | 4 197 | 114 346 | 4 264 |
| Pakistan* | 1 119 | 45 | 50 | 45 | 1 259 | 45 |
| Poland | 650 | 0 | 0 | 0 | 650 | 0 |
| Portugal | 3 720 | 0 | 0 | 0 | 3 720 | 0 |
| Romania | 18 339 | 80* | 80* | 80* | 18 579* | 80* |
| Russian Federation | 136 214 | 3 521 | 3 565 | 3 562 | 146 862 | 3 364 |
| Slovak Republic | 211 | 0 | 0 | 0 | 211 | 0 |
| Slovenia | 382 | 0 | 0 | 0 | 382 | 0 |
| South Africa | 155 679 | 566 | 563 | 582 | 157 390 | 615* |
| Spain | 5 028 | 0 | 0 | 0 | 5 028 | 0 |
| Sweden | 200 | 0 | 0 | 0 | 200 | 0 |
| Ukraine | 123 557 | 830 | 815 | 837 | 126 039* | 875 |
| United States | 362 148 | 1 492 | 1 594 | 1 630 | 366 864 | 1 555* |
| USSR(d) | 102 886 | 0 | 0 | 0 | 102 886 | 0 |
| Uzbekistan | 110 077 | 2 283 | 2 657 | 2 874 | 117 891 | 3 350 |
| Zambia(e) | 86 | 0 | 0 | 0 | 86 | 0 |
| OECD | 1 364 961 | 19 206 | 19 969 | 17 600 | 1 421 736 | 17 768 |
| Total | 2 440 226 | 43 758 | 51 526 | 54 670 | 2 590 180 | 57 230 |

Note: For pre-2008, other sources cite 6 156 tU for Spain, 91 tU for Sweden.

* Secretariat estimate.

(a) Includes 102 241 tU produced in the former Czechoslovakia and CSFR from 1946 through the end of 1992.

(b) Production includes 213 380 tU produced in the former GDR from 1946 through the end of 1989.

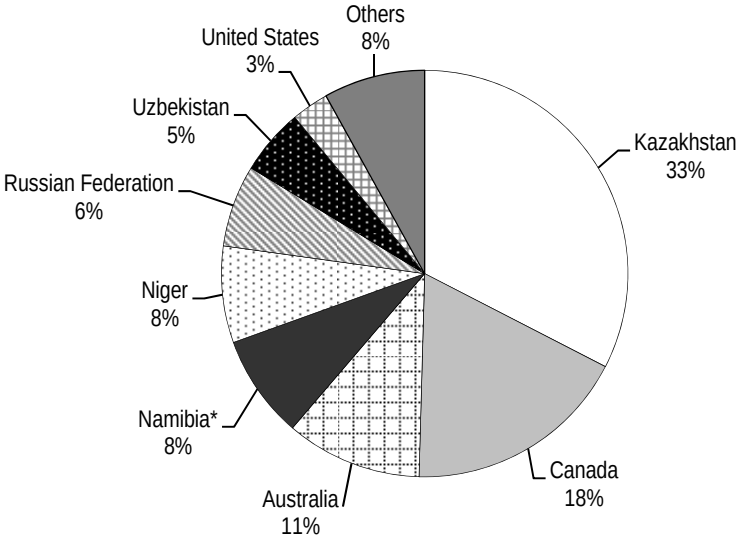
(c) Production comes from mine rehabilitation efforts only.

(d) Includes production in former Soviet Socialist Republics of Estonia, Kyrgyzstan, Tajikistan, Uzbekistan.

(e) Correction based on recalculation of 102 $tU_3O_8$ to tU.

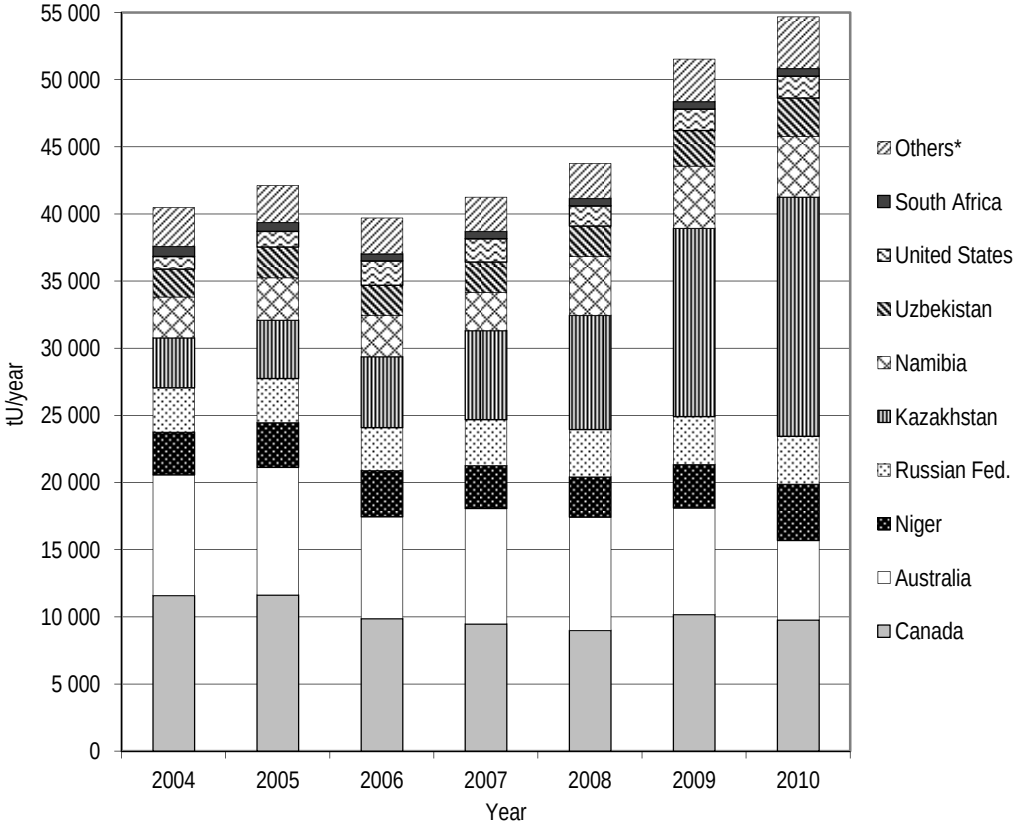

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**Figure 1.5. Uranium production in 2010: 54 670 tU**




* Secretariat estimate.

**Figure 1.6. Recent world uranium production**




Note: Values for India, Namibia, Pakistan and Romania are estimated.

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

Although Namibia's production stabilised to maintain fourth position in 2010, production is expected to decline in 2011 because expansion and extension of mine life plans at Rössing require large amounts of waste stripping for exploitation from 2013 onwards. As a result, Niger is expected to surpass Namibia and take fourth position in 2011. The top four producing countries (Kazakhstan, Canada, Australia and Namibia) retained their dominance accounting for 70% of world production in 2010, virtually unchanged from 2008 and just eight countries, Kazakhstan (33%), Canada (18%), Australia (11%), Namibia (8%), Niger (8%), the Russian Federation (7%), Uzbekistan (5%) and the United States (3%), accounted for about 93% of world production (Figure 1.5).

Overall, world uranium production increased from 43 758 tU in 2008 to 51 526 tU in 2009 (an 18% increase) and 54 670 tU in 2010 (a 6% increase from 2009). These significant increases are principally the result of increased production in Kazakhstan, with additions from Canada and Uzbekistan. Within OECD countries, production increased slightly from 19 206 tU in 2008 to 19 969 tU in 2009, then declined to 17 600 tU in 2010. Production in 2011 is expected to remain stable in OECD countries but to increase globally by 5% to just over 57 000 tU.

### *Present status of uranium production*

**North American** production amounted to 21% (11 405 tU) of world production in 2010. Although total production increased by almost 1 000 tU since 2008, the share of world production declined because of increased production elsewhere. **Canada** has been far outstripped in production increases by Kazakhstan, but remains the dominant North American producer and the second largest producer in the world. The McArthur River mine in Saskatchewan, the world's largest high-grade uranium mine, continued to operate at full capacity. The ore from the McArthur River mine is crushed and treated underground to produce a high-grade ore slurry that is pumped to surface and transported by specially designed trucks to the Key Lake mill for processing. The slurry is downblended with low-grade material to produce a feed grade of 3.4% U that the mill is designed to treat. The McClean Lake mill has been on care and maintenance since July 2010 and is expected to restart in 2013 when ore from Cigar Lake becomes available. The Rabbit Lake production centre treats ore from the Eagle Point mine. Drilling is taking place at Eagle Point to delineate further ore reserves to extend production beyond the current life-of-mine.

ISL facilities are becoming more important in uranium production in the **United States**. In 2009, six small underground mines ceased operation, leaving only four mines in production feeding one operational mill, White Mesa. By 2011, five ISL facilities were producing, five partially permitted and licensed; two mills were on standby status while a third is permitted and licensed but not yet operating (EIA, 2011).

**Brazil** was the only producing country in **South America** in 2009 and 2010. Production at the country's only production centre, Lagoa Real (Caetité), increased slightly from 330 tU in 2008 to 347 tU in 2009, but then dropped steeply to 148 tU in 2010 as regulatory issues related to the tailings ponds were addressed. Expansion of this facility to a nominal capacity of 670 tU/yr remains on course for 2015, with conventional agitated leaching replacing heap leaching. Production of uranium at the St. Quitéria project at the Itataia phosphate/uranium deposit is scheduled to begin in 2015 at an initial capacity of 970 tU per year. 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.

Primary uranium production in the **European Union** (EU) was from only two countries, the **Czech Republic** and **Romania.** A further four countries, **Bulgaria**, **France**, **Germany** and **Hungary** produced minor amounts of uranium from mine remediation activities only (a small portion of Czech Republic production results from similar activities). Total reported EU production in 2010 was 358 tU of which the Czech Republic contributed

254 tU. Romania has not reported production data in almost a decade but the Secretariat estimates that it produces about 80 tU per year. Finland is poised to become a uranium producer through the Talvivaara Mining Company Plc., which operates the Talvivaara Ni-Zn-Cu-Co mine in Sotkamo, eastern Finland, one of the largest sulphide nickel deposits in Europe. The company uses bio-heap leaching to extract the metals from black schist-hosted ore and although the average uranium grade is very low (0.0017% U), the pregnant leach solution contains 15 to 25 mg/L uranium. Talvivaara released plans to build a solvent extraction circuit for by-product recovery of uranium in February 2010 and annual uranium production is expected to be 350 tU, with technical assistance from Cameco. Talvivaara and Cameco signed a uranium off-take agreement in February 2011 which will be in effect until 2027.

Output from **non-EU countries in Europe** amounted to 4 399 tU, marginally up from production in 2008. The **Russian Federation** increased production by 40 tU and Ukraine also increased by 7 tU from 2008 to 2010. The Russian Federation output is expected to decline slightly to about 3 350 tU in 2011 but ongoing development projects, particularly in the Elkon uranium district should see production capacity increased substantially in coming years.

The three producing countries in **Africa**, **Namibia**, **Niger** and **South Africa** were joined by **Malawi** in 2009 when production commenced at the Kayelekera mine. Capacity is being ramped up and expansion plans are in place. The combination of increased production in Niger and new production from Malawi resulted in African production climbing from 7 924 tU in 2008 to 8 524 tU in 2009 and 9 963 tU in 2010. Stabilisation of production in Niger and the decline of production from Namibia while new reserves are being developed will likely result in production dropping to about 9 600 tU in 2011. However, pending mine developments in **Namibia** and further development in **Niger**, particularly with regard to Imouraren, production is likely to increase substantially over the next few years. Additionally, possible production in **Botswana**, **Tanzania** and **Zambia** and several projects under investigation in **South Africa** would contribute to regional production increases.

Dramatic increases in production in the **Middle East**, **Central** and **South Asia** continued into 2010. This was driven mainly by **Kazakhstan** where production increased from 8 512 tU in 2008 to 14 020 tU in 2009 and 17 803 tU in 2010. It is now by far the largest uranium-producing country in the world. Production growth is expected to slow into the future but is still expected to increase to almost 20 000 tU in 2011. **India** and **Pakistan** do not report production figures but their combined total is estimated to be about 450 tU in 2010, up from an estimated 300 tU in 2008. **Uzbekistan** reported production of 2 874 tU in 2010, a significant increase from 2 283 tU in 2008. **Iran** continues to produce small amounts of uranium from its Gachin deposit and plans to commence production from its Saghand facility in 2012. Current market conditions make it unlikely that Jordan will commence production in the near future.

**China**, the only producing country in **East Asia**, reported production figures for the first time in this edition, correcting Secretariat estimates back to 2008. The Secretariat had also provided production estimates in earlier editions, from 2003 to 2005. There are now six production centres operating in China. Production is equally spread between sandstone-hosted and volcanic-hosted deposits with a third of total production coming from unidentified "other" sources.

**Australia** is the only producing country in the **Pacific** region. Production decreased from 8 433 tU in 2008 to 7 934 tU in 2009 and 5 918 tU in 2010 owing to operational and other challenges. Resolution of these issues and anticipation that the Four Mile ISL mine will come on stream should result in future production increases. Expansion plans for Olympic Dam were approved by the Australian and South Australian governments late in 2011 and the planned expansion of Olympic Dam could see uranium production

increasing to over 16 000 tU per year at full capacity. Details on the timing and the ultimate size of this significant expansion have not yet been released.

### *Ownership*

Table 1.22 shows the ownership of uranium production in 2010 in the 22 producing countries. Domestic mining companies controlled about 67.9% of 2010 production, a marginal increase from the 67.7% reported in 2008. Domestic government participation increased from 33.6% in 2008 to 38.8% in 2010. Non-domestic mining companies controlled about 32.2% of 2010 production with an approximately equal share between government and private companies. Non-domestic government participation in uranium production increased from 10.2% in 2008 to 17.1% in 2010. The increased government shares reflect the increasing contribution that production in Kazakhstan and Chinese is making to world production as well as increasing activities of state-owned companies from China, France and the Russian Federation in Kazakhstan; and from China, France, and South Korea in Niger.

**Table 1.22. Ownership of uranium production based on 2010 output**

| Country | Domestic mining companies | | | | Non-domestic mining companies | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | Government-owned | | Privately-owned | | Government-owned | | Privately-owned | | |
| | tU | % | tU | % | tU | % | tU | % | (tU) |
| Australia | 0 | 0.0 | 1 787 | 30.2 | 0 | 0.0 | 4 131 | 69.8 | 5 918 |
| Brazil | 148 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 148 |
| Bulgaria* | 1 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 |
| Canada | 0 | 0.0 | 6 955 | 71.2 | 2 771 | 28.3 | 49 | 0.5 | 9 775 |
| China | 1 350 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 350 |
| Czech Republic | 254 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 254 |
| France* | 9 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 9 |
| Germany | 8 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 8 |
| Hungary | 6 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 6 |
| India* | 400 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 400 |
| Iran, Islamic Rep of* | 7 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 7 |
| Kazakhstan | 9 959 | 55.9 | 0 | 0.0 | 3 785 | 21.3 | 4 059 | 22.8 | 17 803 |
| Malawi* | 102 | 15.0 | 579 | 85.0 | 0 | 0.0 | 0 | 0.0 | 681 |
| Namibia* | 135 | 3.0 | 4 368 | 97.0 | 0 | 0.0 | 0 | 0.0 | 4 503 |
| Niger* | 1 427 | 34.0 | 0 | 0.0 | 2 770 | 66.0 | 0 | 0.0 | 4 197 |
| Pakistan* | 45 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 45 |
| Romania* | 80 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 80 |
| Russian Federation | 3 562 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 3 562 |
| South Africa | 0 | 0.0 | 582 | 100.0 | 0 | 0.0 | 0 | 0.0 | 582 |
| Ukraine | 837 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 837 |
| United States* | 0 | 0.0 | 1 630 | 100.0 | 0 | 0.0 | 0 | 0.0 | 1 630 |
| Uzbekistan* | 2 874 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 2 874 |
| Total | 21 204 | 38.8 | 15 901 | 29.1 | 9 326 | 17.1 | 8 239 | 15.1 | 54 670 |

* Secretariat estimate.

### *Employment*

Although the data are incomplete, Table 1.23 shows that employment levels at existing uranium production centres declined by 1.8% from 2008 to 2009, then rose by 3.1% from 2009 to 2010 and is expected to decline in 2011. However, future production expansions in countries such as Australia, Canada, India, Niger and Namibia can be expected to result in increased employment in the longer term. Table 1.24 provides, in selected countries, employment directly related to uranium production (excluding head office, R&D, pre-development activities, etc.).

**Table 1.23. Employment in existing production centres of listed countries**

(person-years)

| Country | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|---|---|
| Argentina | 60 | 60 | 133 | 133 | 133 | 133 | 133 | 145 |
| Australia[a] | 743 | 889 | 959 | 3 010 | 4 787 | 3 830 | 4 813 | 4 888 |
| Brazil | 140 | 140 | 580 | 580 | 640 | 620 | 620 | 620 |
| Canada[b] | 985 | 1 067 | 1 665 | 1 873 | 1 984 | 2 205 | 2 399 | 2 400 |
| China | 7 500 | 7 000 | 7 300 | 7 400 | 7 450 | 7 500 | 7 560 | 7 650 |
| Czech Republic | 2 409 | 2 312 | 2 251 | 2 294 | 2 287 | 2 248 | 2 164 | 2 140 |
| Germany[c] | 2 230 | 2 101 | 1 835 | 1 775 | 1 770 | 1 638 | 1 489 | 1 452 |
| India | 4 200 | 4 200 | 4 300 | 4 300 | 4 634 | 4 643 | 4 917 | 4 917 |
| Iran, Islamic Rep of | 0 | 0 | 285 | 285 | 285 | 320 | 325 | 340 |
| Kazakhstan | 5 120 | 6 522 | 6 941 | 7 845 | 7 940 | 9 261 | 8 828 | 8 550 |
| Malawi | 0 | 0 | 0 | 2 000* | 1 250 | 1 033 | 1 036 | 1 400* |
| Namibia* | 833 | 860 | 1 400 | 1 900 | >2 543 | >2 781 | >3 142 | >3 647 |
| Niger | 1 598 | 1 657 | 1 741 | 1 900* | 2 156 | 2 764 | 2 981 | 3 231 |
| Romania* | 2 000 | 2 000 | 2 000 | 2 000 | 2 000 | 2 000 | 2 000 | 2 000 |
| Russian Federation | 12 670 | 12 551 | 12 575 | 12 950 | 12 870 | 9 975 | 10 650 | 10 650 |
| Slovenia[c] | 40 | 28 | 20 | NA | NA | NA | NA | NA |
| South Africa | 150 | 150 | 150 | 1 150 | 3 364 | 4 494 | 4 825 | 4 327 |
| Spain[c] | 56 | 56 | 58 | 58 | 43 | 43 | 25 | 23 |
| Ukraine | 4 380 | 4 350 | 4 310 | NA | 4 260 | 4 350 | 4 310 | NA |
| United States | 299 | 524 | 600 | 1 076 | 1 409 | 934 | 948 | NA |
| Uzbekistan | 8 560* | 8 620* | 8 700* | 8 700* | 8 750 | 8 800 | 8 860 | 9 020 |
| Total | 53 973 | 55 087 | 57 803 | 61 229 | 68 012 | 66 791 | 68 883 | 63 753 |

* Secretariat estimate.

(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.

**Table 1.24. Employment directly related to uranium production and productivity**

| | 2008 | | 2009 | | 2010 | |
|---|---|---|---|---|---|---|
| | Production employment (person-years) | Production (tU) | Production employment (person-years) | Production (tU) | Production employment (person-years) | Production (tU) |
| Australia[a] | 4 322 | 8 433 | 3 512 | 7 933 | 4 514 | 5 918 |
| Brazil | 340 | 330 | 340 | 347 | 340 | 148 |
| Canada[b] | 1 416 | 9 000 | 1 379 | 10 174 | 1 305 | 9 775 |
| China | 6 740 | 770 | 6 800 | 1 200 | 6 860 | 1 350 |
| Czech Republic | 1 122 | 275 | 1 122 | 258 | 1 118 | 254 |
| India | NA | 250 | NA | NA | NA | NA |
| Iran, Islamic Rep of | NA | 6 | NA | 8 | NA | 7 |
| Kazakhstan | 6 598 | 8 512 | 7 643 | 14 020 | 6 718 | 17 803 |
| Malawi* | 0 | 0 | 1 033 | 90 | 1 036 | 681 |
| Namibia* | 3 400 | 4 365 | 3 400 | 4 626 | 3 400 | 4 503 |
| Niger* | 1 300 | 2 993 | 1 850 | 3 245 | 1 900 | 4 197 |
| Russian Federation | 5 120 | 3 521 | 4 650 | 3 565 | 4 810 | 3 562 |
| South Africa* | 2 230 | 566 | 1 420 | 563 | 1 400 | 582 |
| Ukraine | 1500 | 830 | 1460 | 815 | 1420 | 837 |
| United States | 952 | 1 492 | 759 | 1 594 | 737 | 1 630 |
| Uzbekistan | 8 750 | 2 283 | 8 800 | 2 657 | 8 860 | 2 874 |

*Secretariat estimate.

(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.

### *Production methods*

Uranium is produced using open-pit and underground mining techniques processed by conventional uranium milling, *in situ* leaching (ISL, sometimes referred to as *in situ* recovery, or 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.

Historically, uranium production has principally involved open-pit and underground mining. However, 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 an increasingly important method of uranium production.

The distribution of production by type of mining or "material sources" for 2007 through 2010 is shown in Table 1.25. The category "other methods" includes recovery of uranium through treatment of mine waters as part of reclamation and decommissioning.

As can be seen in Table 1.25, ISL production was higher than open-pit production in 2007 and exceeded underground production in 2009. ISL is now the major source of uranium production, largely because of the rapid growth of production in Kazakhstan. ISL

continues to grow, largely at the expense of open-pit production, with other ISL projects being developed in Australia, China, the Russian Federation, the United States and Uzbekistan. The co-product/by-product method has remained relatively constant, but could increase in coming years when the planned expansion at Olympic Dam proceeds. Heap leaching has declined in recent years but could increase again in the future if some of the large, low-grade deposits in Namibia come on stream.

**Table 1.25. Percentage distribution of world production by production method**

| Production method | 2007 | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|---|
| Open-pit mining | 24.40 | 27.32 | 25.60 | 22.92 | 17.98 |
| Underground mining | 36.51 | 32.15 | 32.61 | 31.75 | 29.26 |
| ISL | 27.17 | 29.45 | 33.81 | 39.34 | 42.30 |
| In-place leaching | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-product/by-product | 9.50 | 8.91 | 7.25 | 5.66 | 8.22 |
| Heap leaching | 2.30 | 2.16 | 0.71 | 0.29 | 2.06 |
| Other | 0.10 | 0.01 | 0.02 | 0.04 | 0.18 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

### *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 1.26 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 the 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 and Romania.

Several current or potential uranium producing countries including China, India, Iran, Jordan, Malawi, Mongolia, Namibia, Niger, Pakistan, Romania, South Africa and the United States, did not report projected production capabilities to 2035. As a result, estimates of production capability for these countries were developed by the Secretariat using data submitted for past Red Books and company reports. Projections of future production capability for Pakistan and Romania in Table 1.26 are based on reports that these countries intend to meet their future domestic reactor requirements with domestic production, even though the currently identified resource bases are insufficient to meet these projected requirements.

The reported production capability of existing and committed production centres in the A-II category in 2011 is about 73 305 tU. For comparison, the estimated 2010 production capability totalled 70 180 tU. However, actual 2010 production amounted to 54 670 tU, or about 78% of stated production capability. In 2007, production amounted to 76% of stated capability, 84% in 2005 and 75% in 2003, demonstrating that full capability is rarely, if ever, achieved. Total production capability for 2011, including planned and prospective centres (category B-II), amounts to 75 090 tU, slightly lower than the 2010 B-II total capability of 75 405 tU. In 2010, production amounted to 73% of total B-II capability, 73% in 2007, 81% in 2005 and 74% in 2003.

## Table 1.26. World uranium production capability to 2035

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

| Country | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A-II | B-II | A-II | B-II | A-II | B-II | A-II | B-II | A-II | B-II | A-II | B-II |
| Argentina | 120 | 120* | 150 | 150* | 150 | 250 | 500* | 500* | 500* | 500* | 500* | 500* |
| Australia | 9 700 | 9 700 | 10 100 | 16 600 | 10 100 | 24 200 | 10 100 | 27 900 | 9 800 | 27 600 | 9 800 | 27 600 |
| Brazil | 340 | 340 | 1 600 | 1 600 | 2 000 | 2 000 | 2 000 | 2 000 | 2 000* | 2 000* | 2 000* | 2 000* |
| Canada | 16 430 | 16 430 | 17 730 | 17 730 | 17 730 | 19 000 | 17 730 | 19 000 | 17 730 | 19 000 | 17 730 | 19 000 |
| China* | 1 500 | 1 600 | 1 800 | 2 000 | 1 800 | 2 000 | 1 800 | 2 000 | 1 800 | 2 000 | 1 800 | 2 000* |
| Czech Republic | 500 | 500 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 30 | 30 |
| Finland** | 0 | 0 | 0 | 350 | 0 | 350 | 0 | 350 | 0 | 350 | 0 | 350 |
| India* | 295 | 980 | 980 | 980 | 980 | 1 200 | 1 000 | 1 600 | 1 000 | 2 000 | 1 000 | 2 000 |
| Iran, Islamic Rep. of | 70 | 70 | 90 | 90 | 100* | 100* | 100* | 100* | 100* | 100* | 100* | 100* |
| Jordan* | 0 | 0 | 0 | 0 | 2 000 | 2 000 | 2 000 | 2 000 | 2 000 | 2 000 | 2 000 | 2 000 |
| Kazakhstan | 22 000 | 22 000 | 24 000 | 25 000 | 24 000 | 25 000 | 14 000 | 15 000 | 12 000 | 13 000 | 5 000 | 6 000 |
| Malawi* | 0 | 1 000 | 1 270 | 1 270 | 1 425 | 2 525 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mongolia* | 0 | 0 | 0 | 500 | 150 | 1 000 | 150 | 1 000 | 150 | 1 000 | 150 | 1 000 |
| Namibia* | 5 350 | 5 350 | 7 600 | 13 400 | 9 450 | 19 250 | 5 450 | 15 250 | 1 600 | 11 400 | 1 600 | 10 050 |
| Niger* | 5 400 | 5 400 | 5 500 | 10 500 | 5 500 | 10 500 | 5 500 | 10 500 | 2 500 | 7 500 | 2 500 | 7 500 |
| Pakistan*[(a)] | 70 | 70 | 70 | 110 | 140 | 150 | 140 | 140 | 140 | 650 | 140 | 650 |
| Romania*[(a)] | 230 | 230 | 230 | 230 | 350 | 475 | 350 | 475 | 350 | 630 | 350 | 630 |
| Russian Federation | 3 360 | 3 360 | 4 480 | 4 790 | 5 840 | 6 610 | 6 410 | 7 270 | 2 620 | 11 240 | 5 450 | 10 450 |
| South Africa* | 1 050 | 1 050 | 1 588 | 2 360 | 2 686 | 3 460 | 2 795 | 3 565 | 1 386 | 2 155 | 1 381 | 2 150 |
| Ukraine* | 1 500 | 1 500 | 2 700 | 2 700 | 2 700 | 2 700 | 5 200 | 5 200 | 5 200 | 5 200 | 5 200 | 5 200 |
| United States[(b)] | 2 040* | 2 040* | 3 400 | 6 100 | 3 800 | 6 600 | 3 700 | 6 500 | 3 100 | 5 600 | 3 100* | 5 600* |
| Uzbekistan | 3 350 | 3 350 | 4 150 | 4 150 | 4 500 | 4 500 | 5 000 | 5 000 | 5 000* | 5 000* | 5 000* | 5 000* |
| Total | 73 305 | 75 090 | 87 488 | 110 310 | 95 451 | 133 570 | 83 975 | 125 050 | 69 026 | 118 625 | 64 831 | 109 460 |

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.

* Secretariat estimate.

** By-product of nickle production.

(a) Projections are based on reported plans to meet domestic requirements through the discovery of additional resources.

(b) Data from previous Red Book.

Clearly, an expansion in production capability driven by generally higher uranium prices since 2003 is underway. Production has also increased steadily, although not as rapidly as the projected production capability. Increasing production takes time, expertise and investment for the stated production capability increases to be turned into production. In 2009 and 2010, dramatic increases in Kazakhstan's production boosted the world's production substantially. The influence of the Fukushima accident can reasonably be expected to result in a flattening of the rate of uranium production increase in the near term. However, expansions are underway at Olympic Dam in Australia and expansions and an extension for the mine life at Rössing in Namibia. Moreover, Cigar Lake in Canada is planned to come on stream in 2013. The current (2011) projections are marginally lower than those estimated in 2009, as projections are brought in line with the slowdown in nuclear generation capacity growth as a result of the Fukushima accident. At this time it seems that in the longer term the accident will not likely cause a significant decline in nuclear generating capacity, but rather a near-term slowdown in the rate of growth. However, there remain uncertainties of the impact this accident may have on nuclear capacity growth, particularly in East Asia.

The current picture is that the closure of existing mines due to resource depletion is expected to be offset by the opening of new mines. As currently projected, production capability of existing and committed production centres is expected to reach over 95 000 tU/yr in 2020, declining thereafter to about 65 000 tU in 2035. Total potential production capability (including planned and prospective production centres, category B-II) could rapidly climb to over 130 000 tU/yr by 2020, followed by a slow decline to around 110 000 tU/yr in 2035. However, these projections are based on currently known uranium resources that will in all likelihood be supplemented by new discoveries in the future, with appropriate market signals.

### *Recent, planned, committed mines and expansions*

A total of 11 new mines opened in 2009-2010; five of them in Kazakhstan as production capacity continued to increase and a number of other mine development plans were firmed up. Table 1.27 summarises these developments, adding some detail to the global capacity expansions outlined in Table 1.26. Committed production centres (C) are those that are either under construction or are firmly committed for construction, whereas planned production centres (P) are those where feasibility studies are either completed or under way, but for which construction commitments have not yet been made. Expansions (Exp) are planned capacity increases at existing sites (E).

During the period 2009-2021, there are currently expected to be two major peaks in uranium capacity additions arising from new mine openings and the expansion of existing mines. In 2013, an additional 8 000 to 9 000 tU of production capacity is expected to be brought on line, mainly owing to the opening of the Cigar Lake (Canada) and Trekkopje (Namibia) mines. In 2015, over 15 000 tU of production capacity is expected to be brought online, in major part due to the projected start-up of Kintyre (Australia), Husab (Namibia) and Mkuju River (Tanzania) mines. In total, new production capacity could add between 61 430 and 63 775 tU from 2009 to 2021 (Table 1.27). Included in these figures are by-product centres that are expected to be producing uranium from unconventional sources (i.e. Talvivaara in Finland and Santa Quitéria in Brazil), the first time in several years that production from unconventional sources is expected to take place. 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.

## Table 1.27. Recent, planned, committed mines and expansions

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

| | Production centre | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Argentina | Cerro Solo | | | | | | | | *P (100)* | | | | | |
| Australia | Kintyre | | | | | | | *P (2 300-3 000)*[a] | | | | | | |
| | Wiluna | | | | | *P (850)* | | | | | | | | |
| | Olympic Dam | | | | | | | | | | | | | Exp (1 500)*[b] |
| | Beverley (Pepegoona) | | | Exp (420)* | | | | | | | | | | |
| | Honeymoon | | | E (340) | | | | | | | | | | |
| Brazil | Lagoa Real (Caetité) | | | | | | | Exp (330)[c] | | | | | | |
| | Santa Quitéria | | | | | | | C (970)[d] | | | | | | |
| Canada | Cigar Lake | | | | | C (5 000)[e] | | | | | | | | |
| China | Chongyi | Exp (200)[f] | | | | | | | | | | | | |
| Finland | Talvivaara | | | | C (350)[g] | | | | | | | | | |
| India | Mohuldih | | | C (50)* | | | | | | | | | | |
| | Tummalapalle | | | | C (220) | | | | | | | | | |
| | Gogi | | | | | | C (130) | | | | | | | |
| | Lambapur-Peddagattu | | | | | | | | *P (130)* | | | | | |
| | K.P.N.[h] | | | | | | | | | *P (340)* | | | | |
| Iran, Islamic Rep. of | Ardakan | | | | C (50) | | | | | | | | | |
| Jordan | JFUMC | | | | | | | | | | | | *P (2 000)** | |
| Kazakhstan | Semyzbay, Irkol* | E (500) | | | Exp (500) | | | | | | | | | |
| | Kharasan-1* | E (500) | | | | | | Exp (500) | | | | | | Exp (1 500) |
| | Kharasan-2* | E (500) | | | Exp (1 500) | | | | | | | | | |
| | Budenovskoye 1, 3, 4* | E (1000) | | | | | | | | | | | | |
| | Inkai 1, 2, 3* | E (1500) | | | | | | Exp (500) | | | | | | |
| | Zhalpak | | | | | C (500) | | | Exp (250) | | | | | |
| | Moinkum site 3* | | | | C (250) | | | | | | Exp (250) | | | |
| Malawi* | Kayelekera | E (1 270) | | | | Exp (190) | | | | | | | | |

See notes on page 71.

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**Table 1.27. Recent, planned, committed mines and expansions** (*continued*)

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

| | Production centre | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Namibia | Langer Heinrich | | Exp (320) | | Exp (680) | | | | Exp (1 820)* | | | | | |
| | Trekkopje | | | | | C (1 600-2 545) | | | | | | | | |
| | Valencia | | | | | | | | *P (1 350)* | | | | | |
| | Husab/Rössing South | | | | | | | *P (5 800)* | | | | | | |
| | Etango | | | | | | | | *P (2 300-3 000)* | | | | | |
| Niger | Somaïr | Exp (900)[(i)] | | | | | | | | | | | | |
| | Imouraren | | | | | | C (5 000) | | | | | | | |
| | Azelik/Teguidda | | E (700) | | | | | | | | | | | |
| Russian Federation | Khiagda | E (200)[(j)] | | | | | | Exp (1 600) | | | | Exp (1 800) | | |
| | Elkon | | | | | | | | | | | | *P (5 000)* | |
| | Gornoe | | | | | | *P (300)* | | | | | | | |
| | Olovskaya | | | | | | | | *P (600)* | | | | | |
| South Africa | Ezulwini | E (500) | | | | | | | | | | | | |
| | Mine Waste Solutions | | | | C (300)[(k)] | | | | | | | | | |
| | South U plant | | | | Exp (200) | | | | | | | | | |
| Tanzania | Mkuju River | | | | | | | *P (2 000)** | | | | | | |
| Ukraine | Hydromet. plant 2 | | | | | | | *P (1 200)** | | | | | | |
| United States | La Palangana | | E (385) | | | | | | | | | | | |
| | Christensen Ranch | | E (385) | | | | | | | | | | | |
| Total | | 7 070 | 1 790 | 810 | 4 050 | 8 140-9 085 | 5 430 | 15 200-15 900 | 6 550-7 250 | 340 | 250 | 1 800 | 7 000 | 3 000 |

* Secretariat estimate; E = existing (new) production centre; Exp = expansion; C = committed; *P* = *planned*.

(a) Cameco target production date.

(b) Expansion plans have not been finalised; it is assumed first uranium production increase will not take place until 2021.

(c) Planned expansion from 340 tU/yr to 670 tU/yr.

(d) U by-product from phosphate.

(e) Planned opening with possible expansion to 7 000 tU/yr.

(f) Expansion from 150tU/yr to 350 tU/yr – also recent expansions at Benxi (Ginglong) and Yining, but no further details are available.

(g) U by-product from sulphide nickle rich black shale.

(h) Kylleng-Pyndengsohiong, Mawthabah mines.

(i) Heap leaching facility for low-grade ore processing launched.

(j) Pilot production, expansion to 1 800 tU/yr underway.

(k) U from mine tailings.

In addition, a total of 17 prospective production centres (those for which construction plans have not yet been made) were noted in national reports for which a projected start-up date, and in some cases mine capacities, have not yet been determined (Table 1.28). While there is greater uncertainty surrounding the development of these sites, the potential capacity additions from these facilities underscores the availability of uranium deposits of commercial interest. Once again it should 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 a number of years to be brought into production.

**Table 1.28. Prospective mines (estimated production capacity in tU/yr)**

| Country | Production centre |
|---|---|
| Australia | Yeelirrie* |
| | Four Mile* |
| Canada | Midwest* (2 300 tU/yr) |
| | Millenium* (2 750 tU/yr) |
| | Kiggavik* (3 000 tU/yr) |
| Mongolia | Gurvansaikhan (Hairhan deposit) |
| | Coge-Gobi |
| | Emeelt (Gurvanbulag deposit) |
| *Namibia* | Rössing (planned expansion) |
| South Africa | Dominion Reefs (to be reopened) |
| United States | Lost Creek (769tU/yr) |
| | Nichols Ranch |
| | Goliad Uranium (385tU/yr) |
| | Jab and Antelope (769tU/yr) |
| | Moore Ranch (192tU/yr) |
| | Piñon Ridge Mill (385tU/yr) |
| Zambia | Mutanga |

* Reported as planned by the state but unknown start-up date.

*Country* = Secretariat estimate.

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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. The data for 2011 and beyond are estimates and actual figures may differ.

## Current commercial nuclear generating capacity and reactor-related uranium requirements

### *World (375.2 GWe net as of 1 January 2011)*

On 1 January 2011, a total of 440 commercial nuclear reactors were connected to the grid in 30 countries and 67 reactors were under construction (a total of about 65 GWe net).[1] During 2009 and 2010, seven reactors were connected to the grid (a combined total of about 4.8 GWe net) and four reactors were permanently shut down (about 2.6 GWe net). 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 2011. The global NPP fleet generated a total of about 2 559 TWh of electricity in 2009 and about 2 623 TWh in 2010 (Table 2.2).

World annual uranium requirements amounted to 63 875 tU in 2010 and are expected to increase to 65 180 tU in 2011.

### *OECD (311.5 GWe net as of 1 January 2011)*

As of 1 January 2011, the 342 reactors connected to the grid in 18 OECD countries constituted about 83% of the world's nuclear electricity generating capacity. A total of 12 reactors were under construction with a net capacity of about 13 GWe. During 2009 and 2010, two reactors were connected to the grid (about 1.9 GWe net) and three reactors were permanently shut down (about 1.5 GWe net).

The serious accident at the Fukushima Daiichi NPP in Japan on 11 March 2011 has further polarised OECD nuclear energy policies. Japan is reconsidering the role of nuclear power, Germany has accelerated its phase-out and Italy and Switzerland have decided not to build new or replacement reactors, respectively. On the other hand, Sweden remains committed to upholding a recent decision to allow construction of replacement reactors in the existing fleet and the Czech Republic, Finland, France, Hungary, the Slovak Republic and the Republic of South Korea remain committed to maintaining nuclear energy as an important part of the national energy mix. In North America, some new build construction plans are slowly advancing but others have been put on hold, at least temporarily.

The OECD reactor-related uranium requirements were 49 945 tU in 2010 and are expected to increase slightly to 50 600 tU by 2011.

1. Figures include the reactors operating and under construction in Chinese Taipei.

## Table 2.1. Nuclear data summary

(as of 1 January 2011)

| Country | Operating reactors | Generating capacity (GWe net) | 2010 uranium requirements (tU) | Reactors under construction | Reactors started up during 2009 and 2010 | Reactors shut down during 2009 and 2010 | Reactors using MOX |
|---|---|---|---|---|---|---|---|
| Argentina | 2 | 0.9 | 120 | 1 | 0 | 0 | 0 |
| Armenia | 1 | 0.4 | 65 | 0 | 0 | 0 | 0 |
| Belgium | 7 | 5.9 | 925 | 0 | 0 | 0 | 0 |
| Brazil | 2 | 1.9 | 450 | 1 | 0 | 0 | 0 |
| Bulgaria | 2 | 1.9 | 255 | 2 | 0 | 0 | 0 |
| Canada[(a)] | 17 | 12.0 | 1 600 | 0 | 0 | 0 | 0 |
| China[(b)] | 13 | 10.1 | 3 900 | 28 | 2 | 0 | 0 |
| Czech Republic | 6 | 3.7 | 885 | 0 | 0 | 0 | 0 |
| Finland | 4 | 2.7 | 455 | 1 | 0 | 0 | 0 |
| France | 58 | 63.1 | 8 000 | 1 | 0 | 1 | 21 |
| Germany | 17 | 20.5 | 2 800 | 0 | 0 | 0 | 3 |
| Hungary | 4 | 1. 9 | 435 | 0 | 0 | 0 | 0 |
| India | 19 | 4.2 | 735 | 6 | 2 | 0 | 1 |
| Iran, Islamic Rep. of | 0 | 0.0 | 0 | 1 | 0 | 0 | 0 |
| Japan | 54 | 47.4 | 6 295 | 2 | 1 | 2 | 3 |
| Korea, Republic of | 21 | 18.7 | 4 200 | 5 | 1 | 0 | 0 |
| Mexico+ | 2 | 1.4 | 405 | 0 | 0 | 0 | 0 |
| Netherlands+ | 1 | 0.5 | 60 | 0 | 0 | 0 | 0 |
| Pakistan | 2 | 0.4 | 75* | 1 | 0 | 0 | 0 |
| Romania | 2 | 1.3 | 190* | 0 | 0 | 0 | 0 |
| Russian Federation | 32 | 22.7 | 4 500 | 11 | 1 | 0 | 0 |
| Slovak Republic | 4 | 1.8 | 370 | 2 | 0 | 0 | 0 |
| Slovenia | 1 | 0.7 | 210 | 0 | 0 | 0 | 0 |
| South Africa | 2 | 1.8 | 290 | 0 | 0 | 0 | 0 |
| Spain | 8 | 7.4 | 1 390 | 0 | 0 | 0 | 0 |
| Sweden | 10 | 9.3 | 1 580 | 0 | 0 | 0 | 0 |
| Switzerland | 5 | 3.2 | 210 | 0 | 0 | 0 | 0 |
| Ukraine | 15 | 13.1 | 2 480 | 2 | 0 | 0 | 0 |
| United Kingdom | 19 | 10.2 | 985 | 0 | 0 | 0 | 0 |
| United States | 104 | 101.1 | 19 140 | 1 | 0 | 0 | 0 |
| OECD | 342 | 311.5 | 49 945 | 12 | 2 | 3 | 27 |
| Total | 440 | 375.2 | 63 875 | 67 | 7 | 3[(c)] | 28 |

* Secretariat estimate.

\+ Data from *NEA Nuclear Energy Data*, OECD, Paris, 2011.

(a) Does not include three units currently under refurbishment (Point Lepreau, Bruce A units 1 and 2).

(b) The following data for Chinese Taipei are included in the world total but not in the total for China: six NPPs in operation, 4 980 GWe net; 870 tU; two reactors under construction; none started up or shut down during 2009 and 2010.

(c) Does not include Ignalia unit 2 (Lithuania) shut down on 31 December 2009, leaving the country without nuclear generating capacity.

Source: IAEA Power Reactor Information System (www.iaea.org/programmes/a2/) except for generating capacity and 2010 uranium requirements, which use government-supplied responses to a questionnaire, unless otherwise noted and rounded to the nearest five tonnes. MOX not included in U requirement figures.

**Figure 2.1. World installed nuclear capacity: 375.20 GWe net**
(as of 1 January 2011)

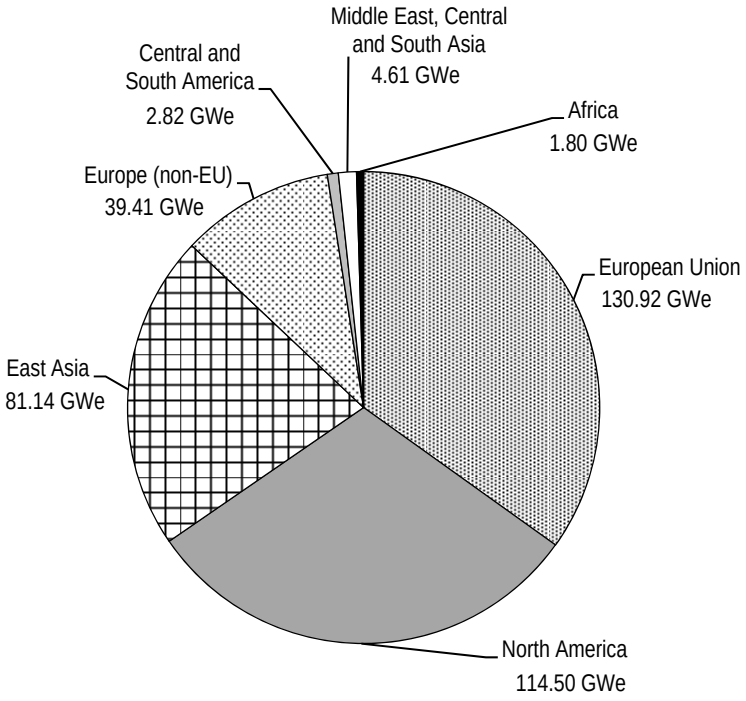
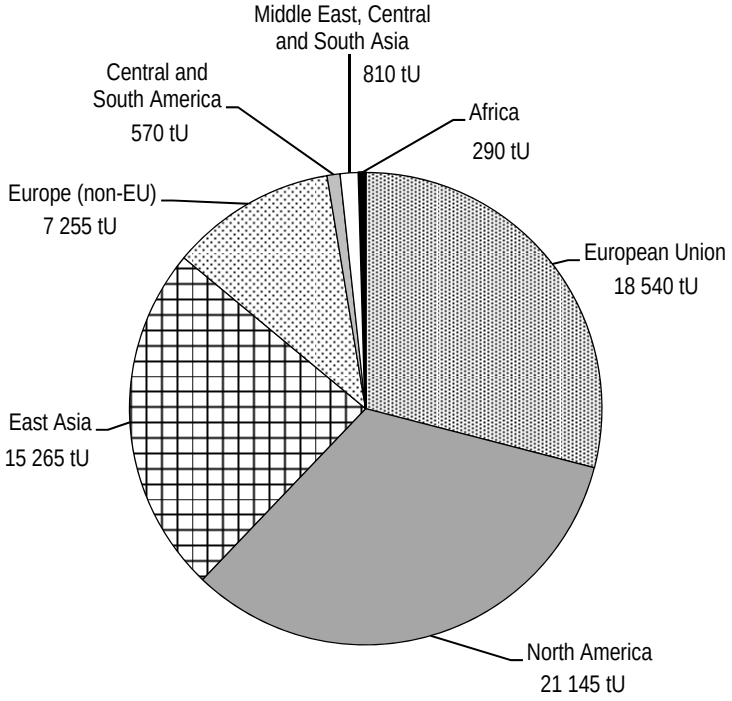



**Figure 2.2. 2010 world uranium requirements: 63 875 tU**



## Table 2.2. Electricity generated at nuclear power plants

(TWh net)

| Country | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|
| Argentina | 6.7 | 6.8 | 7.6[d] | 6.7[d] |
| Armenia | 2.4 | 2.3 | 2.3 | 2.3 |
| Belgium | 45.9+ | 43.4 | 45.0 | 45.7 |
| Brazil | 11.7[d] | 13.2[d] | 12.2[d] | 13.9[a, d] |
| Bulgaria | 13.7* | 14.7* | 14.2* | 14.2* |
| Canada | 88.2 | 88.6 | 85.3 | 85.3 |
| China[c] | 59.3 | 65.3 | 65.7[a, d] | 71.0[a, d] |
| Czech Republic | 24.6 | 25.0 | 25.7[a] | 26.4[a] |
| Finland | 22.5[a] | 22.1 | 22.7[a] | 21.9 |
| France | 418.0 | 417.6 | 390.0 | 407.9 |
| Germany | 133.2 | 140.9 | 128.0 | 133.0 |
| Hungary | 13.8 | 14.0[a] | 14.6+ | 14.8[a]+ |
| India | 15.8[d] | 13.2[d] | 14.8[d] | 20.5[d]+ |
| Japan | 263.8 | 258.1 | 263.1+ | 279.3+ |
| Korea, Republic of | 135.4+ | 143.4[a]+ | 141.0+ | 142.0+ |
| Lithuania | 9.1* | 9.1* | 10.0* | 0.0 |
| Mexico | 9.9+ | 9.4+ | 10.1+ | 5.6+ |
| Netherlands | 4.0 | 4.0 | 4.0+ | 4.0+ |
| Pakistan | 2.3 | 1.7 | 2.6* | 2.6* |
| Romania* | 7.1 | 10.3 | 10.8 | 10.7 |
| Russian Federation | 148.0[d] | 152.1[d] | 152.8[a, d] | 159.4[a, d] |
| Slovak Republic | 14.1+ | 15.4+ | 13.1 | 13.5 |
| Slovenia | 5.3 | 6.0[a] | 5.5+ | 5.4+ |
| South Africa* | 12.6 | 12.8 | 11.6 | 12.9 |
| Spain+ | 52.7 | 56.4 | 50.5 | 59.2 |
| Sweden | 63.8+ | 61.3[b] | 50.0+ | 55.7* |
| Switzerland | 26.5+ | 26.3+ | 26.3* | 25.3* |
| Ukraine | 87.2 | 84.5* | 78.0[d] | 84.0* |
| United Kingdom | 57.3+ | 47.7+ | 62.9+ | 56.9* |
| United States | 806.4[a] | 806.2 | 799.0+ | 803.0+ |
| OECD | 2 180.1 | 2 179.8 | 2 136.8 | 2 184.9 |
| Total | 2 600.3 | 2 611.1 | 2 559.3 | 2 623.0 |

* Secretariat estimate.

\+ *Nuclear Energy Data*, OECD, Paris, 2011.

(a) Generation record.

(b) Provisional data.

(c) The following data for Chinese Taipei are included in the world total but not in the total for China: 39.0 TWh in 2007, 39.3 TWh in 2008, 39.9 TWh in 2009, 39.9 TWh in 2010.

(d) Gross capacity converted to net by Secretariat.

### *European Union (130.92 GWe net as of 1 January 2011)*

As of 1 January 2011, 143 nuclear reactors were operating in the European Union (EU). During 2009 and 2010, no reactors were connected to the grid and one was shut down (Phenix, France, 0.013 GWe). Two European pressurised-water reactors (EPRs) were under construction (one each in Finland and France) and are expected to commence operation by 2014 and 2016, respectively. Construction of a third EPR is expected to begin in France, perhaps as early as 2015. In the Slovak Republic, construction to complete Mochovce units 3 and 4 continues and in Bulgaria preliminary construction work on two reactors has been initiated at the Belene site. Both of these latter two projects are aimed at replacing capacity lost by the required shutdown of older reactor designs in these countries, a condition of entry into the EU. Work on the Bulgarian reactors has not progressed as rapidly as expected however, owing to rising costs and challenges associated with securing investment.

Nuclear phase-out policies remain in place in Belgium and Germany, although such policies were scheduled to be relaxed in these countries prior to the Fukushima accident. The European Commission's proposal to reduce the impacts of climate change by reducing carbon emissions by 20%, combined with concerns over security of energy supply, had caused renewed interest in nuclear energy as a secure source of low-carbon, baseload electricity generation. However, costs are generally expected to rise as a result of increased regulatory requirements stemming from the analysis of the accident at the Fukushima Daiichi NPP. The EU is also committed to carrying out stress tests on the entire reactor fleet and possibly those operating in adjacent countries in response to the Fukushima accident, focusing on natural initiating events, including earthquake, tsunami and extreme weather, the loss of safety systems and severe accident management. Until this process has been completed, it is difficult to say how nuclear energy policy within the EU will further evolve.

In **Belgium**, the government's policy to phase-out nuclear energy by limiting the operational lives of its 7 reactors to 40 years and not permitting construction of new plants continues, although the policy can be overridden if the country's security of energy supply is threatened. In late 2009 the government announced its intention to relax this policy by granting a one-time, ten-year extension to the three oldest units in the fleet (Doel 1, Doel 2 and Tihange 1). However, the legislation has not been amended to enact this policy change and if this situation persists, all NPPs in Belgium would be shut down by 2025. Following the Fukushima accident, it was announced that the decision to extend the lifetime of the three oldest reactors would be put on hold until EU stress tests are carried out. Plans to collect a "contribution" from NPP operators (principally Electrabel, the majority owner of nuclear generating plants in the country) of up to EUR 250 million in order to balance the budget, as well as additional commitments to maintain 13 000 jobs in energy efficiency and to devote one-third of its research budget to renewable energy, remain before the courts as Electrabel's owner, Gaz de France Suez, has challenged these charges.

In **Bulgaria**, following the closure of two additional reactors at Kozloduy (about 0.41 GWe net each) at the end of 2006, only two larger units (about 0.95 GWe net each) remain in operation at the site that once had six operating reactors. The two units generated about 33% of the country's electricity in 2010. To compensate for the loss of nuclear generating capacity and to regain its position as a major exporter of electricity in the region without increasing greenhouse gas emissions, preliminary construction of two VVER reactors (0.95 GWe net each), supplied by the Russian Federation, began in 2008 at the Belene site. Following the Fukushima accident the governments of Bulgaria and the Russian Federation signed a memorandum to stop construction at Belene until June 2011 in order to carry out detailed analyses of nuclear and radiation safety issues at the plant. Prior to this work stoppage the project had faced setbacks due to lack of funds. As of October 2011 negotiations were continuing and it was not expected that a decision on whether to proceed would be made until after EU stress tests are completed.

In the **Czech Republic**, a total of six reactors were in operation on 1 January 2011 with an installed capacity of 3.7 GWe net. Ongoing modernisation and power uprates at the Dukovany NPP (4 VVERs with a capacity of 0.43 GWe net each) are expected to increase generation capacity by about 14% by 2013. The public tender for the construction of two new units at the Temelin plant launched by the Czech Power Company CEZ in August 2009 continues. These units are planned to be in operation shortly after 2020 and just before 2030, respectively. A decision about the installed capacity of the new units has not yet been made since it will stem from the successful bidder in the project. Following the Fukushima accident the government restated the importance of nuclear power to the country and vowed to move ahead with its nuclear development plans.

In **Finland**, construction of the Olkiluoto 3 EPR (about 1.6 GWe net) NPP is now expected to be completed in 2014, five years after the originally planned start-up date. While construction continued, three utility groups (Fortum, TVO and Fennovoima) submitted applications for a decision-in-principle to build a total of three new NPPs. Decisions-in-principle on these applications, delivered by government in May 2009, were positive for TVO and Fennovoima, but Fortum's application was turned down. Although all three projects fulfilled all safety and environmental requirements, projected national energy needs by 2020 currently limit nuclear power development to two new units, as outlined in the Nuclear Energy Law. The proposed new TVO and Fennovoima projects are to produce cost price electricity to meet the needs of Finnish industries that are funding the projects. In 2009, cabinet determined that nuclear and hydro power plants in Finland would be subject to a tax to reduce profits resulting from what was termed "unearned income" accrued from low-carbon generating plants built before the Kyoto Protocol of 1997. It has been reported that the government of Finland is considering introducing a tax on nuclear fuel, potentially amounting to as much as EUR 100 million annually. In October 2011, Fennovoima announced that it would build its new reactor in Pyhajoki in northern Finland, with construction expected to begin in 2015.

In **France**, one reactor (the Phenix fast reactor, 0.13 GWe net) was shut down in early 2010 and no new reactors have been added to the grid. Construction of a new EPR at the Flamanville site began in late 2007 and the unit is scheduled to begin commercial operation by 2016. A survey is expected to be launched in 2012, presumably after the presidential elections, for the construction of a second EPR at Penly. With favourable survey results, this reactor would be expected to be in operation before 2020. Like Flamanville, Penly is the site of two currently operating reactors. In 2006, AREVA began construction of the EUR 3 billion centrifuge enrichment facility (Georges Besse II) in Tricastin to replace the existing, energy intensive gas diffusion plant. Construction has proceeded on schedule and limited commercial production began in late 2010. The modular project is expected to be ramped up to full production capacity of 7.5 million SWU around 2016, with the potential to expand thereafter to 11 million SWU, depending on market conditions. In late 2010, it was decided to extend minimum capacity operations at the EURODIF gas diffusion plant for two years until 2012 in order to smooth the transition to the Georges Besse II centrifuge plant and to prepare for the definitive shut down of the gas diffusion facility. In late 2010, EDF received approval to run the 30-year-old, 900 MWe Tricastin unit 1 reactor for an additional 10 years, the first EDF NPP to receive such an extension. Since as much as 80% of the electricity produced at Tricastin is used to power the EURODIF gas enrichment plant, and centrifuge enrichment requires less than 5% of the electricity that the diffusion process does, much of the Tricastin electrical output will be available for other uses in the near future. In the wake of the Fukushima accident, the government of France called for a review of all the nuclear facilities to assess their abilities to resist flooding, earthquakes, power outages, failure of the cooling systems and operational management incidents. For the 80 facilities identified as priorities, including nuclear power reactors, operators (AREVA, CEA and EDF) had submitted reports by 15 September 2011. The French Nuclear Safety Authority (ASN) is expected to provide government with its review of these reports in early 2012. For most

other facilities, operators must submit reports by 15 September 2012. However, the government remains committed to nuclear power.

In **Germany**, changes to the Nuclear Power Act (NPA) in 2002 enshrined the nuclear phase-out in German law, whereby each reactor was assigned a residual electricity output such that the total output corresponded to an average 32-year lifetime. This has already brought about the early shutdown of two reactors. In December 2010, the NPA was amended to increase the assigned residual electricity output, extending the operating lives of the existing reactors by an average of 12 years. Nuclear power stations that started their commercial operation up to and including 1980 were granted 8 more years of output and newer reactors were granted 14 more years. However, following the Fukushima accident the German government decided to reassess the risks posed by nuclear energy and a comprehensive safety review of all 17 operating NPPs was launched. The seven NPPs commissioned prior to 1980 were immediately shut down for the duration of a three-month moratorium and review. On 30 May 2011, the German cabinet announced that it had agreed to accelerate the nuclear phase-out by shutting down permanently the seven oldest reactors that were taken offline during the review plus the Krümmel NPP which had been offline for maintenance. The remaining nine reactors will be taken offline between 2015 and 2022. A tax on spent fuel rods, under consideration since the December 2010 amendments, is to remain in place despite the accelerated shutdown schedule. This tax has been challenged by utilities operating reactors in the country who are also seeking compensation for the shutdown of eight reactors. Parliament voted in favour of the accelerated exit from nuclear power in July 2011.

In **Hungary**, the four VVER reactors in operation at the Paks NPP (1.9 GWe net), a critical component of domestic electricity supply, accounted for over 43% of the total Hungarian electricity generation in 2010. In order to enhance the economic and operational effectiveness of the plant, a programme that included power uprates, maintenance optimisation and operating lifetime extension (by 20 years) was initiated in 2005. With the uprate and optimisation programme completed in 2010, focus has turned to critical lifetime extensions of the four Paks units, the first of which expected to be initiated in late 2011. A national energy policy developed by the Hungarian parliament for the period of 2008-2020 designed to foster the long-term safety, competitiveness and sustainability of energy supply, included the construction of new reactors, beginning with two at the Paks site. In 2010, preliminary work for the two new Paks units was conducted. The Hungarian government remains committed to nuclear power and indicated that it had not undertaken a review of the country's nuclear programme following the Fukushima accident, noting that the Paks NPP meets the strictest safety requirements. The Paks plan will be evaluated as part of the EU stress tests.

In **Italy**, the centre-right government elected in 2008 set in motion processes to bring about the removal a 20-year ban on nuclear power. A new National Energy Strategy, to be released in 2011, is expected to include the rebuilding of the nuclear sector, improving competition in electricity production, diversifying energy sources and reducing greenhouse gas emissions. Numerous legislative and organisational steps related to the new nuclear programme have been taken since 2008 and nuclear co-operation agreements have been signed, with the goal of having the first new NPPs under construction by 2013. Italy is currently heavily reliant on imported fuels to meet over 85% of its energy needs and has high electricity prices and occasional electricity shortages. However, in the wake of the Fukushima accident the Italian government put the nuclear development plan on hold for at least one year. The continuation of the moratorium will not however restrict ongoing work on the disposal of radioactive waste, including the development of a national repository. However, Italians voted overwhelmingly against a return to nuclear power in a national referendum held in mid-June 2011.

In **Lithuania**, Ignalina 2 (1.2 GWe net) was shut down at the end of 2009 in accordance with agreements governing entry into the EU (Ignalina 1 had been shut down on 31 December 2004 for the same reason). The closure of these reactors

significantly reduces the electricity generation capabilities of the country (Ignalina 2 provided almost 73% of the electricity generated in the country in 2008). Facing a looming electricity shortage the government ran a competitive tender process in 2010 that failed when one bidder did not comply with requirements and a second withdrew from the process. In 2011, new bids were received from Westinghouse and Hitachi-GE, breathing new life into the project that aims to have new reactors (to a maximum capacity of 3.4 GWe) in operation by 2020. Talks on these latest bids with possible partners Latvia and Estonia are to be carried out in order to further the development of a large new power plant to supply the region. Activity has also been focused on developing links to the European electrical grid. Although public support for nuclear power in Lithuania reportedly dropped sharply following the Fukushima accident, the Lithuanian government remains firmly committed to nuclear power. In July 2011, it was announced that the government was in discussions with Hitachi-GE with the goal of signing a contract by the end of 2011 for the construction of an advanced boiling water reactor (ABWR, 1.35 GWe) that is to begin operation in 2020.

In the **Netherlands**, the government published in February 2011 a list of conditions that anyone planning to build a new NPP would be required to meet in order for the government to process an application. These requirements include that the reactor design and safety levels meet the highest standards, including withstanding an airplane crash, and that the plant owner is responsible for dealing with waste and decommissioning (and posting financial guarantees to do so). Should these conditions be met, the government indicated that permitting could proceed to allow reactor construction by 2015, the end of the current government's term. The government also made it clear that although there will be no state investment in new NPPs, it is willing to work towards streamlining and simplifying the regulatory approval processes. Both DELTA (in partnership with EDF) and Energy Resources Holding are expected to submit applications for the new build which is expected to take place at Borssele, the site of the single operating PWR in the country. Following the Fukushima accident, the Dutch government stated that it intends to push ahead with plans to build a second reactor in the country.

In **Poland**, the government is continuing to move forward with plans to construct 6 GWe of new nuclear power generation. Poland currently generates approximately 90% of its electricity in coal-fired plants. The original schedule for nuclear development had called for the first 3 GWe NPP to be in operation by 2020, but this target date has been pushed back to approximately 2025 to provide time to fill gaps in expertise. A second 3 GWe NPP is expected to be in operation by 2030. A consortium led by state-owned Polska Grupa Energetyczna (PGE, the Polish Energy Group) is to organise the project. Poland intends to engage a foreign partner to share in the investment. Both a site selection process and a tender for the reactors are expected to be launched in 2012.

In **Romania**, the two CANDU reactors currently in operation at the Cernavoda NPP provided about 20% of the electricity generated in the country in 2010. The government of Romania plans to expand the facility by adding two more reactors by 2035, but the project has not progressed as rapidly as planned, principally due to uncertainties and the current investment climate. The Romanian government launched a tender in 2007 for the USD 5 billion construction of Cernavoda units 3 and 4 (each with a capacity of 0.72 GWe). In November 2008, EnergoNuclear SA was formed with foreign investors to undertake the construction, commissioning and operation of these two new reactors. However, in January 2011 GDF Suez, RWE and Iberdrola announced that they had decided to terminate their participation in EnergoNuclear SA, citing economic and market uncertainties. CEZ had previously sold its share in the company to state-owned Nuclearelectrica (the owner of Cernavoda) at the end of 2010. The entities remaining in the project – ArcelorMittal Romania and Enel Italy – are reportedly interested in proceeding, although the construction start date has been pushed back from 2010 to 2012.

The Fukushima accident has not caused the government to change its nuclear construction plans.

In the **Slovak Republic**, a total of four reactors with a combined capacity of 1.8 GWe net were in operation as of 1 January 2011. In 2010, the four operating reactors provided about 52% of the total electricity generated in the country. Power uprating of Mochovce 1 and 2 and Bohunice units 3 and 4 was completed in 2008 and 2010, respectively. Loading of fuel with higher enrichment (up to 4.87%) in the Mochove reactors began in 2011 and is scheduled to begin in the Bohunice units in 2012. Work to complete construction of Mochovce 3 and 4 (construction of the two reactors was stopped in 1992) was officially initiated in 2008 with completion expected in 2012 and 2013. When completed, the two units will add 0.9 GWe of electrical generating capacity to the grid. In December 2008, the Czech company CEZ was selected to form a partnership with the Slovak government to build an additional two reactors at the Bohunice site. These reactors were expected to be completed in the 2020 time frame but the schedule for the first of these two units had reportedly slipped by five years, according to the national regulator. The government of the Slovak Republic supports the construction of NPPs as part of its plan to make the country self-sufficient in energy and there is no evidence that the Fukushima accident has altered this plan.

In **Slovenia**, the single nuclear reactor in operation (Krško, 0.69 GWe) is jointly owned and operated with Croatia by Nuklearna Elektrana Krško. The Krško reactor began commercial operation in 1983 with an operational design lifetime of 40 years. Steam generators were replaced and the plant was uprated in 2001. The unit accounted for 37% of the electricity generated in Slovenia in 2010, although a proportion of this is exported to supply about 20% of Croatia's electricity supply. The government of Slovenia is expecting to build a second NPP by 2025, subject to parliamentary approval and a possible referendum. Following Fukushima, the President of Slovenia ordered a check of the reactor's capability to withstand a strong earthquake, but gave no indication that the government would alter its plan to build a second reactor.

In **Spain**, the energy policy of the new government elected in November 2011 is based on a sustainable, balanced and diversified energy mix that takes into account all energy sources and available capacities while reducing dependence on external energy sources. Having in mind that nuclear energy contributes both to the diversification of energy supply sources and to the reduction of greenhouse emissions, the nuclear assets that are currently in operation – which represent important generation capacity in the country – could not be disregarded whenever they comply with the conditions on nuclear safety and radiological protections imposed by the Nuclear Safety Council (CSN). Through 2010 and 2011, the Spanish government approved ten-year licence extensions for Ascó units 1 and 2, Almaraz units 1 and 2, Vandellós unit 2 and the lone Cofrentes unit, after a favourable report by the CSN. The eight NPPs currently in operation in Spain (7.4 GWe net) provided about 20% of the electricity generated in 2011.

In **Sweden**, the government narrowly voted in favour of two bills that gave new life to the country's nuclear power programme in 2010. The first allows for the construction of replacement reactors once the existing reactors have reached the end of the operational lifetime, effectively overturning the 1980 ban on the construction of new NPPs and the phase-out of nuclear energy. The replacement reactors must be built on an existing site and can only begin operation once an older plant is permanently shut down. None of the ten currently operating reactors (a total of 9.3 GWe net, providing 37% of the electricity generated in 2010) are expected to be retired from service before 2020. The second bill increases the amount of compensation paid by companies who own nuclear reactors and increases by four times the financial liability of these same owners. Following the Fukushima accident, the government ordered a comprehensive review of the current reactor fleet ahead of the EU stress tests but indicated that the recent legislative changes outlined above would not be reconsidered.

In the **United Kingdom**, the government remains committed to establishing a framework to allow private industry to replace nuclear generating capacity in order to meet demand and new carbon emission reduction targets with no government subsidies. Several of the current fleet of aging reactors, as well as generating facilities powered by coal, are set to be retired from service over the course of the next ten years and the construction of replacement power generation facilities is crucial. The government remains committed to its nuclear development policy following the Fukushima accident, noting the observation from the regulatory body that the United Kingdom does not face the same severity of natural hazards that were the cause of the Fukushima accident. However, a slight delay in reactor design approval is expected. To support the construction of new, low-carbon emitting generation facilities, the government is undertaking a reform of the liberalised electricity market. Reforms under consideration include maintaining a minimum price for carbon dioxide emissions, long-term feed-in tariffs for low-carbon generating sources that would "top-up," prices paid for generation if wholesale prices are low, capacity payments to ensure security of supply as intermittent and inflexible low-carbon generation capacity increases and emission performance standards that would limit the amount of carbon dioxide that the most polluting power plants could emit. A public consultation period on the National Policy Statements on Energy closed in mid-2011 and the package was approved by parliament, confirming eight potential sites for new nuclear construction. Planning reforms to expedite plant construction were also passed. However, uncertainty following the Fukushima accident has slowed development plans, with EDF Energy announcing that it would not be making an investment decision until the end of 2012 and the Project Horizon consortium reportedly seeking a cash injection of EUR 5 billion in October 2011. On 31 October 2011, EDF Energy submitted an application to the Infrastructure Planning Commission to build a new NPP.

The reactor-related uranium requirements for the EU in 2010 amounted to about 18 540 tU and are expected to decline slightly to 18 020 tU in 2011.

### *North America (114.50 GWe net as of 1 January 2011)*

At the beginning of 2011, a total of 104 reactors were connected to the grid in the United States, 17 in Canada and 2 in Mexico. Construction to complete one reactor in the United States continued (Watts Bar 2, completion expected in 2012) and none were shut down in 2009 and 2010. Three CANDU reactors undergoing extensive refurbishment in Canada (Bruce A units 1 and 2 and Point Lepreau, a combined total of 2.135 GWe) are not included in the totals above.

In **Canada**, several possible new nuclear build projects under consideration by private companies and provincial governments have not as yet progressed to firm commitments to proceed. Following the Fukushima accident, the government of Ontario stated that it remained committed to a policy of nuclear energy supplying 50% of the province's electricity even though plans for new build have been suspended in the wake of an unsuccessful bidding process in 2009. Both Ontario Power Generation (OPG) and Bruce Power had submitted formal applications for new reactor construction and AREVA, Westinghouse and Atomic Energy of Canada Ltd. submitted bids. Bruce Power subsequently announced that due to declining energy demand in Ontario it would focus on reactor refurbishment projects rather than going ahead with its application for new reactor construction. Proposals to build up to four reactors to provide power for development of the oil sands and building a second reactor in New Brunswick have not gained momentum owing to concerns about costs and other considerations. Refurbishment projects remain underway in Ontario and New Brunswick although some delays and cost overruns have been encountered (all are currently expected to be returned to service in 2012). Hydro Québec recently decided to postpone a decision to proceed with the refurbishment of the single CANDU reactor in operation in the province. In December 2009, the federal government announced that it was inviting proposals for

investment in the commercial CANDU Reactor Division of Atomic Energy of Canada Ltd. (AECL), the next step in restructuring the Crown Corporation. In late June 2011, it was announced that the engineering company SNC-Lavalin had acquired the CANDU Reactor Division for CAD 15 million and royalty payments arising from future life extension projects and CANDU sales. In late August 2011, it was announced that an independent environmental assessment panel appointed by the Canadian government had concluded that a proposal to build as many as four reactors at the Darlington site was unlikely to cause any adverse environmental impacts.

In **Mexico**, a four-year, USD 605 million refurbishment programme of the two units at Laguna Verde by the Federal Electricity Commission was successfully completed in 2011, increasing the power of the two units by about 20% and extending the plant's operating life to 40 years, pending regulatory approval. The two units (a total of 1.4 GWe net) typically provide about 4% of the electricity generated in the country. Despite the Fukushima accident, the possibility of building additional NPPs at Laguna Verde and other sites on the coast of the Gulf of Mexico to reduce dependence on gas-fired electricity generating plants remains under consideration. A feasibility study is reportedly ongoing but a decision to proceed has not yet been made.

In the **United States**, although a total of 17 combined construction and operating licence applications representing more than 35 GWe of new nuclear generating capacity had been filed by the end of 2010, delays or other concerns have slowed progress on most. Five projects are considered sufficiently advanced to be categorised by the Energy Information Administration as "fully committed" to the construction of a total of nine new reactors (Calvert Cliffs, Levy County, South Texas, Virgil Summer, and Vogtle) and construction of two Vogtle AP 1000 units is expected to begin at the end of 2011. Although these developments represent solid movement towards building new reactors, financing and loan guarantees remain important issues. The cost of labour and materials are high and the sheer size of the investments led some utility executives to suggest that new nuclear build is unlikely proceed without loan guarantees (part of the incentives for new, low-carbon emitting power plant construction contained in the Energy Policy Act of 2005). Despite slow progress in new build projects, nuclear generating capacity continues to grow. In 2007, the Tennessee Valley Authority (TVA) resumed construction of the Watts Bar 2 reactor, a programme that is expected to cost about USD 2.5 billion. It is anticipated that the Westinghouse-designed 1 800 MWe reactor will be on line in 2013. This follows the successful return to service in May 2007 of TVA's Browns Ferry-1 plant (shut down since 1985) after a USD 1.8 billion restart programme. And in August 2011, TVA approved a USD 4.9 billion project to finalise construction of the 1 260 MWe Bellefonte 1 PWR reactor that was over 50% complete when construction was stopped in the 1980s. In addition, 135 power uprates had been approved by the Nuclear Regulatory Commission (NRC) as of 31 December 2010, adding about 5.8 GWe of generating capacity. Another 12 requests for uprates are under review and a further 35 applications are expected between 2011 and 2015, potentially adding another 2.385 GWe in generating capacity. By the end of 2010, 67 reactors have been approved to add 20 years to their initial 40-year life expectancy and another 16 application are currently under review. Following the Fukushima accident, the NRC ordered a review of all operating reactors to assess how each would cope with extreme events, including loss of power. The President has repeatedly expressed support for developing new nuclear generating capacity.

Annual uranium requirements for North America were about 21 145 tU in 2010 and are expected to increase to 22 005 tU in 2011.

### *East Asia (81.14 GWe net as of 1 January 2011)*

As of 1 January 2011, 94 reactors[2] were in operation in East Asia. In this region, which is undergoing the strongest growth in nuclear capacity in the world, four NPPs were connected to the grid (about 3.4 GWe net) during 2009 and 2010 while none were shut down. During these same two years, construction of a total of 23 reactors was initiated. If all are completed, a total of about 27.3 GWe net will be added to the grid in the East Asia region.

In **China**, there were 13 reactors in operation (10.1 GWe net) and 26 under construction (about 27.2 GWe net) as of 1 January 2011. In 2009, construction of nine reactors was initiated and in 2010 construction of an additional ten reactors officially began. When completed, these 19 reactors will add 24.6 GWe of generating capacity to the grid. This pace of NPP construction in China is expected to continue in order to meet the government's plan to substantially increase the total nuclear capacity to as much as 58 GWe by 2020. A number of technologies are already in use or expected to be used to increase capacity, including the AP 1000, VVER 1000, EPR 1600, Candu 6 and the CPR-1000 designs (a Chinese design based on French designs). The government has also expressed the intent to further increase nuclear capacity to over 80 GWe by 2030, accompanied by the gradual development and phase-in of a closed fuel cycle with fast reactors. Such ambitious plans would not, however bring about a large change in the relative contribution of nuclear generating capacity to the energy mix in China. For example, the planned rapid growth in nuclear capacity by 2020 is only expected to raise the share of nuclear generation from 4% to 5%, such is the rate at which demand is expected to increase and, as a result, other means of generating electricity are expected to grow. Following the Fukushima accident, the Chinese government imposed a two-year freeze on new nuclear projects, required safety checks at all operating plants, suspended the approval of 28 planned reactors and temporarily halted approvals for the construction of NPPs in marine areas. By June 2011 safety checks had been completed on all operating reactors with no problems identified but by October 2011 it remained unclear what implications potential new regulatory requirements, including those stemming from an assessment of planned and approved projects involving the Generation II CPR-1000 design, would have on nuclear development plans.

In **Japan**, construction of the Tomari 3 pressurised water reactor (0.866 GWe) was completed in 2009 and in 2010, construction of Ohma advanced boiling water reactor (1.325 GWe) was initiated. Hamaoka 1 and 2 were permanently shut down in January 2009 (1.321 GWe). Work had also been continuing to restart the Monju fast reactor. However, on 11 March 2011 north-east Japan was struck by a 9.0 magnitude earthquake and large tsunami that engulfed large areas of the north-eastern coastal region, including NPPs. Although all reactors reportedly shut down safely as planned during the earthquake, the tsunami protection barrier around the Fukushima Daiichi NPP was inadequate to stop the inflow of seawater that put all back-up power sources out of operation. As a result, all offsite and onsite sources of power were lost and three of the six reactors in operation at the time could not be adequately cooled. Meltdown of fuel occurred in these three reactors and explosions caused by hydrogen releases extensively damaged the reactor buildings. Offsite radiation releases occurred, forcing the evacuation of 80 000 residents within a 20 km radius of the plant. This serious accident (INES scale 7) has led to a reconsideration of the country's nuclear development programme. Four of the Fukushima Daiichi reactors have since been permanently shut down due to the extent of the damage, and efforts to achieve a cold shutdown are expected to continue until early 2012. In addition to the immediate closure of the four Fukushima Daiichi reactors, all three operating reactors at the Hamaoka NPS were shut down in order to strengthen the

2. There were also six NPPs in operation in Chinese Taipei (about 4.9 GWe net) and two plants under construction (about 2.6 GWe net).

plant's tsunami defences. The Fukushima accident has caused a complete reconsideration of the role of nuclear power in Japan in the national energy plan. As of October 2011, it remains unclear what the longer term impact of this event will be on Japan's nuclear programme. Given the marked resistance to nuclear power by the public and local politicians, it is also proving challenging to restart other reactors as they are taken out of service for routine maintenance. This has resulted in a steep drop in nuclear generating capacity.

In the **Republic of Korea**, construction of Shin Kori 4 (1.34 GWe) began in 2009 and construction of the Shin Kori 3 and 4 reactors, the first APR 1400 units to be built, continues with commissioning expected in 2013 and 2014, respectively. Shin Kori 1 was connected to the grid in 2010. In late 2008, the government of the Republic of Korea announced a new "National Energy Basic Plan" that calls for an increase in nuclear generating capacity to amount to about 40% of the country's generation facilities by 2030. By the end of 2022, nuclear capacity is expected to reach 32.9 GWe, representing a 33% share of total generation capacity. In late 2009, a KEPCO consortium won an open bidding process to install four NPPs in the United Arab Emirates by 2020, marking the first export of a Korean commercial NPP. Following the Fukushima accident, the government ordered a safety inspection of all 21 NPPs in operation. Although no problems were identified in the review, planned safety upgrades amounting to USD 922 million are to be implemented over the next five years, principally to strengthen defences against natural hazards such as earthquakes and tsunamis. The government also announced that there would be no changes to its national energy plan, believing that there is no alternative to nuclear power at this stage.

Although **Mongolia** does not currently have NPPs, it has signalled its interest in developing nuclear generation capacity by using small and medium-sized reactors after signing an agreement with the Russian Federation on the exploration, extraction and processing of uranium resources.

The 2010 reactor-related uranium requirements for the East Asia region were 15 265 tU and for 2011 are expected to increase to 15 850 tU.

### *Europe (non EU) (39.41 GWe net as of 1 January 2011)*

As of 1 January 2011, 53 reactors were in operation in 9 countries. This region is also undergoing strong growth with 13 reactors under construction that will add about 11 GWe net when completed. During 2009 and 2010, one new plant was connected to the grid in the Russian Federation (Rostov 0.95 GWe), none were shut down and construction was initiated on four reactors in the Russian Federation (a total of 4.2 GWe net).

Two NPPs were connected to the grid in **Armenia**, one in 1976 and the second in 1980, each with a design lifetime of 30 years. Both were shut down following a major earthquake in 1989. In 1995, the younger of the two (unit 2) was brought back on line after the country experienced severe power shortages. In 2010, this single unit, Armenia 2 (0.38 GWe) provided 39% of the electricity generated in the country. Concerns have been expressed about the continued operation of the reactor, particularly following the Fukushima accident, since the region is seismically active and the design has no primary containment structure. Armenia has however resisted efforts to close the plant, arguing that it is essential to the country's energy security and significant effort has been directed towards safety and security upgrades. Plans to replace the unit (expected to be shut down in 2016) are currently underway, with the planned new 1 GWe unit expected to be operational as early as 2017. Armenia has engaged an engineering firm Worley Parsons to manage the project, estimated to amount to a total cost of USD 4.5 billion. In June 2011, Armenia signed a confidentiality agreement with Russian NPP vendor JSC Atomstroyexport to exchange documentation essential to advancing the new build project. In the following months, both French and American vendors expressed an

interest in the project, but as of October 2011 no contract to construct the plant had been signed.

In the **Russian Federation**, 32 reactors (22.7 GWe net) were in operation as of 1 January 2011, providing about 17% of the total electricity generated in the country in 2010. A total of 11 reactors were under construction (9.2 GWe net combined), including the Beloyarsk 4 fast reactor (0.8 GWe net), where construction was initiated in July 2006. In 2009, construction of Rostov 3 (1.0 GWe net) and Novovoronezh 2-2 (1.0 GWe net) officially began and in 2010, construction of Rostov 4 (1.0 GWe net) and Leningrad 2-2 (1.1 GWe net) was initiated. No reactors were shut down over these two years. In April 2009, the government of the Russian Federation allocated an additional USD 1.5 billion to the state corporation Rosatom in order to attain the goal of NPPs generating about 25% to 30% of the country's electricity in the face of the economic crisis. Achieving this target will require the construction of a total of 26 new reactors. Although current economic conditions limit the planned rate of construction to one reactor per year, in a few years it is expected that the rate of build will increase to 2-3 GWe/year of capacity. By 2050 the current plan calls for inherently safe nuclear plants to be in operation using fast reactors with a closed fuel cycle and MOX. Plans are also in place to upgrade existing power plants by using improved fuels more efficiently and to extend operating lives. Following the Fukushima accident, the government of the Russian Federation ordered an urgent review of all NPP construction projects, both at home and abroad, although it expressed its intent to continue with its nuclear development plans. In September 2011, Rosatom announced that it intends to extend the life of all its existing reactors to 45 years, including the 11 controversial RBMK reactors, the design involved in the Chernobyl accident.

In **Switzerland**, proposals to build a total of three reactors to replace plants in the current fleet as they reach the end of their operational lifetime were filed in 2008. Switzerland's electricity is produced mainly by hydro and nuclear power, supplemented by imports, but the potential for further hydro development is limited. Following the defeat of a referendum to continue the nuclear phase-out, the Nuclear Energy Act was passed in 2003, setting the stage for the construction of replacement reactors. The replacement reactor proposals had been progressing through the approval process, including a favourable vote in canton Bern, but the Fukushima accident brought these processes to an abrupt halt. On 14 March 2011, the government suspended the approval process for replacement reactors and ordered a safety review of the existing five operating reactors. The safety review identified a number of issues related to earthquakes and floods caused by dam failures and utilities were ordered to address issues identified, including improved instrumentation, earthquake resistance in a fuel storage building and back-up supply of cooling water, by 31 August 2011. On 25 May 2011, cabinet decided to cancel the approval process for the replacement reactors and proposed that all five existing reactors be shut down between 2019 and 2034 (at the end of their 50-year lifetimes) with replacement power to be provided by hydro, renewable energy and fossil fuels, if necessary, combined with an energy efficiency programme. In late September 2011, the upper house of Swiss parliament voted overwhelmingly in favour of these proposals, moving the country closer towards a nuclear phase-out. The legislation will now go to the lower house for debate and vote and may require a public referendum before becoming law. The five operating reactors in Switzerland typically produce about 40% of electricity generated in the country.

In **Turkey**, after a failed bidding process to construct the country's first NPPs in 2009, an agreement was reached with the Russian Federation to build, own and operate four VVER 1.2 GWe units at the Akkuyu site on the Mediterranean coast at an estimated cost of USD 20 billion. In the longer term, it is reported that the Russian Federation may sell up to 49% of its stake in the project to investors from Turkey and elsewhere. The Turkish Electricity Trade and Contract Corporation has guaranteed the purchase of a fixed amount of the electricity output (70% of the generation from the first two units and 30%

from the remaining two). These reactors are expected to enter into service in the 2018 to 2022 time frame. In the longer term, Turkey plans to install an additional four reactors on the Black Sea coast and has reportedly been in discussions with Japan and the Republic of Korea about the project. Following the Fukushima accident, the government stated that it was determined to move ahead with its nuclear development programme despite the earthquake hazards in the region. Turkey's growing economy faces rapidly escalating electricity demand and nuclear energy is seen as cost-effective means of meeting rising demand. Meeting future energy demand is currently estimated to require an annual investment of USD 5 billion.

In **Ukraine**, 15 reactors with a combined installed capacity of 13.1 GWe net were in operation on 1 January 2011. In 2010, these reactors produced 48% of the electricity generated in the country. Two reactors are currently under construction (Khmelnitski 3 and 4) that, when completed, will add 1.9 GWe capacity to the grid. Construction of these two reactors originally began in the mid-1980s, but was suspended in 1989. In 2010, Ukraine's national electricity generator Energoatom signed an agreement with Atomstroyexport of the Russian Federation to complete the USD 4 billion construction project and the two reactors are now expected to be commissioned in 2016 and 2017. The agreement reportedly involves the Russian Federation providing financing for the design, construction and commissioning of the two reactors and all components supplied by Ukraine will be financed by the Ukrainian budget. The current Ukrainian government strategy calls for the nuclear share to be retained through 2030 at the current level of 45-50% of the total national electricity generation. This is expected to require the construction of 12 new reactors, 10 of which with a capacity of about 1.5 GWe net, along with life extensions of reactors in the existing fleet. Following the Fukushima accident, there is no indication that the government intends to change the nuclear development strategy.

Although other countries in the region do not currently have NPPs, the government of **Belarus** has been actively considering the possibility of building nuclear capacity to meet future energy demand and to reduce greenhouse gas emissions. In October 2011, it was reported that an agreement had been signed with Atomstroyexport for the construction of the country's first NPP, a two-unit VVER 1.2 GWe design expected to be completed in 2017 and 2018. The total cost of this project has been estimated to amount to USD 9 billion, with the Russian Federation reportedly prepared to provide Belarus with a USD 7 billion loan for goods and services connected with the construction.

Reactor-related uranium requirements in 2010 for the Europe (non-EU) region were about 7 255 tU and are expected to increase slightly to 7 280 tU in 2011.

### *Middle East, Central and Southern Asia (4.61 GWe net as of 1 January 2011)*

As of 1 January 2011, 21 reactors were in operation in this region and 8 were under construction (a total of 4.6 GWe net). During 2009 and 2010, two reactors were connected to the grid and none were shut down.

In **India**, 19 reactors (4.2 GWe net) were operational on 1 January 2011 and 6 reactors (3 PHWRs, 2 PWRs of Russian design and a prototype fast reactor), with a total capacity of 3.8 GWe net, were under construction. In 2009 and 2010, construction of two PHWRs was completed (Rajastan 5 and 6, a combined total of 0.4 GWe net). In 2010, the 19 reactors in operation provided a little less than 3% of the electricity generated in the country. Government plans call for the increase of the country's nuclear generation capacity to as much as 30 GWe by 2020 and as much as 63 GWe by 2030. In December 2010, the Nuclear Power Corporation of India Ltd (NPCIL) and AREVA signed agreements for a general framework and early works for the construction of two EPRs at Jaitapur in the western state of Maharashtra. The agreement reportedly includes fuel supply at the site that may eventually host as many as six EPRs. Following the Fukushima accident, the Prime Minister ordered NPCIL to conduct a review of safety and security at the operating plants.

There is reportedly consideration being given to additional environmental safeguards to ensure the safety of future plants and the additional four units proposed at the Kudankulam site have been refused environmental clearance until additional information on the safety of designs proposed is provided. Although the safety and security review identified no concerns of significance and the government intends to proceed with its nuclear development plans, public demonstrations at the Kudankulam plant, where two VVER 1.0 GWe units are ready for commissioning, and other indications of public and local political resistance could reshape at least some of these development plans.

In the **Islamic Republic of Iran**, the long anticipated start-up of the Bushehr-1 reactor (about 0.9 GWe net) supplied by Atomstroyexport took place on 4 September 2011, with the reactor supplying power to the grid for the first time. The start-up date of the reactor had been pushed back a number of times due to technical difficulties and other issues. The government of Iran has announced its intention to develop up to 20 GWe net of installed nuclear capacity by 2026 in order to reduce its reliance on fossil fuels.

In **Jordan**, preparatory work to develop the country's uranium resources and construct new NPPs to generate electricity and desalinate water is underway in the face of rising energy demand and the current need to import around 95% of its energy needs. Nuclear co-operation agreements have been signed with several countries, including Argentina, Canada, France, the Russian Federation, the United Kingdom and the United States in support of this policy. In September 2009, an engineering firm was engaged to conduct a siting study for the country's first NPP that is planned to host four units. Challenges such as financing the venture and developing the electricity grid to accommodate distribution, possibly to neighbouring countries, must be overcome along the way however. The country has also thus far refused to give up its right to enrich uranium, a position that may limit international co-operation in nuclear development.

In **Pakistan**, two reactors (about 0.43 GWe net) were operational on 1 January 2011. In 2010, the two reactors provided 2.5% of the electricity produced in the country. In early 2011, a third reactor (0.3 GWe net) was added to the grid (Chasnupp-2), completed under an agreement with the China National Nuclear Corporation and placed under IAEA safeguards. In the face of severe power shortages, the government of Pakistan is reported to have begun construction of an additional two units (0.3 GWe each) with financial and technical assistance from China, after the IAEA Board of Governors approved a safeguards agreement. These units are expected to be completed in the 2016-2018 time frame. In early 2011, the government of Pakistan assigned to the Pakistan Atomic Energy Commission the task of adding ten NPPs (around 8.8 GWe net) to the grid by 2030. Following the Fukushima accident, the government of Pakistan ordered a safety review of its nuclear installations but has shown no sign of changing its nuclear development plan.

In the **United Arab Emirates**, increasing energy demand combined with the decision to reduce domestic consumption of natural gas to maintain the inflow of foreign capital have been central considerations in the government's decision to develop nuclear power generation. It signed agreements with the IAEA on the development of NPPs for peaceful purposes and nuclear co-operation agreements with France, Japan and the United States. In late 2009, a consortium from the Republic of Korea led by KEPCO won a contract to build four APR 1400 reactors (about 5.4 GWe net). Preliminary construction work is underway and the first of these units is expected to be completed by 2017. Although this proposed first nuclear power station will likely generate about 3% of the electricity supply in the country, the government plan is reportedly to have nuclear power supply 15% of the electricity generated by 2025. There are no indications that the government is reconsidering this plan following the Fukushima accident.

Other countries in the region, currently without NPPs, have been considering the development of such facilities, including **Bangladesh**, **Bahrain**, **Iraq**, **Israel**, **Kazakhstan**, **Kuwait**, **Oman**, **Qatar**, **Saudi Arabia**, **Syria** and **Yemen**. Reports at the time of writing

indicate that despite the Fukushima accident the governments of Bangladesh, Kazakhstan and Saudi Arabia are advancing plans to construct nuclear generating capacity.

Reactor-related uranium requirements for the Middle East, Central and Southern Asia region were about 810 tU in 2010 and are expected to increase to 1 165 tU in 2011.

### *Central and South America (2.82 GWe net as of 1 January 2011)*

As of 1 January 2011, a total of four reactors were in operations in two countries in this region and two reactors were under construction.

In **Argentina**, two reactors (Atucha 1 and Embalse; 0.34 GWe and 0.6 GWe, respectively) were in operation on 1 January 2011. In 2010, these two reactors accounted for a little less than 6% of the electricity produced in the country. In August 2006, the state generating company Nucleoeléctrica Argentina restarted construction of Atucha-2 (0.7 GWe net), with the reactor expected to be brought on line in 2011. Construction had been suspended in 1984 when the reactor was about 80% complete because of a lack of funds. The government of Argentina is also considering the construction of another two reactors to provide additional electrical generating capacity by 2017 and 2020. In support of the development plan, initiatives are underway to reactivate the production of heavy water, the development of the small-sized prototype CAREM reactor and the reopening of an enrichment plant. With the licence for the Embalse reactor due to expire in 2014, the government intends to conduct the necessary work to upgrade equipment and extend the life of the Embalse reactor by ten years. Following the Fukushima accident, the government indicated that it was going to continue with its nuclear development plan.

In **Brazil**, two reactors (Angra 1 and 2; 0.5 GWe net and 1.3 GWe net, respectively) were in operation on 1 January 2011. In 2010, these two reactors accounted for about 3% of the electricity generated in Brazil. Construction of the Angra-3 reactor (1.2 GWe net) was restarted in 2010 with completion of the USD 5.1 billion project expected in 2015. Work on this reactor originally began in 1984 but was suspended in 1986. The government of Brazil is considering the possibility of building an additional four to eight reactors by 2030 (increasing installed nuclear generating capacity to as much as 7 GWe) in order to meet rising energy demand. In support of this programme, domestic enrichment capacity is being expanded. In the wake of the Fukushima accident, the government of Brazil is reportedly reconsidering its nuclear development programme.

Other countries in the region, currently without NPPs, have been considering the development of such facilities, including **Bolivia**, **Chile**, **Cuba**, **Uruguay** and **Venezuela**. Given the risk of strong seismic events in **Chile**, the government intends to reconsider nuclear development and observe the response of the Japanese authorities to the Fukushima accident. **Venezuela** has also put its nuclear development plans on hold. Recently passed legislation in **Uruguay** promotes development of renewable energy sources, for the time being putting nuclear development plans on hold.

The uranium requirements for Central and South America amount to about 570 tU in both 2010 and 2011.

### *Africa (1.8 GWe net as of 1 January 2011)*

Nuclear capacity remained constant in Africa with the region's only two reactors located in **South Africa**. In 2010, these two units accounted for about 5% of the total electricity generated in the country. Coal-fired plants are dominant, providing about 90% of the country's electrical generating capacity. In order to meet electricity demand and reduce carbon emissions, South Africa's state-owned utility Eskom solicited bids for a fleet of up to 12 reactors in 2007, but the process was put on hold owing to the financial crisis. The South African government recently approved a 20-year plan that envisions increased reliance on nuclear generating capacity combined with development of

capacity from renewable resources. Under the plan, referred to as the "Integrated Resource Plan", nuclear capacity is to be increased to 23% of generation by 2030. In 2010, the government decided to stop investment in development of the pebble bed modular reactor, a high-temperature, helium-cooled reactor (0.1 GWe net), citing the inability to secure customers or an investment partner and the severity of the economic crisis. Following Fukushima, the government indicated that it would reconsider its nuclear development plan and reassess the safety of its nuclear facilities, but remained convinced that nuclear power would remain a necessary part of the energy strategy.

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

Annual reactor-related uranium requirements for Africa amount to about 290 tU in 2010 and 2011.

#### *South-eastern Asia (0 GWe net as of 1 January 2011)*

This region has no current commercial nuclear generating capacity. However, the governments of **Cambodia**, **Indonesia**, **Malaysia**, the **Philippines**, **Thailand** and **Vietnam** have considered the deployment of nuclear power in the coming years to meet electricity demand without substantially increasing greenhouse gas emissions. Following the Fukushima accident, the Vietnamese government indicated that it would proceed with its nuclear development plans. In November 2010, the Ministry of Industry and Trade in **Vietnam** signed an agreement with Rosatom to construct the country's first NPP. Two 1.2 GWe VVERs are to be built at Ninh Thuan on a turnkey basis. Construction is expected to begin in 2014, with the first reactor expected to be commissioned by 2020. The agreement also reportedly covers nuclear fuel and the return of used fuel for reprocessing. This is the first of what is expected to be as many as 12 NPPs by 2030. Following the Fukushima accident the government of **Thailand** decided to delay its nuclear development plan by three years. It had previously stated its plans to build two NPPs, the first now scheduled to be commissioned in 2023, in order to reduce exposure to fluctuating natural gas prices, the fuel currently used to produce 70% of the country's electricity.

#### *Pacific (0 GWe net as of 1 January 2011)*

This region currently has no commercial nuclear capacity. Current policy prohibits the development of commercial nuclear energy in **Australia**. The government of **New Zealand** also has a policy prohibiting the development of nuclear power but is reported to be considering options for future electricity supply in light of greenhouse gas reduction targets and declining supplies of natural gas.

### 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. As noted, the majority of the anticipated near-term capacity is already in operation, thus short-term requirements can be projected with relative certainty.

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 tended to increase from 71.0% (IAEA, 2012) to generally over 80% since 2000. In 2010, the average world nuclear energy availability

factor (as defined by the IAEA) was 81%. Increased availability tends to increase uranium requirements. Unexpected events have however disrupted the trend of increasing availability factors. After reaching 82.9% in 2006, the world average availability factor declined slightly because of an extended shutdown of seven large reactors at the Kashiwazaki Kariwa station in Japan following a strong earthquake in July 2007. After recovering to 81% in 2010, the world average availability factor can be expected to decline again following the Fukushima accident.

Other factors that affect uranium requirements include fuel-cycle length and discharge burn-up and strategies employed to optimise the relationship between the price of natural uranium and enrichment service.[3] Recent high uranium prices, compared to before 2003, have provided the incentive for utilities to reduce uranium requirements by specifying lower tails assays at enrichment facilities, to the extent possible in current contracts and the ability of the enrichment facilities to provide the increased services. As noted in the 2010 Annual Report of the Euratom Supply Agency (ESA), the average tails assay used by utilities in the EU was 0.25% and the tails assay for enriched uranium products delivered to EU utilities ranged between 0.17% and 0.33% (ESA, 2011).

Tails assay variation and strategies to optimise reactor operation and fuel costs are evident in the uranium requirements data collected for this edition, since global requirements have increased to 63 520 tU and 63 875 tU in 2009 and 2010, respectively after dropping to 59 065 tU in 2008, even though global generating capacity increased by <1% between 2008 and 2010. Uranium requirements (defined in the Red Book as anticipated acquisitions, not necessarily consumption) are however expected to increase in the coming years as new capacity comes online, particularly in Asia, with projected global requirements expected to exceed 70 000 tU by 2015.

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 can be achieved safely and upgrading their generating capacity, where possible. This strategy is especially pronounced in the United States but other countries (e.g. Canada, France, Hungary, Mexico, the Netherlands, the Slovak Republic, the Russian Federation and Sweden) have or are planning to upgrade their generating capacities and/or extend the lives of existing power plants. Regulatory responses to the Fukushima accident may however affect at least some of these plans.

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. Many factors influencing decisions on building new nuclear generating capacity must be considered before any new significant building programmes will be undertaken. These factors include projected electricity demand, security and cost of fuel supplies, the cost of funding these capital intensive projects, the cost competitiveness of nuclear compared to other generation technologies and environmental considerations, such as greenhouse gas emission reduction targets. Proposed waste management strategies, the risk of a nuclear accident and non-proliferation concerns stemming from the relationship between the civil and military nuclear fuel cycles need to be addressed. In the wake of the Fukushima accident, the safety of nuclear energy as well as public acceptance will require greater attention. This is, of course, a pivotal issue in the yet to be determined role that nuclear power will play in Japan.

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.

Despite the reaction of some countries to back away from nuclear power following the Fukushima accident (the strengthening of nuclear phase-out programmes in Belgium, Germany and Switzerland and the decision to not proceed with nuclear power development in Italy following a national referendum), recent events indicate that many nations have decided that, on balance, objective analysis of these factors supports the construction of new NPPs. Significant building programmes are underway in India and the Republic of Korea and following a pause to reassess safety, are expected to continue in China. And although the global financial crisis has slowed new build plans in for example, the Russian Federation and South Africa, these and other nations remain committed to long-term growth in nuclear electricity generating capacity. Smaller scale programmes to increase nuclear generating capacity are also underway in for example, the Czech Republic and Finland, while Poland continues to work towards construction of its first reactors. In the United States, preconstruction activities are underway for two new reactors and two other plants remain under consideration.

The 2011 *World Energy Outlook* (WEO) notes that if governments follow the path of current energy policy severe climate change impacts can be expected and greenhouse gas emissions from electricity production are at the heart of the issue (IEA, 2011). Global electricity demand is expected to increase by about 2.4% a year on average and about 80% of the overall demand growth to 2035 is expected to occur in non-OECD countries, led by China and India which together account for nearly two-thirds of projected global growth. The 2011 WEO includes an examination of the impacts of a significantly reduced role for nuclear power, should such a scenario result from the Fukushima accident, concluding that a significant reduction in nuclear power generation would make achieving greenhouse gas emission reduction goals extremely challenging and costly.

It must be noted however that the global economic slowdown, the credit crisis and the recent decline in natural gas prices have made it more challenging to raise funds for capital intensive projects like NPP construction. Nonetheless, construction programmes, particularly in east and central Asia, along with capacity upgrades and life extensions, are on balance expected to outweigh reactor shutdowns and world installed nuclear capacity is projected to increase through 2035, in turn increasing uranium requirements.

### *Projections to 2035*[4]

Forecasts of installed capacity and uranium requirements, although uncertain due to the above-mentioned factors, point to future growth. Installed nuclear capacity is projected to grow from about 375 GWe net at the beginning of 2011 to between about 540 GWe net (low case) and 746 GWe net (high case) by the year 2035. The low case represents growth of 44% from 2011 nuclear generating capacity, while the high case represents a net increase of about 99% (Table 2.3 and Figure 2.3).

4. Projections of nuclear capacity and reactor-related uranium requirements are based on official responses from member countries to questionnaires circulated by the Secretariat. For countries that did not provide this information, Secretariat projections are based on data from the IAEA *Energy, Electricity and Nuclear Power Estimates for the Period up to 2030*. From 2030 to 2035, based on development trends, planned retirements and government stated intentions, where available. Because of the uncertainty in nuclear programmes in the years 2015 onward, high and low values are provided.

These projections are subject to even greater uncertainty than usual following the 11 March 2011 accident at the Fukushima Daiichi NPP in Japan. Despite this significant event, the low case projection has increased by almost 6% compared to the last edition of this publication in 2009, largely due to advancing plans for growth in nuclear generating capacity in the developing world and a strengthening of low case projections in the United States due to life extensions. In contrast, the high case projection has declined by almost 5% compared to 2009 as some countries have pulled back somewhat from significant growth projections. Given the impact of the Fukushima accident on capacity projections the information presented here is based on information available as of 1 September 2011 (as opposed to 1 January, as in previous editions), in order to incorporate significant policy changes arising from the accident, notably in Germany, Italy and Switzerland.

The nuclear capacity projections vary considerably from region to region. The East Asia region is projected to experience the largest increase that, by the year 2035, could result in the installation of between 100 GWe and 150 GWe of new capacity, representing over 125% to over 185% increases over 2011 capacity, respectively. Nuclear capacity in non-European Union countries on the European continent is also projected to increase considerably, with between 21 and 50 GWe of capacity increases projected by 2035 (increases of about 55% and 125%, respectively). Other regions projected to experience growth include the Middle East, Central and Southern Asia; Central and South America; Africa and South-eastern Asia. For North America, projected nuclear generating capacity in 2035 is expected to increase by between 7% and 28% (low and high cases, respectively). In the European Union, nuclear capacity is projected to decrease by 11% in the low case scenario according to the implementation of nuclear phase-out policies. In the high case projection, at least some of these phase-out plans are eased or eliminated, producing an increase in nuclear generating capacity of 24% by 2035.

World reactor-related uranium requirements by the year 2035 (assuming a tails assay of 0.30%) are projected to increase to a total of between 97 645 tU/yr in the low case and 136 385 tU/yr in the high case, representing increases of about 50% and 110%, respectively, compared to 2011 requirements (Table 2.4 and Figure 2.4). As in the case of nuclear capacity, uranium requirements vary considerably from region to region, mirroring projected capacity increases. Annual uranium requirement increases are projected to be largest in the East Asia region (between 105% in the low case and over 160% in the high case above 2011 uranium requirements). In contrast to steadily increasing uranium requirements in the rest of the world, annual requirements in the European Union are either projected to decline by over 8% (low case) or increase by over 38% (high case) by the year 2035.

## Table 2.3. Installed nuclear generating capacity[a] to 2035

(MWe net, as of 1 September 2011)

| Country | 2010 | 2011 | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Low | High | Low | High | Low | High | Low | High | Low | High |
| Algeria* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 600 |
| Argentina[b] | 935 | 935 | 1 670 | 1 670* | 4 200 | 4 200* | 4 200 | 4 200* | 4 200 | 4 200* | 4 200 | 4 470* |
| Armenia | 375 | 375 | 375 | 375 | 1 000 | 1 000 | 1 000 | 2 000 | 2 000 | 2 000 | 2 000 | 2 000 |
| Bangladesh* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 000 | 0 | 1 000 |
| Belarus* | 0 | 0 | 0 | 0 | 0 | 1 000 | 2 000 | 2 000 | 2 000 | 2 000 | 2 000 | 2 000 |
| Belgium[c] | 5 927 | 5 927 | 5 927 | 5 927 | 4 099 | 5 927 | 2 085 | 5 927 | 0* | 7 000* | 0* | 7 000* |
| Brazil | 1 875 | 1 875 | 1 875 | 3 120 | 3 120 | 4 120 | 3 120 | 5 120 | 3 120 | 7 120 | 4 200* | 8 150* |
| Bulgaria* | 1 906 | 1 906 | 1 906 | 1 906 | 3 800 | 3 800 | 3 800 | 3 800 | 3 800 | 3 800 | 3 800 | 4 800 |
| Canada | 12 000 | 12 000 | 13 300 | 14 300* | 10 800 | 12 800* | 10 800* | 14 800* | 8 000* | 14 300* | 10 480* | 16 300* |
| China[a] | 10 100 | 11 880 | 25 000 | 35 000 | 40 000 | 58 000 | 58 000 | 71 300 | 71 300 | 83 800 | 83 800 | 108 800 |
| Czech Republic | 3 700 | 3 740 | 3 810 | 3 820 | 3 830 | 3 850 | 3 850 | 5 920 | 5 920 | 6 130 | 5 100 | 7 250 |
| Egypt* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 000 | 0 | 3 000 | 0 | 3 000 |
| Finland | 2 730 | 2 750 | 4 360 | 4 360 | 4 360 | 4 540 | 4 360 | 4 540 | 3 870 | 4 050 | 3 380 | 3 560 |
| France | 63 130 | 63 130 | 63 130 | 63 130 | 64 690 | 65 210 | 66 300* | 66 300* | 66 300* | 66 300* | 66 300* | 66 300* |
| Germany | 20 500 | 12 068 | 10 800 | 10 800 | 8 100 | 9 500* | 0 | 9 500* | 0 | 9 500* | 0 | 6 750* |
| Hungary | 1 890 | 1 890 | 1 890 | 1 890 | 1 890 | 1 890 | 1 890 | 2 890* | 1 890 | 2 890* | 1 890 | 2 890* |
| India[b] | 4 189 | 4 391 | 6 990 | 8 330 | 8 480* | 23 000 | 17 495* | 33 600 | 21 365* | 37 090* | 25 235* | 49 700* |
| Indonesia* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 000 | 0 | 2 000 | 0 | 2 000 |
| Iran, Islamic Rep. of | 0 | 915 | 915 | 915 | 3 175 | 5 075 | 6 975 | 7 925 | 6 975* | 7 925* | 6 975* | 7 925* |
| Italy | 0 | 0 | 0 | 0 | 0* | 1 600 | 0* | 6 400 | 2 000* | 12 800 | 4 000* | 12 800 |
| Japan | 47 400 | 44 681* | 40 215* | 43 775* | 39 555* | 47 535* | 44 250* | 55 300* | 47 285* | 60 175* | 51 410* | 65 060* |
| Jordan* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 000 | 1 000 | 2 000 | 1 000 | 2 000 |
| Kazakhstan | 0 | 0 | 0 | 0 | 0 | 600 | 300* | 600* | 300* | 600* | 300* | 600* |
| Korea, Rep. of+ | 18 700 | 18 700 | 24 500 | 25 500* | 31 500 | 32 500* | 35 900 | 37 700* | 42 700 | 44 500* | 42 700 | 52 000* |
| Lithuania* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 500 | 0 | 3 000 | 0 | 3 000 |
| Malaysia* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 000 | 0 | 1 000 |
| Mexico+ | 1 365 | 1 365 | 1 400 | 1 600 | 1 634 | 1 634 | 1 634 | 1 634 | 1 634 | 1 634 | 1 634 | 1 634 |

See notes on page 97.

## Table 2.3. Installed nuclear generating capacity[(a)] to 2035 (*continued*)

(MWe net, as of 1 September 2011)

| Country | 2010 | 2011 | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Low | High | Low | High | Low | High | Low | High | Low | High |
| Morocco* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 000 | 0 | 1 000 |
| Netherlands+ | 480 | 480 | 480 | 480 | 480 | 2 100 | 2 100 | 3 700 | 2 100 | 3 700 | 1 600 | 3 200 |
| Pakistan* | 425 | 725 | 725 | 725 | 900 | 1 325 | 1 200 | 1 200 | 1 200 | 4 200 | 2 200 | 6 200 |
| Poland* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 500 | 1 500 | 3 000 | 1 500 | 3 000 |
| Romania* | 1 300 | 1 300 | 1 300 | 1 300 | 1 300 | 2 000 | 2 000 | 2 700 | 2 000 | 2 700 | 2 000 | 2 700 |
| Russian Fed.[(b)] | 22 693 | 22 700 | 27 730 | 27 730 | 28 950 | 34 875 | 29 800 | 42 950 | 29 150 | 47 750 | 29 900 | 49 650 |
| Saudi Arabia* | 0 | 0 | 0 | 0 | 0 | 1 000 | 1 000 | 2 000 | 1 000 | 3 000 | 2 000 | 4 000 |
| Slovak Republic | 1 818 | 1 818 | 2 638 | 2 782 | 2 638 | 3 804 | 2 638 | 3 804 | 2 638 | 3 804 | 2 638 | 3 804 |
| Slovenia+ | 666 | 666 | 666 | 666 | 666 | 666 | 666 | 1 666 | 666 | 1 866 | 666* | 1 866* |
| South Africa* | 1 800 | 1 800 | 1 800 | 1 800 | 1 800 | 1 800 | 1 800 | 6 600 | 5 000 | 9 800 | 6 600 | 13 000 |
| Spain+ | 7 360 | 7 360 | 6 920 | 6 920 | 6 920 | 6 920 | 7 120* | 7 920* | 7 120* | 7 920* | 7 120* | 7 920* |
| Sweden+ | 9 300 | 9 460* | 9 500* | 9 500* | 9 460* | 9 460* | 9 460* | 9 460* | 9 460* | 10 500* | 6 500* | 10 500* |
| Switzerland | 3 253 | 3 253 | 3 253 | 3 253 | 2 873* | 3 253 | 1 538* | 3 253 | 373* | 2 873* | 0* | 1 538* |
| Thailand* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 000 | 0 | 2 000 |
| Turkey* | 0 | 0 | 0 | 0 | 0 | 1 140 | 1 140 | 3 420 | 2 280 | 4 560 | 2 280 | 5 312 |
| Ukraine[(b)] | 13 100 | 13 100 | 15 000 | 17 000 | 15 800 | 19 200 | 17 900 | 24 900 | 19 000 | 24 900 | 24 700 | 29 000 |
| United Arab Emirates* | 0 | 0 | 0 | 0 | 2 700 | 5 400 | 5 400 | 5 400 | 5 400 | 5 400 | 5 400 | 5 400 |
| United Kingdom[(b)] | 10 200 | 9 920 | 8 800 | 8 800 | 4 500* | 6 000* | 7 000* | 9 500* | 8 700* | 13 000* | 9 700* | 14 500* |
| United States | 101 000 | 101 200 | 105 700 | 105 700 | 110 500 | 110 500 | 110 500 | 111 140 | 110 500 | 118 500 | 110 500 | 129 100 |
| Vietnam* | 0 | 0 | 0 | 0 | 0 | 1 000 | 2 000 | 2 000 | 2 000 | 4 000 | 2 000 | 4 000 |
| OECD total | 311 519 | 299 622 | 306 583 | 312 497 | 307 829 | 330 163 | 312 565 | 363 908 | 324 270 | 397 136 | 328 732 | 421 106 |
| World total[(a)] | 375 199 | 367 172 | 400 217 | 420 716 | 430 094 | 505 806 | 474 743 | 595 951 | 508 346 | 671 661 | 540 308 | 746 408 |

* Secretariat estimate, to 2030, based on *Energy, Electricity and Nuclear Power Estimates for the Period up to 2030*, IAEA (Vienna), August 2011; from 2030 to 2035, based on development trends, planned retirements and government stated intentions, where available.

+ Data from *Nuclear Energy Data*, NEA (Paris), 2011.

(a) The following data for Chinese Taipei are included in the world total but not in the totals for China: 4 982 MWe net in 2010 and 2011, 7 582 net for the low and high cases in 2015, 6 374 and 7 582 MWe net for the low and high cases in 2020, 3 522 and 7 582 MWe net for the low and high cases in 2025, 2 600 and 6 374 for the low and high cases in 2030, and 2 600 and 4 441 MWe net for the low and high cases in 2035, respectively. These projections are based on government policy announcements as of September 2011.

(b) MWe gross converted to net by the Secretariat.

## Table 2.4. Annual reactor-related uranium requirements[(a)] to 2035

(tonnes U, rounded to nearest five tonnes)

| Country | 2010 | 2011 | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Low | High | Low | High | Low | High | Low | High | Low | High |
| Algeria* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 105 |
| Argentina | 120 | 120 | 265 | 265 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 640 |
| Armenia | 65 | 65 | 65 | 65 | 155 | 315 | 155 | 470 | 310 | 310 | 310 | 310 |
| Bangladesh* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 175 | 0 | 175 |
| Belarus* | 0 | 0 | 0 | 0 | 0 | 175 | 350 | 350 | 350 | 350 | 350 | 350 |
| Belgium | 925 | 1 080 | 730 | 1 080 | 730 | 1 080 | 365 | 1 080 | 0* | 1 225* | 0* | 1 225* |
| Brazil | 450 | 450 | 450 | 750 | 750 | 1 000 | 750 | 1 250 | 750 | 1 750 | 1 025* | 2 000* |
| Bulgaria* | 255 | 270 | 335 | 335 | 670 | 670 | 670 | 670 | 670 | 670 | 670 | 840 |
| Canada | 1 600 | 1 600 | 1 750 | 1 900* | 1 500 | 1 750* | 1 500* | 2 025* | 1 225* | 1 885* | 1 500* | 2 175* |
| China[(a)] | 3 900 | 4 150 | 4 600 | 6 450 | 6 450 | 8 200 | 10 100 | 12 000 | 12 300 | 16 200 | 14 400 | 20 500 |
| Czech Republic | 885 | 840 | 650 | 680 | 665 | 680 | 680 | 850 | 850 | 900 | 910 | 1 300 |
| Egypt* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 175 | 0 | 525 | 0 | 525 |
| Finland | 455 | 510* | 700 | 760 | 700 | 760 | 700 | 760 | 520 | 560 | 520 | 560 |
| France | 8 000 | 8 000 | 7 500 | 8 500 | 7 500 | 8 500 | 8 000* | 9 000* | 8 000* | 9 000* | 8 000* | 9 000* |
| Germany | 2 800 | 2 110* | 1 890* | 1 890* | 1 420* | 1 660* | 0 | 1 660* | 0* | 1 660* | 0 | 1 180* |
| Hungary | 435 | 435 | 435 | 435 | 435 | 435 | 435 | 610* | 435 | 610* | 220 | 610* |
| India | 735* | 925* | 1 600 | 1 800 | 1 485* | 4 025* | 3 060* | 5 880* | 3 740* | 6 490* | 4 415* | 8 700* |
| Indonesia* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 175 | 0 | 350 | 0 | 350 |
| Iran, Islamic Rep. of | 0 | 160* | 160 | 160 | 590 | 910 | 1 230 | 1 390 | 1 230* | 1 390* | 1 230* | 1 390* |
| Italy | 0 | 0 | 0 | 0 | 0* | 1 080 | 0* | 1 655 | 350* | 1 530 | 700* | 1 530 |
| Japan | 6 295 | 6 400* | 7 040* | 7 660* | 6 920* | 8 320* | 7 745* | 9 680* | 8 275* | 10 530* | 9 000* | 11 385* |
| Jordan* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 175 | 175 | 350 | 175 | 350 |
| Kazakhstan | 0 | 0 | 0 | 0 | 0 | 60 | 50* | 100* | 50* | 100* | 50* | 100* |
| Korea, Rep. of[+] | 4 200 | 4 400 | 5 100 | 5 300 | 6 400 | 6 500 | 7 500 | 7 800 | 8 800 | 9 000 | 8 800 | 9 000 |
| Lithuania* | 105 | 0 | 0 | 0 | 0 | 0 | 0 | 265 | 0 | 525 | 0 | 525 |
| Malaysia* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 175 | 0 | 175 |
| Mexico[+] | 405 | 410* | 420 | 435* | 365 | 435* | 200 | 410* | 210 | 410* | 200 | 410* |
| Morocco* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 175 | 0 | 175 |

See notes on page 99.

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## Table 2.4. Annual reactor-related uranium requirements[(a)] to 2035 (*continued*)

(tonnes U, rounded to nearest five tonnes)

| Country | 2010 | 2011 | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Low | High | Low | High | Low | High | Low | High | Low | High |
| Netherlands+ | 60 | 60 | 60 | 60 | 60 | 250 | 250 | 440 | 250 | 440 | 190 | 380 |
| Pakistan* | 75 | 80 | 105 | 125 | 155 | 230 | 490 | 490 | 210 | 735 | 385 | 1 085 |
| Poland* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 265 | 265 | 525 | 265 | 525 |
| Romania* | 190 | 190 | 190 | 190 | 190 | 290 | 290 | 390 | 290 | 390 | 290 | 390 |
| Russian Federation | 4 500 | 4 500 | 5 800 | 5 800 | 5 900 | 7 000 | 6 000 | 8 700 | 5 900 | 9 600 | 6 100 | 11 100 |
| Saudi Arabia | 0 | 0 | 0 | 0 | 0 | 175 | 175 | 350 | 175 | 525 | 350 | 700 |
| Slovak Republic | 370 | 390 | 505 | 520 | 505 | 540 | 505 | 540 | 505 | 540 | 505 | 540 |
| Slovenia+ | 210 | 170* | 0 | 0 | 220 | 230 | 230* | 405* | 230* | 405* | 230* | 405* |
| South Africa | 290 | 290 | 290 | 290 | 290* | 290* | 595* | 1 155* | 875* | 1 715* | 1 155* | 2 275* |
| Spain | 1 390 | 1 320 | 1 350 | 1 350 | 1 350 | 1 350 | 1 275* | 1 340* | 1 275* | 1 340* | 1 275* | 1 340* |
| Sweden+ | 1 580 | 1 645 | 1 900* | 1 900 | 1 900* | 1 900 | 1 900* | 1 900* | 1 900* | 2 000* | 1 100* | 2 000* |
| Switzerland | 210 | 235 | 225 | 365 | 385 | 535 | 270* | 535 | 65 | 500* | 0* | 275* |
| Thailand | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 350 | 0 | 350 |
| Turkey* | 0 | 0 | 0 | 0 | 0 | 200 | 200 | 600 | 400 | 800 | 400 | 930 |
| Ukraine | 2 480 | 2 480 | 2 480 | 3 230 | 3 020 | 3 600 | 3 020 | 3 660 | 3 600 | 4 800 | 4 800 | 5 300 |
| United Arab Emirates* | 0 | 0 | 0 | 0 | 475 | 945 | 945 | 945 | 945 | 945 | 945 | 945 |
| United Kingdom | 985 | 1 000 | 1 040 | 1 205 | 790* | 1 050* | 1 225* | 1 660* | 1 525* | 2 275* | 1 700* | 2 540* |
| United States | 19 140 | 19 995 | 20 930 | 20 930 | 24 160 | 24 160 | 24 160 | 24 295 | 24 160 | 25 840 | 24 075 | 28 070 |
| Vietnam* | 0 | 0 | 0 | 0 | 0 | 175 | 350 | 350 | 350 | 700 | 350 | 700 |
| OECD total | 49 945 | 50 600 | 52 225 | 54 970 | 56 005 | 61 415 | 57 140 | 67 510 | 59 240 | 71 975 | 59 590 | 75 380 |
| World total | 63 875 | 65 180 | 69 890 | 75 755 | 77 850 | 91 400 | 86 280 | 108 375 | 92 215 | 123 160 | 97 645 | 136 385 |

* Secretariat estimate, to 2030, based on *Energy, Electricity and Nuclear Power Estimates for the Period up to 2030*, IAEA (Vienna), August 2011; from 2030 to 2035, based on development trends, planned retirements and government stated intentions, where available; if uranium requirement data are not provided in questionnaire response, requirements are calculated assuming requirements of 175 tU/GWe/yr.

+ Data from *Nuclear Energy Data*, NEA (Paris), 2011.

(a) The following data for Chinese Taipei are included in the world total but not in the totals for China: 870 tU/yr in 2010, 900 tU/yr in 2011, 1 325 tU/yr in the low and high cases in 2015, 1 115 tU/yr and 1 325 tU/yr in the low and high cases in 2020, 615 tU/yr and 1 325 tU/yr in the low and high cases in 2025, 455 tU/yr and 1 115 tU/yr in the low and high cases in 2030 and 455 tU/yr and 775 tU/yr in the low and high cases in 2035, respectively.

**Figure 2.3. Projected installed nuclear capacity to 2035**
(low and high projections)

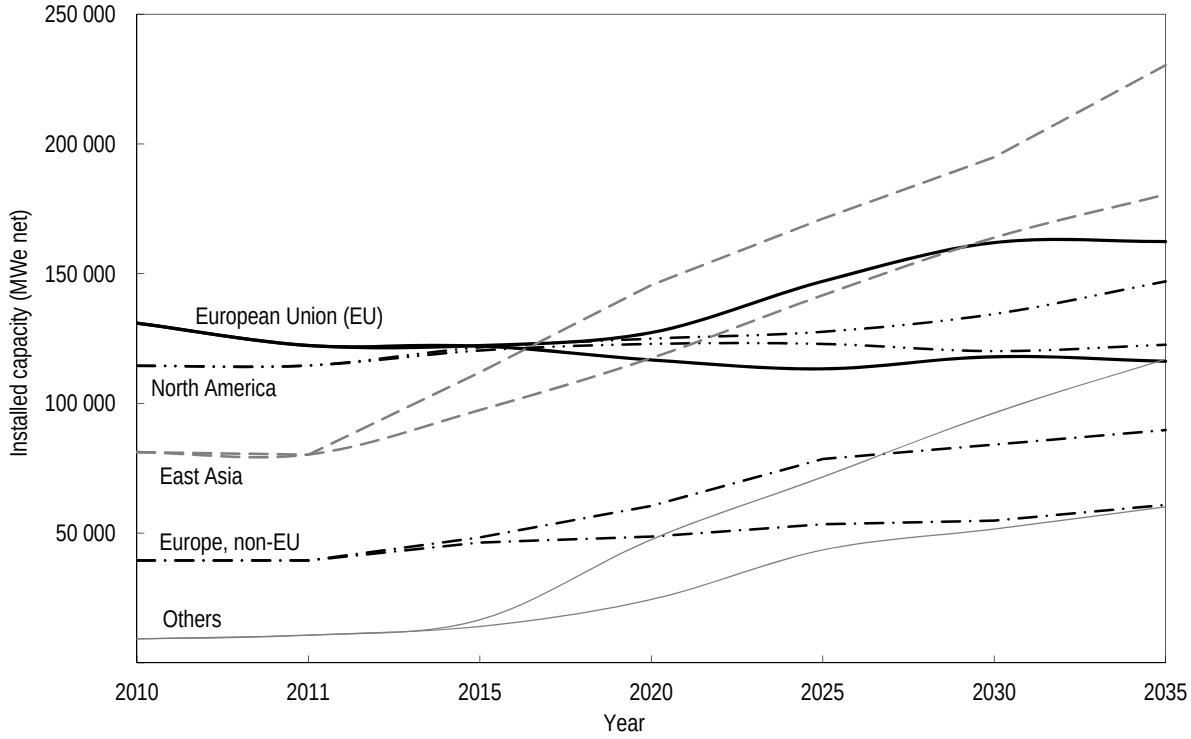
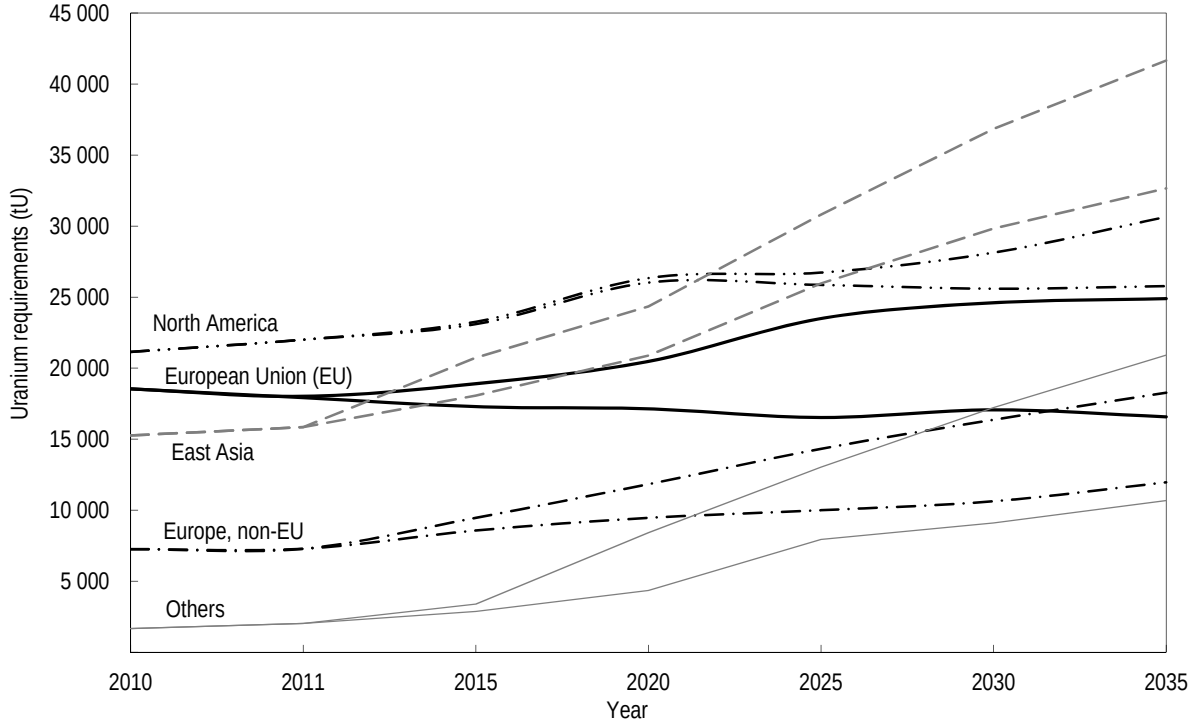



**Figure 2.4. Annual reactor uranium requirements to 2035**
(low and high projections)





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## Uranium supply and demand relationships

Uranium supply and demand remains in balance 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 last several years, has satisfied some 50-85% of world requirements. The remainder has been provided or derived from secondary sources including stockpiles of natural and enriched uranium, downblending of weapons grade uranium, reprocessing of spent fuel and the re-enrichment of depleted uranium tails.

### *Primary sources of uranium supply*

Uranium was produced in 22 countries in 2010, 2 more than in 2008, with total global production amounting to 54 670 tU (representing an increase of 25% and 6% from 2008 and 2009, respectively). Production began in Malawi for the first time in 2009 and Germany resumed limited production through mine remediation efforts (small amounts of uranium are recovered from similar activities in Bulgaria, the Czech Republic, France and Hungary). In 2009, Kazakhstan passed Canada to become the world's largest producer of uranium and remained in this position in 2010, continuing its run of impressive production increases over the past years (65% and 27% in 2009 and 2010, respectively). A further 12% increase expected in 2011. The top five producing countries in 2010 (Kazakhstan, Canada, Australia, Namibia and Niger) accounted for 77% of world production and just eight countries, Kazakhstan (33%), Canada (18%), Australia (11%), Namibia (8%), Niger (8%), the Russian Federation (7%), Uzbekistan (5%) and the United States (3%), accounted for 93% of global uranium mine production.

In comparison, 30 countries currently consume uranium in commercial NPPs creating an uneven distribution between producing and consuming countries. In 2010, only Canada and South Africa produced sufficient uranium to meet domestic requirements (Figure 2.5). All others must use 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 become a matter of some concern. However, efforts to better inform port authorities of the risks involved and better recognition of the longstanding record of successful shipments of these materials have resulted in some improvements in the situation.

Due to the current availability of secondary supplies, primary uranium production volumes are significantly below world uranium requirements. In 2010, world uranium production (54 670 tU) provided about 85% of world reactor requirements (63 875 tU). In OECD countries, 2010 production of 17 600 tU provided about 35% of requirements (49 945 tU; Figure 2.6). Remaining requirements were met by imports and secondary sources.

### *Secondary sources of uranium supply*

Uranium is unique among energy fuel resources in that a significant portion of demand is 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 produced by reprocessing spent reactor fuels and from surplus military plutonium.
- Uranium produced by re-enrichment of *depleted uranium* tails.

**Figure 2.5. Estimated 2011 uranium production and reactor-related requirements for major producing and consuming countries**

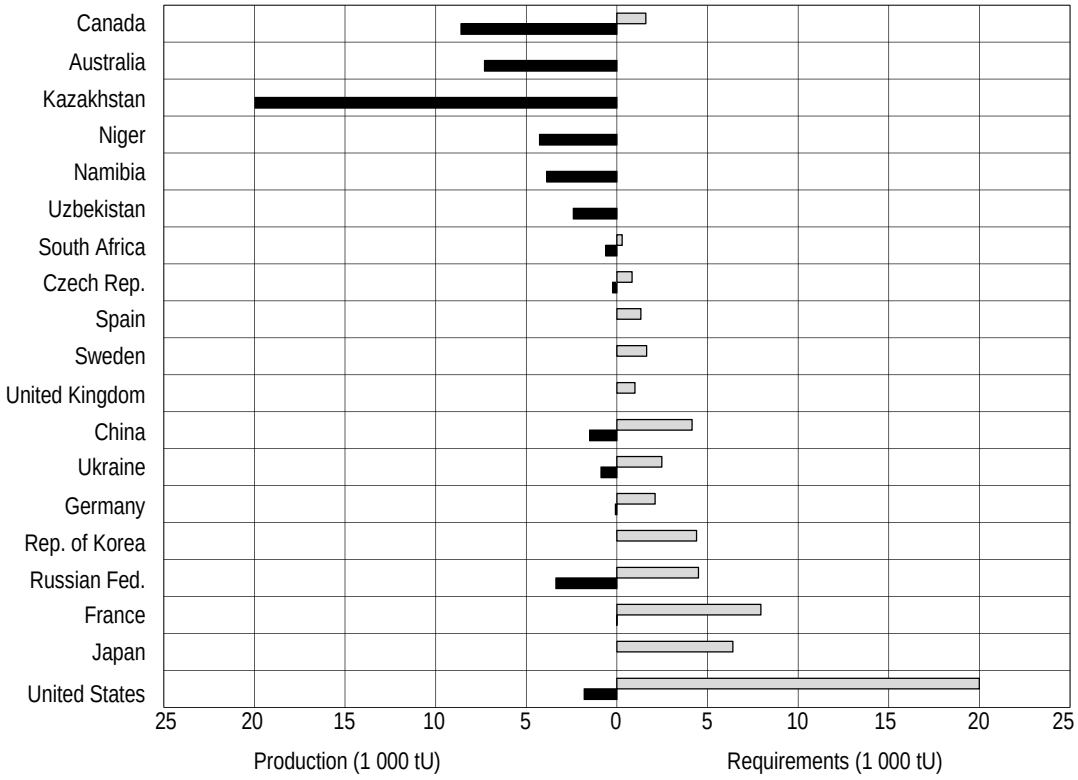
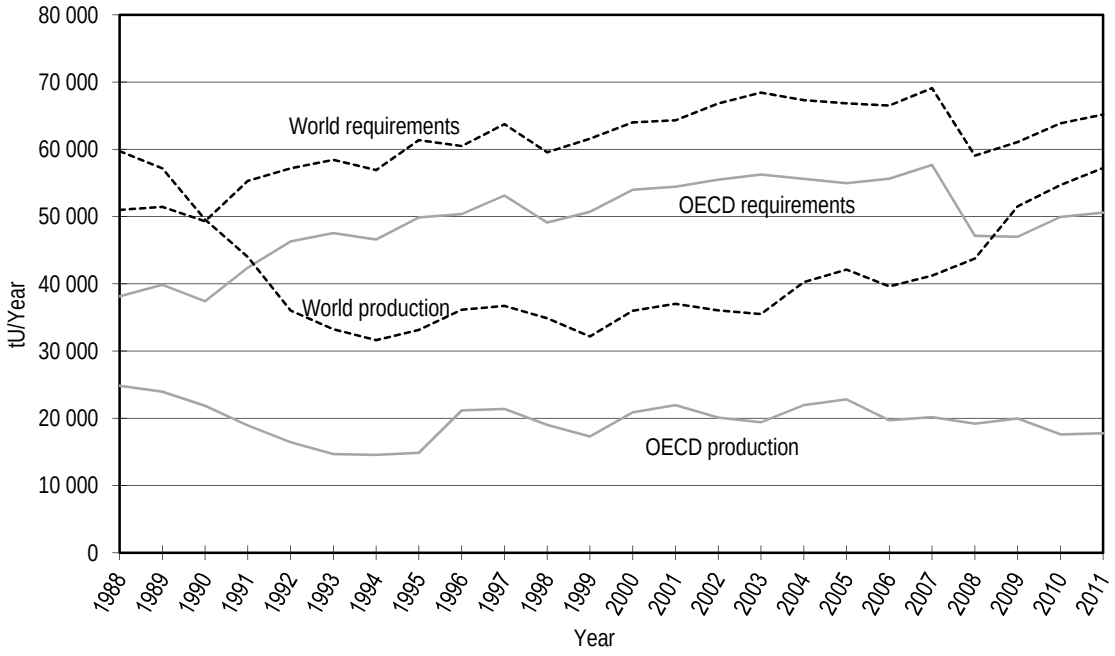



**Figure 2.6. OECD and world uranium production and requirements***

(1988-2011)




* 2011 values are estimates.



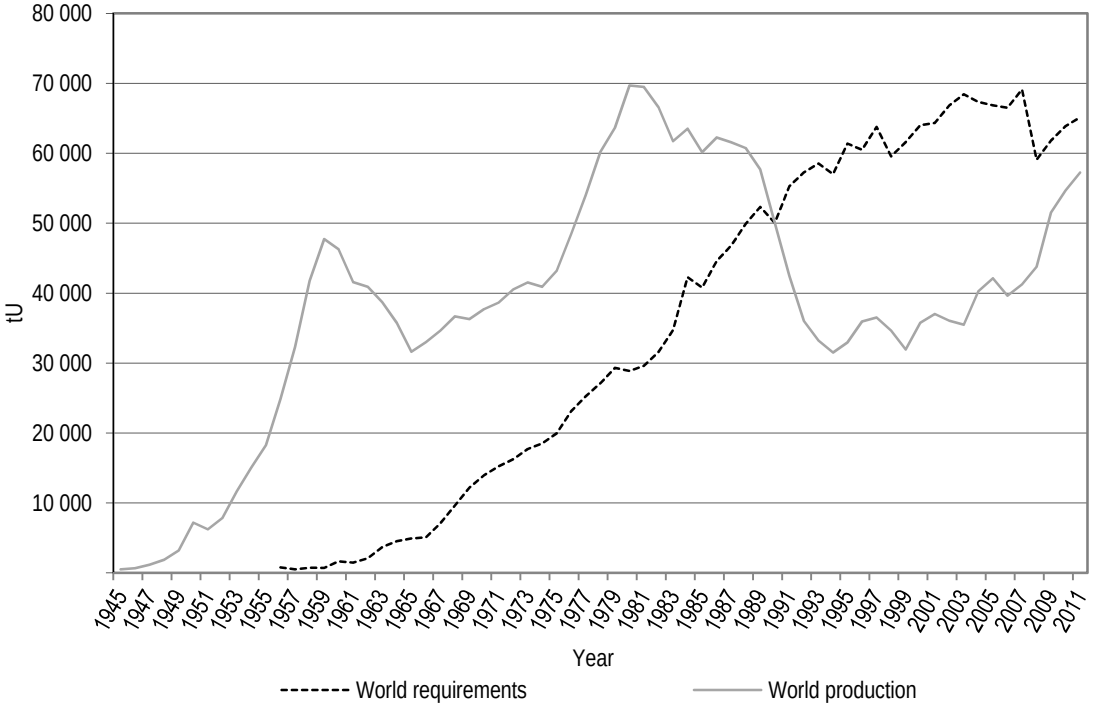
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*Natural and enriched uranium stocks and inventories*

From the beginning of commercial exploitation of nuclear power in the late 1950s to 1990, uranium production consistently exceeded commercial requirements (Figure 2.7). This was mainly the consequence of a lower than expected nuclear electricity generation growth rate and high levels of production for strategic purposes. This over production created a stockpile of uranium potentially available for use in commercial power plants. Since 1990, production has fallen below demand as secondary supplies have fed the market. Initially, production dropped well below demand but clearly the gap has closed significantly in the last two years as mine production is increasing and uranium requirements have declined. The decline in uranium requirements in 2008 is likely related to utilities specifying lower tails assays at enrichment facilities and a reduced number of reactors being refuelled. Since 2008, requirements have increased as overall installed generating capacity continues to grow, despite unplanned closures in Germany and Japan resulting from the Fukushima accident, while production increases continue to close the gap to reactor requirements, reducing the draw-down of secondary supply.

**Figure 2.7. Annual uranium production and requirements***

(1945-2011)



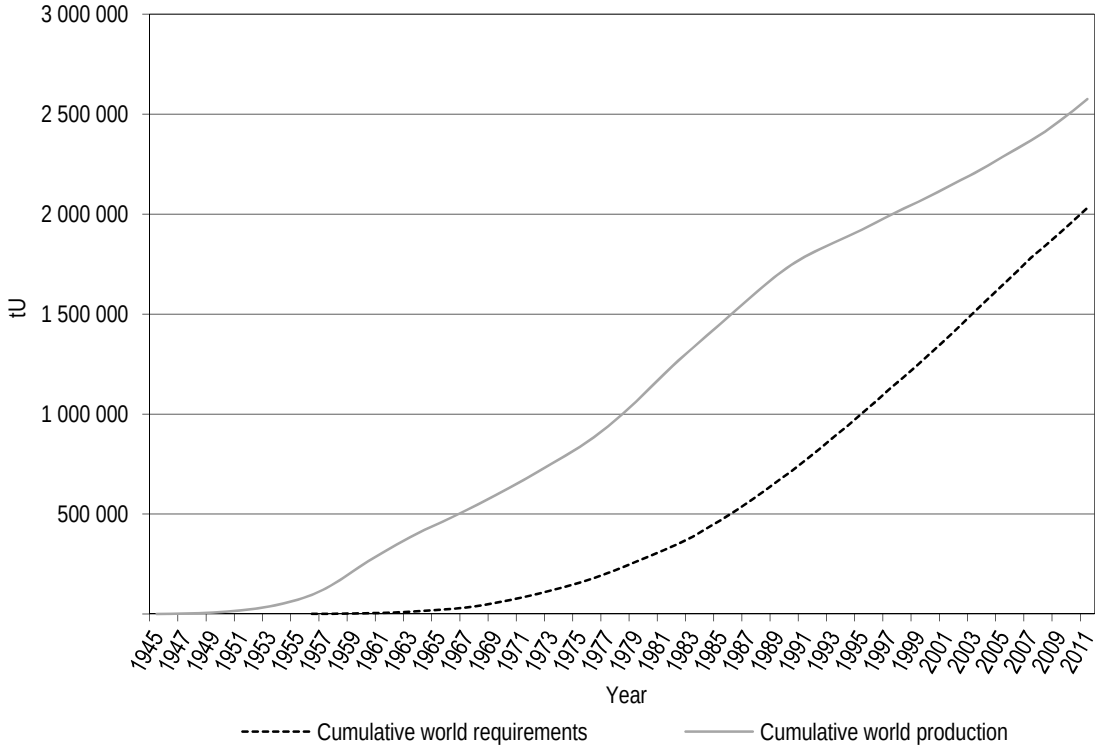

* 2011 values are estimates.

Following the political and economic reorganisation in Eastern Europe and the former Soviet Union in the early 1990s, steps have been taken to move towards the development of an integrated commercial world uranium market. More uranium is now available from the former Soviet Union, most notably Kazakhstan, but also the Russian Federation and Uzbekistan, as is more information on the production and use of uranium in the former Soviet Union. Despite these developments and the increased availability of information regarding the amount of uranium held in inventory by utilities, producers and governments, uncertainty remains regarding the size of these inventories as well as the availability of uranium from other sources. This, combined with uncertainty about the desired levels of inventories, continues to have a significant influence on the uranium market.

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 potentially commercially available inventories. Cumulative production through 2010 is estimated to have amounted to over 2 590 000 tU, whereas cumulative reactor requirements through 2010 amounted to about 2 030 000 tU. This leaves an estimated remaining stock of roughly 560 000 tU. This should be considered the upper limit of what could potentially become available to the commercial sector (Figure 2.8). This base of already mined uranium, minus an unknown but potentially significant amount lost during processing, 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. Since the end of the Cold War, increasing amounts of uranium, previously reserved for strategic purposes, have been released to the commercial sector. However, a portion of this will likely remain reserved for military uses.

**Figure 2.8. Cumulative uranium production and requirements***

(1945-2011)




* 2011 values are estimates.

Civilian inventories include strategic stocks, pipeline inventory and excess stocks available to the market (more recently including material held by financial investors). Utilities are believed to hold the majority of commercial stocks because many have policies that require carrying the equivalent of one to two years of natural uranium requirements. Despite the importance of this secondary source of uranium, relatively little is known about the size of these stocks because few countries are able or willing, due to confidentiality concerns, to provide detailed information on stockpiles held by producers, consumers or governments (Table 2.5).

**Table 2.5. Uranium stocks in countries that have reported data**

(tonnes natural U equivalent as of 1 January 2011)

| Country | Natural uranium | Enriched uranium |
|---|---|---|
| Argentina[a] | 52 | 0 |
| Australia[b] | 0 | 0 |
| Belgium | NA | NA |
| Brazil | 0 | 0 |
| Bulgaria[c] | 0 | 81 |
| Canada[b] | NA | 0 |
| China | NA | NA |
| Czech Republic[d] | NA | NA |
| Finland[e] | NA | NA |
| France[f] | NA | NA |
| Germany | NA | NA |
| Hungary[g] | 5 | 0 |
| India | NA | NA |
| Iran, Islamic Rep. of | NA | NA |
| Kazakhstan | NA | NA |
| Korea, Republic of[c, h] | 2 000 | 6 000 |
| Mexico | NA | NA |
| Mongolia | 0 | 0 |
| Netherlands | NA | NA |
| Niger | 0 | 0 |
| Poland | 0 | 0 |
| Portugal | 168 | 0 |
| Russian Federation | NA | NA |
| Slovak Republic | 0 | NA |
| South Africa | NA | NA |
| Spain[i] | NA | >611 |
| Switzerland[j] | 1 674 | 997 |
| Turkey | 2 | 0 |
| Ukraine | 0 | 0 |
| United Kingdom | NA | NA |
| United States[k] | 36 381 | 26 982 |
| Vietnam | 0 | 0 |
| Total | 40 482 | >34 671 |

(a) Government data only. Commercial data are not available.

(b) Government stocks are zero in all categories. Commercial data are not available.

(c) Data from 2009 Red Book.

(d) CEZ maintains strategic and working inventories in various forms, including fuel assemblies.

(e) The nuclear power utilities maintain reserves of fuel assemblies sufficient for 7-12 months use.

(f) A minimum strategic inventory of three years 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's forward consumption in pipeline inventory.

(i) Regulations require a strategic inventory of at least 611 tU be maintained jointly by nuclear utilities.

(j) Utilities also hold 171 t (U equivalent) of reprocessed uranium.

(k) Government and utility stocks only; producer stocks amounted to an additional 5 234 tU but a breakdown into amounts of natural and enriched uranium is not available. Government stocks also include 25 950 t (U equivalent) of depleted uranium.

Available data from some sources suggest that the industry has been depleting inventories in recent years. In the United States, 2010 year-end total commercial uranium inventories (natural and enriched uranium equivalent) amounted to 38 517 tU, a decrease of about 10% compared to 2009 levels of 42 901 tU. In the European Union deliveries (17 566 tU) were below the amount loaded into reactors in 2010 (18 122 tU) for the third consecutive year (ESA, 2011). These data suggest that commercial inventories have been reduced somewhat in the two largest regions of uranium demand. However, uranium requirements are growing rapidly in East Asia and by the early 2020s demand in this region is expected to surpass both that of North American and the EU. Questionnaire responses received during the compilation of this volume unfortunately revealed little about inventory policies of countries in the East Asia region.

Despite purchases being below fuel loaded in the EU in the last three years, the Euratom Supply Agency reports that total uranium inventories held by EU utilities amounted to a total of 45 272 tU at the end of 2010 (ESA, 2011). It also notes that aggregate utility inventories increased substantially between 2005 and 2009 before declining in 2010. The World Nuclear Association (WNA) reports that questionnaire responses from industry show a clear build-up of utility inventory since 2003 (120 000 tU at the end of 2010), which it considers to be a response to the general increase in uranium prices since 2003 and preparations for first core loads in new reactors that typically require two to three times more in mass than reloads during reactor operations (WNA, 2011).

In recent years, commercial entities other than utilities hold quantities of uranium for investment purposes. Although the amount is variable and largely dependent on uranium price dynamics, the WNA (2011) notes that about 5 000 tU was held by financial investors in April 2010. Recent efforts by governments and international agencies have also resulted in the creation of nuclear fuel banks, another form of inventory. These are discussed in more detail later in this chapter.

Available information collected for this publication suggests that no significant excess inventories are held in non-EU Europe, but responses summarised in Table 2.5 clearly show the poor response rate, largely owing to commercial sensitivities. Although China did not report inventories here, the WNA (2011) estimated that it accumulated 16 000 tU in inventory in 2009 and 2010 alone. Japan is also thought to hold significant but unreported uranium inventories (two years forward supply for the fleet) to protect against supply disruption, and the fate of this inventory could impact the near-term uranium market if reactors are not restarted following safety checks after the Fukushima accident.

While substantial, inventories in these countries are generally thought to be relatively small compared to the inventory held by the Russian Federation. The inventory of enriched uranium product and natural uranium held by the Russian Federation, though never officially reported, is believed to be substantial and is a major factor of uncertainty in the uranium market. These inventories have been drawn upon for several years.

Large stocks of uranium, previously dedicated to the military in both the United States (US) and the Russian Federation, have become available for commercial applications, bringing a significant secondary source of uranium to the market. Highly-enriched uranium (HEU) and natural uranium held in various forms by the military could total several years of global supply of natural uranium equivalent (NatU) for commercial applications.

In December 2008, the US Department of Energy (DOE) released a plan to manage its excess uranium inventory that amounts to about 59 000 tNatU (DOE, 2008). This plan includes the sale or transfer of 22 700 tNatU over ten years (2008-2017). Designed partly to minimise adverse impacts on the domestic uranium mining industry, the plan specifies that transfers cannot exceed 10% of the US commercial uranium requirements in any given year.

In a series of seven transactions from December 2009 through June 2011, DOE released 1 873 tU to pay USD 256 million for clean-up services provided by two contractors at the Portsmouth, Ohio, enrichment facility, and additional transactions are planned. Six out of seven of these transactions involved the United States Enrichment Corporation (USEC), the former operator of the Portsmouth facility. DOE released a total of 1 473 tU in these six transactions and USEC provided USD 194 million in clean-up services at Portsmouth. The seventh transaction involved a second contractor. In June 2011, DOE released 400 tU and the contractor agreed to provide USD 62 million in decontamination and decommissioning services. DOE officials reported that transfers of natural uranium to this contractor for clean-up services are expected to continue through 2013.

- Highly-enriched uranium from the Russian Federation

The Russian Federation and the US signed a 20-year, government-to-government agreement in February 1993 for the conversion of 500 t of Russian HEU from nuclear warheads to low-enriched uranium (LEU). The HEU purchase agreement provides for the blending down of 500 tonnes of HEU to LEU over 20 years. USEC, the US government's sole executive agent for implementing the HEU purchase agreement, receives deliveries of LEU from the Russian Federation for sale to commercial NPPs. USEC purchases and sells only the enrichment component of this LEU under existing commercial contracts with purchasers of enrichment services. An agreement for the maintenance of a domestic uranium enrichment industry, signed on 17 June 2002 by DOE and USEC, contained conditions for USEC to continue as the US government's sole executive agent for this agreement.

On 24 August 2011, USEC announced that it had recycled 425 t of HEU into over 12 000 t LEU, in the process eliminating the equivalent of 17 000 warheads. The programme is on schedule to finish downblending the equivalent of 20 000 nuclear warheads into commercial NPP fuel by the end of 2013. As early as June 2006, the Russian Federation indicated that the HEU agreement will not be renewed when the initial agreement expires in 2013.

Under a separate agreement, the natural uranium feed component of the HEU purchase agreement is sold under a commercial arrangement between three western corporations (Cameco, AREVA, and Nukem) and Techsnabexport (TENEX) of the Russian Federation. Imports of uranium from the Russian Federation outside of these agreements have been limited by the *Agreement Suspending the Antidumping Duty Investigation on Uranium from the Russian Federation* (suspension agreement) signed between the US Department of Commerce (DOC) and the Ministry of Atomic Energy of the Russian Federation in 1992. As a result of the suspension agreement, DOC suspended antidumping investigations and the Russian Federation agreed to sell uranium to the United States under a quota system whereby Russian imports would have to be matched by an equivalent quantity of newly produced US uranium.

On 1 February 2008, an amendment to the suspension agreement allows very small quantities of Russian LEU to enter the United States beginning in 2011 and much higher sales of Russian uranium products directly to US utility companies under quota from 2014 to 2020. In addition, Russian origin fuel supply to new reactors will be quota-free. Since the signing of this amendment, agreements for nuclear fuel supply deliveries have been signed by US utilities and the Russian Federation, including a contract between USEC and TENEX in March 2011 for the ten-year supply of LEU beginning in 2013. By 2015 the LEU supplied will amount to about one-half the level currently supplied under the HEU purchase agreement. However, quantities supplied under the new contract will come from the Russian Federation's commercial enrichment activities as opposed to the downblending of excess Russian weapons material.

On 30 September 2008, the Domenici amendment to the suspension agreement was enacted into law, allowing the Russian Federation access to as much as 20% of the

post-2013 US uranium nuclear fuel market, on the condition that the Russian Federation completes the downblending of an additional 500 t of HEU under the terms and conditions of the existing HEU purchase agreement. The Domenici amendment also contains a provision to allow the Russian Federation access to 25% of the post-2013 US uranium market, on the condition that the Russian Federation signs a new agreement to blend down a further 300 t of HEU. At the time of writing the Russian Federation has displayed no interest in undertaking such actions.

- Highly-enriched uranium from the United States

In 1996, the United States declared 174.3 t of HEU as surplus and committed to its disposition, with about 151 t planned to be eventually blended down for use as LEU fuel in research and commercial reactors and 23 t slated for downblending and disposal as low-level radioactive waste.

The DOE and Tennessee Valley Authority (TVA) signed an interagency agreement in April 2001, whereby TVA committed to utilising LEU derived from blending down about 33 t of US surplus HEU (the BLEU project). In 2004, this agreement was modified to increase the total to 39 t of HEU and an additional 5.6 t of HEU was added to the programme in 2008. This LEU is considered "off-spec" because it contains $^{234}U$ and $^{236}U$ in excess of the specifications established for commercial nuclear fuel. Portions of this material are being downblended at DOE's Savannah River Site (SRS) and by a TVA contractor. Downblending began at SRS in 2003 and at the contractor facility in 2004. On 10 October 2010, Nuclear Fuel Services announced that 22.8 t HEU had been downblended, creating 312 t of LEU for use in TVA's Browns Ferry and Sequoya reactors as a low cost, reliable source of fuel. Its use is expected to be continued until 2016. In May 2011, TVA reported that it was considering implementing agreements and contracts with DOE to obtain an additional 28 t of HEU for downblending in order to meet TVA reactor fuel needs for the two reactors through 2022.

In November 2005, the DOE announced that an additional 200 t of HEU had been declared surplus, of which 160 t will be used for naval propulsion, 20 t is to be downblended to LEU fuel for use in power or research reactors, and 20 t reserved for space and research reactors that currently use HEU, pending development of fuels that would enable the conversion to low-enriched uranium fuel cores. For power reactors, the LEU would become available gradually over a 25-year period.

Also in 2005, DOE announced its intention to set aside 17.4 t of HEU to be downblended to LEU fuel and held in reserve to address any disruptions in domestic or foreign nuclear fuel supply. In August 2011, DOE announced that the American Assured Nuclear Fuel Supply had been established to secure sufficient LEU for six reloads of an average 1 000 MWe reactor (230 t LEU), derived from the downblending of this HEU that is expected to be completed in 2012. The remaining 60 t HEU produced in this process is expected to be sold on the market to pay for downblending and processing costs.

In December 2008, an additional 67.6 t of HEU was declared unallocated (not presently obligated or approved for a specific purpose or programme) in the DOE's *Excess Uranium Inventory Management Plan* (DOE, 2008). DOE stated that this material will become available for disposition gradually over several decades at a rate controlled by weapons dismantlement initiatives and the rejection of material from naval reactors.

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

The constituents of spent fuel from power plants are a potentially substantial source of fissile material that could displace primary uranium production. When spent fuel is discharged from a commercial reactor it is potentially recyclable, since 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 mixed oxide

fuel (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 yet significantly altered world uranium demand because only a relatively small and recently declining number of reactors are using this type of fuel. Additionally, 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 2011 there were 28 reactors, or about 6% of the world's operating fleet, licensed to use MOX fuel, including reactors in France, Germany, India and Japan (Tables 2.1 and 2.6). Additional reactors could be licensed to use MOX in China and the Russian Federation.

MOX reprocessing and fuel fabrication facilities exist or are under construction in China, France, India, Japan, the Russian Federation, the United Kingdom and the United States. In 2011, it was announced that the Sellafield MOX plant would be closed owing to reduced demand for services in Japan following the Fukushima accident.

Japan Nuclear Fuel Ltd. has been testing plutonium separation at the Rokkasho reprocessing plant since March 2006 and Japanese utilities have been planning to use MOX fuel in 16 to 18 reactors, following consultations and licensing. Initially, MOX fuel manufactured overseas will be used, followed by the use of MOX fuel produced at the JMOX fuel fabrication facility adjacent to the Rokkasho reprocessing plant. JMOX construction began in 2010. By mid-2010, three reactors in Japan had received fuel loads with MOX produced overseas, the last being reactor No. 3 at Fukushima Daiichi. Commercial operation of JMOX was expected to begin in 2015 (capacity of 130 tHM/yr), although the status of this programme is unclear at this time following the Fukushima accident.

In 2003, the Cadarache MOX fuel production plant in France ceased commercial production and in 2006 the MOX fuel plant in Belgium (BELGONUCLÉAIRE) was shut down. In 2007, the MELOX plant in Marcoule, France was licensed to increase production from 145 t to 195 t of MOX fuel/yr (corresponding to 1 560 tNatU equivalent). 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 (for a total of about 120 t yearly; 960 tNatU equivalent) 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-27 increased slightly in 2010 to 10 636 kg Pu from 10 282 kg Pu in 2009. Use of plutonium in MOX fuel reduced natural uranium requirements in the EU by an estimated 1 276 tU in 2010 and 1 234 tU in 2009. Since 1996, the ESA estimates that MOX fuel use in EU reactors has displaced a cumulative total of 17 032 tU through the use of 141.8 t of plutonium (ESA, 2011). 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 during that period. Responses to the questionnaire provided some data on the production and use of MOX (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 done only in France and the Russian Federation, principally because the production of RepU is a relatively costly endeavour, in part due to the requirement for dedicated conversion, enrichment and fabrication facilities. Changing market conditions and non-proliferation concerns are, however, leading to renewed consideration of this recycling option. After being shut down in 2005, reprocessing was restarted in 2008 at the THORP plant in the United Kingdom. In France since around 2010, about 600 tNatU/yr are recycled in four EDF reactors at the Cruas NPP as reprocessed uranium. Beyond this, very

limited information is available concerning how much reprocessed uranium is used. Available data indicate that it represents less than 1% of projected world requirements annually (Table 2.7).

**Table 2.6. MOX production and use**

(tonnes of equivalent natural U)

| Country | Pre-2008 | 2008 | 2009 | 2010 | Total to 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| ***MOX production*** | | | | | | |
| Belgium | 523 | 0 | 0 | 0 | 523 | 0 |
| France | 13 030 | 1 008 | 1 560 | 1 560 | 17 158 | 1 560 |
| Japan | 607 | 4 | 23 | 37 | 671 | 2 |
| United Kingdom | 33 | NA | NA | NA | NA | NA |
| United States | 0 | 0 | 0 | 0 | 0 | 0 |
| ***MOX use*** | | | | | | |
| Belgium | 520 | 0 | 0 | 0 | 520 | 0 |
| France | NA | 800 | 800 | 880 | NA | 960 |
| Germany | 6 070 | 250 | 210 | 100 | 6 630 | 100 |
| Japan | 532 | 0 | 135 | 146 | 813 | 0 |
| Switzerland | 1 407 | 0 | 0 | 0 | 1 407 | 0 |
| United States | 0 | 0 | 0 | 0 | 0 | 0 |

NA = Not available or not disclosed.

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

(tonnes of equivalent natural U)

| Country | Pre-2008 | 2008 | 2009 | 2010 | Total to 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| ***Production*** | | | | | | |
| France | 12 200 | 800 | 800 | 1 000 | 14 800 | 1 000 |
| Japan[(a)] | 645 | 0 | 0 | 0 | 645 | 0 |
| Russian Federation | NA | NA | NA | NA | NA | NA |
| United Kingdom | 54 079 | 1 689 | 613 | NA | NA | NA |
| ***Use*** | | | | | | |
| Belgium[(b)] | 508 | 0 | 0 | 0 | 508 | 0 |
| France | 2 300 | 300 | 300 | 600 | 3 500 | 600 |
| Germany | NA | 950 | NA | NA | NA | NA |
| Japan[(a)] | 195 | 0 | 12 | 8 | 215 | 0 |
| Switzerland | 1 770 | 320 | 473 | 291 | 2 854 | 309 |
| United Kingdom | ~15 000 | NA | NA | NA | ~15 000 | NA |

NA = Data not available.

(a) For fiscal year.

(b) From 1993 to 2002.

- Mixed oxide fuel produced from surplus weapons-related plutonium

In September 2000, the United States and the Russian Federation signed an agreement for the disposition of surplus plutonium, whereby both countries will each dispose of 34 t of surplus weapon-grade plutonium (enough to make more than 4 000 nuclear weapons), at a rate of at least two tonnes per year in each country, once facilities are in place. Both countries agreed to dispose of surplus plutonium by fabricating MOX fuel suitable for irradiation in nuclear reactors. This approach will convert the surplus plutonium into a form that cannot be readily used to make a nuclear weapon. In 2009, US President Barack Obama and Russian President Dmitry Medvedev signed a joint statement on nuclear co-operation in Moscow that reaffirmed this commitment.

In the United States, MOX fuel will be fabricated at the DOE's Savannah River site in South Carolina, beginning in 2016, using surplus military plutonium to fabricate fuel for commercial reactors. The Tennessee Valley Authority (TVA) is evaluating the use of MOX at its Sequoyah and Browns Ferry plants, but no formal agreement to use MOX has been signed.

On 1 August 2007, DOE's National Nuclear Security Administration (NNSA) initiated construction of a MOX fuel fabrication facility at Savannah River and as of 2011, the project was proceeding on schedule with first production of MOX fuel expected in 2016 and commercial quantities available in 2018. Work at the Russian MOX facility has not however, proceeded as rapidly.

The 68 t of weapons-grade plutonium would displace about 14 000 to 16 000 tonnes of natural uranium over the life of the programme. This represents about 1% of world annual uranium requirements over this period.

*Uranium produced by re-enrichment of depleted uranium tails*[5]

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

At the end of 2005 the inventory of depleted uranium was estimated to amount to about 1 600 000 tU and to be increasing by about 60 000 tU annually based on uranium requirements of 66 000 tU per annum (NEA, 2007). If this entire inventory was re-enriched to levels suitable for nuclear fuel it would yield an estimated 450 000 tNatU, which would be sufficient for about seven years of operation of the world's nuclear reactors at the 2006 uranium requirement levels.[6] However, this would require significant spare enrichment capacity that is not currently available.

Deliveries of re-enriched tails from the Russian Federation have been an important source of uranium for the EU, representing 1-3.7% of the total n atural uranium delivered annually to EU reactors between 2005 and 2009 (Table 2.8). However, contracts with EU utilities came to an end in 2010 and in 2011 the Russian Federation stopped the re-enrichment of depleted uranium tails. EU enrichers are now putting in place long-term strategies to manage enrichment tails arising 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.

5. 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.
6. OECD Nuclear Energy Agency (2007), *Management of Recyclable Fissile and Fertile Materials*, Paris, France. This total assumes 1.6 million tU at 0.3% $^{235}U$ assay is re-enriched to produce 420 000 tU of equivalent natural uranium, leaving 1 080 000 tU of secondary tails with an assay of 0.14% $^{235}U$.

**Table 2.8. Russian Federation supply of re-enriched tails to European Union end users**

| Year | Re-enriched tail deliveries (tU) | Percentage of total natural uranium deliveries |
|---|---|---|
| 2005 | 474 | 2.8 |
| 2006 | 728 | 3.3 |
| 2007 | 388 | 1.8 |
| 2008 | 688 | 3.7 |
| 2009 | 193 | 1.1 |
| 2010 | 0 | 0 |

Source: Euratom Supply Agency (2010, 2011), *Annual Report 2009, 2010*, Luxembourg.

In the United States, the DOE and the Bonneville Power Administration initiated a pilot project to re-enrich 8 500 t of the DOE's enrichment tails inventory. This project produced approximately 1 939 tNatU between 2005 and 2006 for use by the Columbia Generating Station between 2007 and 2015. Following this successful programme, conversion company ConverDyn and enrichment company URENCO USA announced in October 2011 the creation of the competitive American tails upgrade partnership (CATUP) to manage stocks of depleted uranium tails. The partners envision converting natural uranium concentrates into $UF_6$ at Converdyn's facility and exchanging it for depleted uranium from DOE that will in turn be upgraded at URENCO USA's centrifuge enrichment plant.

Until 2009, a fraction of the depleted $UF_6$ flow generated through enrichment activities in France was sent to the Russian Federation for re-enrichment. This fraction was limited to materials with mining origins that would allow their transfer (in accordance with international and bilateral agreements dealing with the exchange of nuclear materials). The return flow was exclusively used to overfeed the enrichment plant in France (the Georges Besse gaseous diffusion plant run by EURODIF, an AREVA subsidiary).

In addition, in 2008 and 2009, a few thousand tonnes of depleted uranium were removed from storage, converted to $UF_6$ and enriched to natural uranium grade at the Georges Besse gaseous diffusion plant, thanks to the then prevailing economic conditions (primarily high uranium spot prices).

Additional information on the production and use of re-enriched tails is not readily available. The information provided (Table 2.9) indicates that its use is relatively limited.

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

(tonnes of equivalent natural U)

| Country | Pre-2008 | 2008 | 2009 | 2010 | Total to 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| ***Production*** | | | | | | |
| France[a] | NA | NA | NA | 0 | NA | NA |
| United States | 1 940 | 0 | 0 | 0 | 1 940 | 0 |
| ***Use*** | | | | | | |
| Belgium[b] | 345 | 0 | 0 | 0 | 345 | 0 |
| Finland | 843 | 0 | 0 | 0 | 843 | 0 |
| France[c] | NA | NA | NA | NA | NA | NA |
| Sweden[d] | 1 080 | 517 | 0 | 0 | 1 697 | NA |
| United States | 682 | 0 | 694 | 0 | 1 376 | 191 |

NA = Data not available.

(a) In 2008 and 2009, a few thousand tonnes of depleted uranium were re-enriched to natural uranium grade at the Georges Besse gaseous diffusion plant.

(b) Purchased for subsequent re-enrichment.

(c) Until 2009, a small amount of tails were re-enriched in the Russian Federation and recycled within the Georges Besse enrichment plant.

(d) *Nuclear Energy Data*, OECD, Paris, 2010, 2011.

### *Uranium market developments*

*Uranium price developments*

Some national and international authorities, i.e. Australia, the United States and the ESA, produce price indicators to illustrate uranium price trends. Additionally, spot price indicators for immediate or near-term delivery (typically less than 15% of all uranium transactions, although growing to 25% in some years) are regularly provided by industry sources such as TradeTech, the Ux Consulting Company LLC (UxC) and others. Figure 2.9 displays annual average delivered prices reported by various government sources.

The overproduction of uranium, which lasted through 1990 (Figure 2.7), combined with the availability of secondary sources, resulted in uranium prices trending downward from the early-1980s until 1994 when they reached their lowest level in 20 years. Between 1990 and 1994 there were significant reductions in many sectors of the world uranium industry, including exploration, production and production capability. This decreasing supply situation, combined with growing demand for uranium and the bankruptcy of an important uranium trading company, resulted in a modest recovery in uranium prices from October 1994 through mid-1996. This brief recovery however, ended as increasingly better information on inventories and supplies maintained downward pressure on uranium prices until the turn of the century.

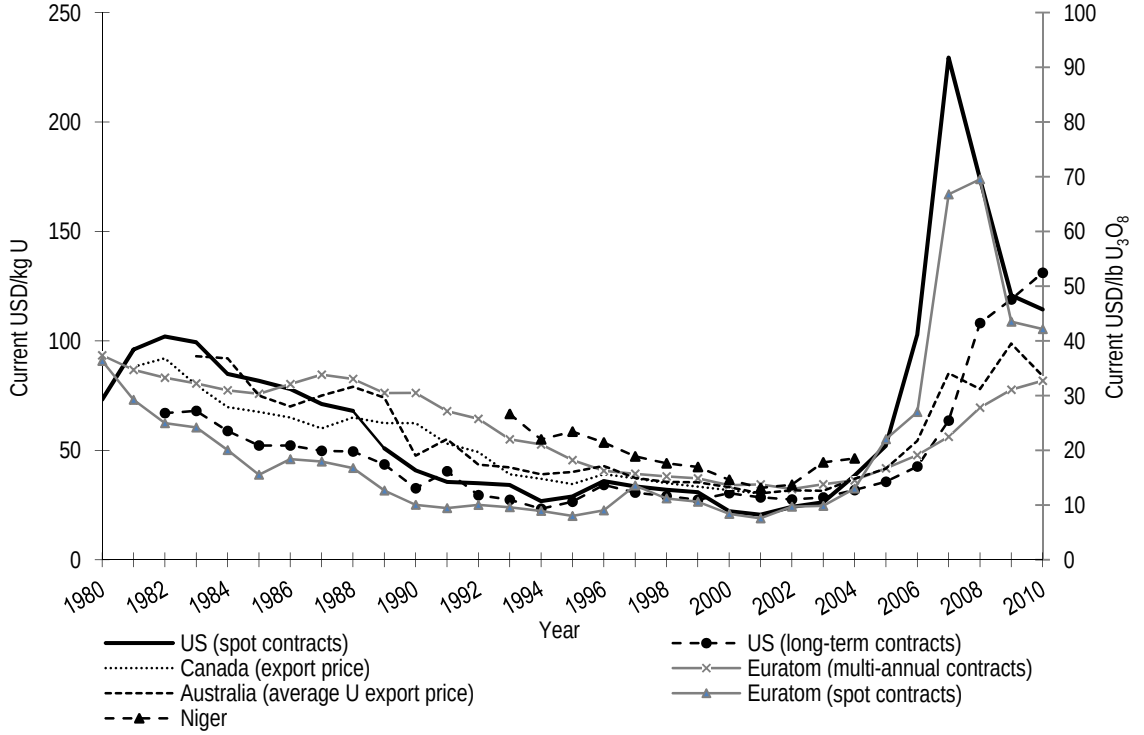
Beginning in 2001, uranium prices began to rebound from historic lows to levels not seen since the 1980s and continued to rise at a rapid rate through 2007. Price information from a limited number of government sources all display this trend (Figure 2.9). In 2009 and 2010, EU and US long-term price indices continued to rise while short-term indices (EU and US spot contracts) continued to decline, although less dramatically than in 2008. The Australia average export price also declined from 2009 to 2010. Depending on the nature of the purchases (long-term contracts versus spot market), the information available on uranium purchases in 2010 indicates that purchase prices ranged between USD 82/kgU and USD 131/kgU (USD 32/lb$U_3O_8$ and USD 50/lb$U_3O_8$).

While the trend of increasing prices is also evident for spot market transactions since 2001, and in particular after 2003, the price has been much more volatile than long-term price indicators since 2006. In June 2007, the spot market price reached as high as USD 136/lb $U_3O_8$ (USD 354/kgU) before declining to USD 85/lb $U_3O_8$ (USD 221/kgU) in October 2007 and USD 52.00/lb $U_3O_8$ (USD 135.20/kgU) at the end of 2011 (Figure 2.10).[7] Note that Figure 2.9 reflects mostly long-term contracts and thus the dynamic changes of the past two years are not as evident as the changes shown in Figure 2.10.

A variety of reasons have been advanced to explain spot price dynamics between 2003 and 2011, including problems experienced in nuclear fuel cycle production centres in 2003 that highlighted dependence on a few critical facilities in the supply chain, as well as the changes in the value of the US dollar, the currency used in uranium transactions. In addition, an increasing sense of the finite nature of inventories, the expansion of nuclear power generation in countries such as China, India and the Russian Federation, the recognition by many governments that nuclear power can produce competitively priced baseload electricity that is essentially free of greenhouse gas emissions and the role that nuclear can play in enhancing security of energy supply all likely contributed to the strengthening market through to 2007. The influence of speculators in the market also helped push uranium prices upward at this time. The downturn in the spot price since June 2007 has been attributed to a market correction, the reluctance of traditional buyers to engage in transactions at such high prices and ultimately the global financial crisis stimulating sales by distressed sellers needing to urgently raise capital.

7. Spot price data courtesy of TradeTech (www.uranium.info).

**Figure 2.9. Uranium prices: 1980-2010**



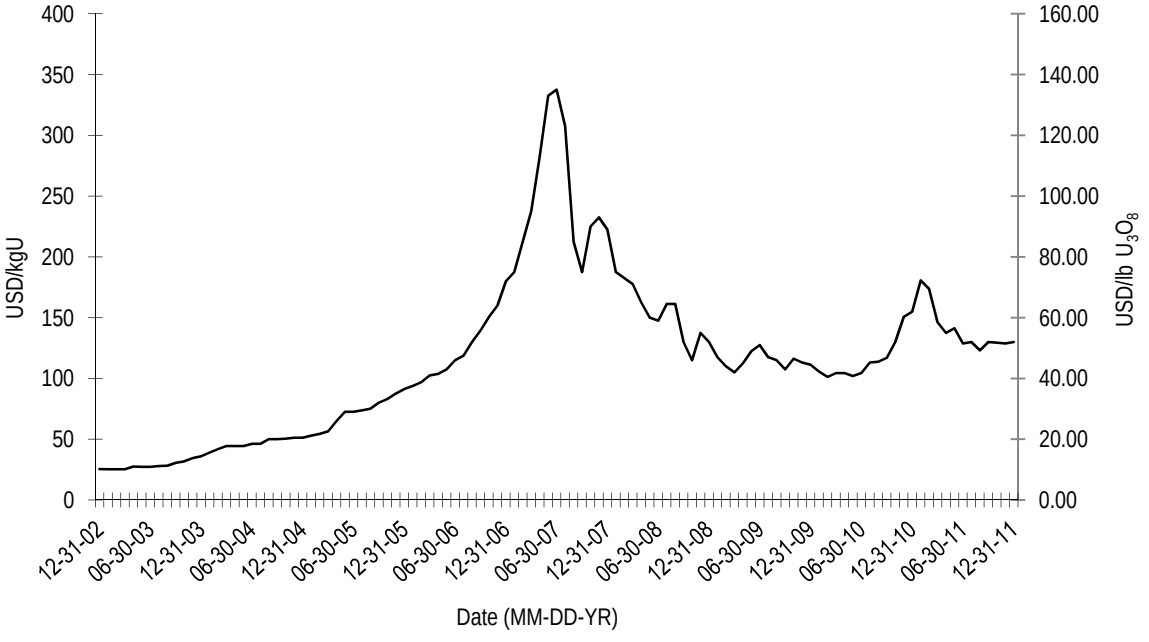

Source: Australia, Canada, Euratom Supply Agency, Niger, United States.

1. Euratom prices refer to deliveries during that year under multi-annual contracts.

2. Beginning in 2002, Natural Resources Canada (NRCan) suspended publication of export price pending policy review.

**Figure 2.10. NUEXCO exchange value trend**

(31 December 2002-31 December 2011)



Since peaking in 2007, the uranium spot price began a gradual overall 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 in China and India as programmes of strong nuclear growth began to be implemented. In the second half of 2010, the spot price began to rally once again as news that China was active in the long-term market stimulated speculative activity in the spot market on perceptions of tightening supply-demand. By early 2011, the spot price had reached USD 72/lb $U_3O_8$ (USD 187/kgU), then started to decline owing to buyer resistance price and reports that China was offering material for purchase on the spot market. The Fukushima accident then precipitated a rapid decline in price that continued through the middle of the year before prices stabilised at slightly above USD 50/lb $U_3O_8$ (USD 130/kgU).

*Policy measures in the European Union*

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 European Union, all uranium purchase contracts by EU end-users (i.e. nuclear utilities) must be approved by ESA. Based on its contractual role and its close relations with the industry, ESA continuously monitors the market with a particular focus on supplies of natural and enriched uranium to the EU. 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.

Nuclear materials for EU reactors come from diverse sources (ESA, 2011). In 2010, Russian origin uranium supplied 28% of the uranium delivered to the EU, followed by Kazakhstan (16%), Niger, Canada and Australia (12% each). HEU feed (downblended weapons grade material from the Russian Federation) accounted for slightly over 3% of total deliveries, about the same amount as uranium supplied from sources within the EU (mainly the Czech Republic and Romania). These deliveries were made under terms and conditions contained in a number of contracts of variable duration with 96% of total deliveries covered under long-term contracts and 4% under spot market contracts. In 2010, the ESA processed a total of 55 contracts and amendments, of which 4 were classified as multiannual (long-term) and 17 as purchases on the spot market.

Energy policy developments in the EU in 2010 included publication of the EU Energy 2020 strategy, the start of activities to develop a low-carbon energy roadmap to 2050, the launch of a European nuclear sustainable industrial initiative and a revised proposal for the management of spent fuel and radioactive waste.

Uranium is sold mostly under long-term contracts and the terms are not made public. Until recently, ESA had been publishing two categories of natural uranium prices on an annual basis, i.e. multiannual 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 in 2009 a new natural uranium multiannual contracts index price (MAC-3). This index price, developed to better reflect short-term changes in uranium prices and to track market trends more closely, is a three-year moving average of prices paid under new multiannual (long-term) contracts for uranium delivered to EU utilities in the reporting year. In 2010, the MAC-3 average price index rose to EUR 78.12/kgU (USD 103.56/kgU or USD 39.83/lb$U_3O_8$), up 23% from 2009, whereas the average spot price for deliveries was EUR 79.48 (USD 105.38/kgU or USD 40.53/lb$U_3O_8$), an increase of 2% compared to 2009 (ESA, 2011). In contrast, the price per pound $U_3O_8$ decreased from 2009 to 2010 owing to the appreciation of the US dollar. EU industry representatives recommended that ESA should calculate retroactively MAC-3 indices and to publish them in a forthcoming Annual Report. Table 2.10 displays the existing ESA uranium price index series.

**Table 2.10. ESA average natural uranium prices (2006-2010)**

| Year | Multiannual contracts | | Spot contracts | | New multiannual contracts (MAC-3) | |
|---|---|---|---|---|---|---|
| | *EUR/kgU* | *USD/lb $U_3O_8$* | *EUR/kgU* | *USD/lb $U_3O_8$* | *EUR/kgU* | *USD/lb $U_3O_8$* |
| 2006 | 38.41 | 18.38 | 53.73 | 25.95 | NA | NA |
| 2007 | 40.98 | 21.6 | 121.8 | 64.21 | NA | NA |
| 2008 | 47.23 | 26.72 | 118.19 | 66.86 | 84.75 | 47.94 |
| 2009 | 55.70 | 29.88 | 77.96 | 41.83 | 63.49 | 34.06 |
| 2010 | 61.68 | 31.45 | 79.48 | 40.53 | 78.12 | 39.83 |

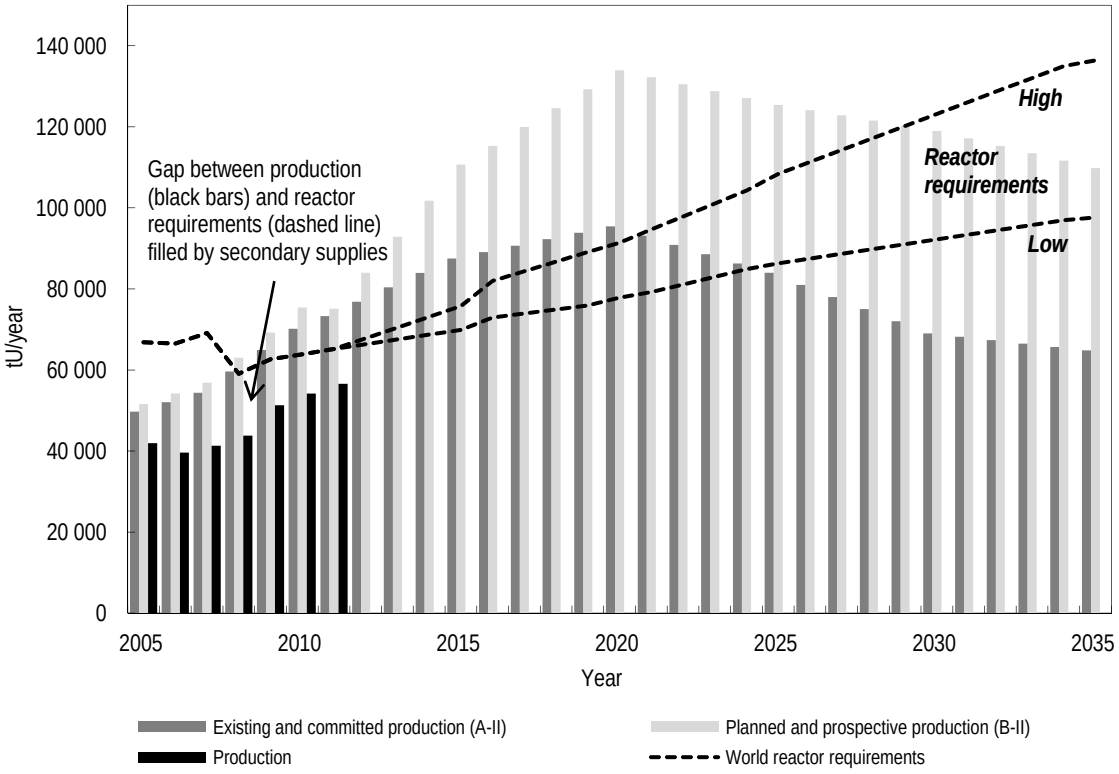
### *Supply and demand to 2035*

Market conditions are the primary driver of decisions to develop new or expand existing primary production centres. As market prices have in general significantly increased since 2003, even with episodes of declining prices since the onset of the financial crisis and following the Fukushima accident, plans for increasing production capability have continued in response to the overall general positive market signal. A number of countries, notably Kazakhstan but also Australia, Brazil, Canada, Namibia, Niger and the Russian Federation, have reported plans for significant additions to planned future production capability. In addition, production has begun in Malawi and other countries, notably Botswana, Jordan, Mongolia, Tanzania and Zambia, are working towards production in the near future. These developments are timely as global demand is projected to increase, despite the Fukushima accident, and secondary sources are expected to decline in availability. However, with rising mining and development costs and a pause in nuclear development following the Fukushima accident, declining market prices and uncertainty have caused delays in at least some of these planned developments.

The supply and demand picture is evolving as more countries, particularly in the developing world, are increasing nuclear generating capacity or considering development of nuclear capacity for the first time. And, despite some delays, uncertainties and challenges in raising funds for mine development, producers are moving to increase production capability and governments are laying the groundwork (e.g. legislation, regulations) for mine development in countries that have not previously hosted uranium production. As reactor requirements are projected to rise through to 2035, an expansion of production capability is also projected to occur (Figure 2.11). As of 2011, these expansion plans, if successfully implemented, are expected to cover high case demand requirements throughout much of this period, even without secondary supplies that have met from 15% to 50% of requirements between 2000 and 2010 in a given year. As noted above, secondary sources are expected to continue to be an important component of supply for some years to come, despite the end of the Russian-US programme to downblend HEU. However, limited information available on secondary supplies makes it difficult to determine how long they will contribute to meeting future demand.

If all existing and committed mines produce at or near stated production capability, high-case demand is projected to be met or exceeded through 2020. If planned and perspective production centres are included, high-case demand requirements are projected to be met until 2030. Planned capability from all reported existing and committed production centres is projected to satisfy 66% of the low case requirements and 48% of the high case requirements in 2035. With planned and prospective production centres, primary production capability would satisfy low case requirements to 2035, but would fall short of meeting high case demand (meeting 80% of high case requirements in 2035). Meeting high case demand requirements would consume about 35% of the total identified resource base by 2035.

**Figure 2.11. Projected annual world uranium production capability to 2035 compared with projected world reactor requirements***




Source: Tables 2.2 and 2.4.

* Includes all existing, committed, planned and prospective production centres supported by RAR and inferred resources recoverable at a cost of <USD 130/kgU.

Are currently defined uranium resources sufficient to cover uranium requirements arising for the entire lifetime of all the reactors projected to be in operation in the high case scenario at 2035? Addressing this question requires making a number of assumptions concerning uranium requirements for reactors being built today and their maximum operational service lifetime (Table 2.11). Using these conservative assumptions total uranium requirements are estimated to amount to over 7.8 million tU, some 600 000 tU (8.4%) more than all high cost (<USD 260/kgU) identified resources and additional conventional resources noted in Chapter 1. This long-term projected deficit is however less than the 790 300 tU added to the identified resource total from 2009 to 2011 alone. Long-term estimated fuel requirements assume additional conservatism in that all reactors are expected to be fuelled by freshly mined uranium without secondary supplies (previously mined uranium, including enrichment tails and reprocessed spent nuclear fuel) and unconventional uranium resources. It also assumes that operating procedures that could reduce uranium consumption, such as lower enrichment tails assays or higher fuel burn-ups, remain similar to those used today.

The ability of the 2011 uranium resource base to provide over 90% of lifetime fuel requirements for all new reactors expected to be connected to the grid between 2011 and 2035 in the high case growth scenario underlines the relative abundance of uranium and the response of the industry to the market signal of generally higher prices since 2003. Uranium is relatively common and increased uranium prices that would likely accompany significant reactor deployment would stimulate mine development and exploration activity, leading to new discoveries, as has been the case in past periods of increased exploration (NEA, 2006). While it is unrealistic to expect currently identified

resources to fuel decades of reactor development, allowing reactor deployment to take place at a plausible but high rate but holding resource figures constant, the result illustrates the overall adequacy of uranium resources to fuel even high case growth projections of nuclear electricity generation in the 21st century.

**Table 2.11. Assumptions used to estimate global reactor fuel requirements**

| Design | Lifetime (yrs) | Lifetime with extension (yrs) | Fuel requirements (tU/GWe/yr)[1] |
|---|---|---|---|
| PHWR | 30 | 55 | 145 |
| Gen II PWR | 40 | 60[2] | 175 |
| Gen II BWR | 40 | 60 | 185 |
| Gen III PWR | 60 | 80[3] | 165 |
| Gen III BWR | 60 | 80 | 165 |

1. Assuming 0.30% $^{235}$U tails assay.

2. Russian designs – lifetime with extension 50 years.

3. Russian designs – lifetime with extension 60 years.

Although Figure 2.11 could be taken to suggest an oversupplied market in the near term, experience shows that this is not likely to be the case. Production capability is not production. The gap between production (black bars) and requirements (dashed line) from 2005 (and earlier) to 2010 has been met by drawing down secondary supplies. The challenge is to continue closing the gap between world production and high and low reactor requirements in the coming years, particularly in light of increased production costs and declining market prices for uranium from mid-2007 through 2009 and the price reduction following the Fukushima accident.

World production has never exceeded 89% of reported production capability (NEA, 2006) and since 2003 has varied between 73% 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. And, as always, technical challenges in the operating and developing mine and mill facilities will need to be overcome. These factors can be expected to reduce and/or delay projected production from planned and prospective centres. Infrastructure development and geopolitics could become more significant factors, particularly as new production centres are increasingly being planned in developing countries with little or no previous experience in uranium mining. 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 be required, supplemented by secondary supplies and uranium savings achieved by specifying low enrichment tails assays when economics are favourable, to the extent possible. After 2013, secondary sources of uranium are generally expected to decline in availability and reactor requirements will have to be increasingly met by primary production (NEA, 2006). Therefore, despite the significant additions to production capability reported here, bringing facilities into production in a timely fashion remains important. To do so, strong market conditions will be fundamental to bringing the required investment to the industry.

A key element of the uranium market continues to be the availability of secondary sources, particularly the level of stocks available and the length of time remaining until those stocks are exhausted. As Table 2.5 shows, 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) continues to make its way to the market after 2013 cannot be discounted. These uncertainties hamper effective decision making on new production capability. However, it is clear that the generally stronger market of recent years, compared to the last two

decades of the 20th century, has driven increased exploration and the development of production capability.

## The long-term perspective

Uranium demand is fundamentally driven by the number of operating nuclear reactors, which ultimately is driven by the demand for electricity. The International Energy Agency's (IEA) 2011 *World Energy Outlook* (WEO) new policies scenario projection (incorporating current announcements and commitments by governments that may not yet be official policy) states that 5 900 GW (gross) of new generating capacity will be needed by 2035 if projected increases in electricity demand are to be met and ageing infrastructure is replaced (IEA, 2011). Electricity demand is expected to increase by about 2.4% a year on average and about 80% of the overall demand growth to 2035 is expected to occur in non-OECD countries, led by China and India (accounting for nearly two-thirds of the overall growth). The role that nuclear energy will play in helping meet projected electricity demand will depend on how effectively a number of factors discussed earlier are addressed (i.e. economics, safety, non-proliferation concerns, security of energy supply, waste disposal, environmental considerations, etc.) and in particular public acceptance of the technology in the wake of the Fukushima accident. The 2011 WEO includes an examination of the impacts of a significantly reduced role for nuclear power, should such a scenario result from this accident. Although not a forecast, the low nuclear case analysis indicates that a significant reduction in nuclear power generation would make achieving greenhouse gas emission reduction goals extremely challenging and costly.

The extent to which nuclear energy is seen as beneficial in meeting greenhouse gas reduction targets could increase the role that nuclear energy plays in meeting future electricity demand. The International Panel on Climate Change (IPCC) noted that electricity generated from fossil fuels has been the biggest source of greenhouse gas emissions growth since 1970 (two times greater than the next largest energy contributor and growing at a much faster rate) (IPCC, 2007). The WEO notes that the power sector currently accounts for 41% of global energy-related $CO_2$ emissions (IEA, 2011). Under the scenario built in the WEO new policies scenario, fossil fuel use continues to rise (in particular coal) to 2035, with consequent increases in global emissions and heightened concerns for security of energy supply. General circulation models indicate that this scale of growth in emissions produces a global temperature increase of 3.5°C with severe consequences in terms of sea-level rise, changes in rainfall patterns and in turn floods, droughts and heat-wave incidence.

An alternative 450 policy scenario outlines strong policy actions required to avoid the most serious consequences of climate change (so named for the 450 ppm atmospheric level of $CO_2$ equivalent that climate scientists have deemed necessary to achieve a 50% chance of limiting warming to 2°C and avoid serious impacts). This scenario calls for more vigorous policy action to restrain $CO_2$ emissions to 2020 and thereafter the establishment of economy wide emission targets to collectively ensure limiting $CO_2$ equivalent concentration to 450 ppm. The implementation of strong energy efficiency measures, increased adoption of renewable energy (including biofuels), rapid growth in nuclear power and increasing deployment of carbon capture and storage are all required by that scenario. The power sector plays a crucial role in this scenario, with emissions declining by 60% compared to 2009 levels. Along with achieving the goal of limiting climate change impacts, emissions of other air pollutants (e.g. sulphur dioxide, nitrogen oxides and particulate matter) that have a negative effect on human health and the environment would also be reduced. Energy security is also expected to be enhanced by reducing import dependence with diversification of the energy mix. Although considerable financial benefit would be achieved by adopting the 450 scenario, considerable investment is also required (estimated to amount to USD 36.5 trillion from 2011 to 2035).

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 utilise either the heat from a nuclear reactor and/or the electricity produced (NEA, 2008). 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, Kazakhstan and Japan. The IAEA is fostering research and collaboration on the issue through its Technical Working Group on Nuclear Desalination. Analyses indicate that nuclear energy can be competitive compared to fossil-fuelled energy sources of desalination (IAEA, 2002).

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 (NEA, 2008).

Energy use for transportation, 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 powered vehicles are seen as potential replacements for fossil fuels. Nuclear energy offers baseload electricity production that could be used to power electric vehicles, as well as the potential of producing hydrogen that could make this alternate energy carrier available with significantly less greenhouse gas emissions compared to current methods of hydrogen production.

Small and medium-sized reactors (SMRs; reactors with effective electric power of less than 700 MWe) could be suitable for areas with small electrical grids and for remote locations. SMRs offer smaller upfront investment costs and reduced financial risks associated with their deployment compared to larger reactors typically being built today (1 000-1 700 MWe). A recently released report summarises the development status and deployment potential of SMRs expected to be available for commercial use in the next 10-15 years, with a principal focus on reactors of less than 300 MWe (NEA, 2011). While a number of these designs are under development, others are undergoing licensing and two are under construction in China and the Russian Federation.

Multilateral fuel cycle initiatives also have the potential to alter uranium demand. 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 the Russian Federation at the International Uranium Enrichment Centre in Angarsk under IAEA auspices. This LEU reserve, comprising 120 t LEU, with one-third of the material enriched to a level of 4.95%, was verified by the IAEA Department of Safeguards that same month. The reserve will be made available to IAEA member states in good standing whose supplies of LEU are disrupted for reasons unrelated to technical or commercial issues. It is to be available for nuclear power generation at market prices and the proceeds will be used to replenish the LEU stock. The Russian Federation is covering the cost of LEU storage, maintenance, safety, security and safeguards. The LEU reserve is not intended to distort the functioning of the commercial market, but rather to reinforce existing market mechanisms of member states.

In addition, the IAEA decided to establish a LEU bank (owned and operated by the IAEA) in December 2010 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 back-up 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 two to three reloads for a 1 000 MWe light water reactor. Donors have pledged about USD 125 million and EUR 25 million to cover the estimated operational expenses and the purchase and delivery of the LEU to a host state or states. In March 2011, the IAEA approved a proposal for nuclear fuel assurance by the United Kingdom, co-sponsored by the member states of the European Union, the Russian Federation and the United States. This initiative is designed to assure that a commercial contract for nuclear fuel is not interrupted for non-commercial reasons. As a response to this initiative, the Germany proposed the establishment of a multilateral uranium-enrichment plant, dubbed the Multilateral Enrichment Sanctuary Project (MESP). Administered by the IAEA, the MESP would allow independent access to these services, complementing other proposals on assurances of supply of nuclear fuel.

In August 2011, DOE announced that the American Assured Nuclear Fuel Supply had been established to secure 230 t LEU, sufficient for six reloads of an average 1 000 MWe reactor, derived from the downblending of the 17.4 t HEU, expected to be completed in 2012. The fuel will be available for use in civilian reactors by nations that are not pursuing uranium enrichment and reprocessing technologies. Qualifying countries will have access to the fuel at the current market price only in the event of an emergency that disrupts the normal flow of fuel supply.

Technological advancements also promise to be a factor in defining the long-term future of nuclear energy and uranium demand. 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 utilisation. The introduction and use of advanced reactor designs would also permit the use of other materials as nuclear fuel, such as uranium-238 and thorium, thereby expanding the available resource base. Moreover, fast neutron reactors could produce more fuel than they consume, since spent fuel could be recovered, reprocessed and reused to produce additional energy.

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). In GIF, Argentina, Brazil, Canada, France, Japan, the People's Republic of China, the Republic of Korea, the Republic of South Africa, the Russian Federation, Switzerland, the United Kingdom, the United States and Euratom are working together to carry out the research and development needed to establish the feasibility and performance capabilities of the next generation (Gen IV) of reactor designs. These designs have stated objectives of construction and operation in a manner that should provide sustainable energy generation that meets clean air objectives, optimises resource utilisation, has clear life-cycle cost advantages over other energy sources, excels in safety and reliability and minimises nuclear waste. In 2002, the GIF reviewed 130 proposals and selected six nuclear energy system concepts to be the focus of continued collaborative research and development. These concepts are 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. The two systems that are the focus of the most active research efforts are the sodium-cooled fast reactor and the very-high-temperature reactor. In 2011, a new task force was set up related to "safety design criteria" for the sodium-cooled fast reactor, taking into account the specific characteristics of this reactor, the general safety approach of Generation-IV reactors, and the lessons learnt from the Fukushima Daiichi accident. A joint GIF/IAEA workshop dedicated to sodium reactor safety was organised in December 2011 in Vienna to promote information exchange.

Established in 2000, the objective of INPRO is to help to ensure that nuclear energy is available to contribute, in a sustainable manner, to the energy needs in the 21st century. As of 2011, 34 IAEA member states (Algeria, Argentina, Armenia, Belarus, Belgium, Brazil, Bulgaria, Canada, Chile, China, the Czech Republic, Egypt, France, Germany, India, Indonesia, Israel, Italy, Japan, Jordan, Kazakhstan, the Republic of Korea, Morocco, Netherlands, Pakistan, Poland, the Russian Federation, the Slovak Republic, the Republic of South Africa, Spain, Switzerland, Turkey, Ukraine and the United States) and the European Commission were engaged in the INPRO project and several other member states or international organisations were observers in INPRO meetings. 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. In the period 2010-11, the INPRO action plan included work in the area of Nuclear Energy Systems Assessments to support long-term strategic planning and nuclear energy development, global and regional scenario developments leading to a vision of sustainable nuclear energy in the 21st century, considering the use of uranium and thorium fuels.

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 and other uses in the long term. Identified resources[8] are sufficient for well over 100 years, considering 2010 uranium requirements of 63 875 tU. If estimates of current rates of uranium consumption in power reactors[9] are used, the identified resource base would be sufficient for over 130 years of reactor supply. Exploitation of the entire conventional resource[10] base would increase this to well over 300 years, though significant exploration and development would be required to move these resources into more definitive categories.

The uranium resource base described in this document is not only more than adequate to meet projected growth requirements to 2035, it is of sufficient size to fuel over 90% of the entire lifetime of all the reactors projected to be built under the high case growth scenario. Meeting low case growth requirements to 2035 would consume a little over 40% of the identified resources available at a cost of <USD 130/kgU (31% of identified resources available at a cost of <USD 260/kgU). Meeting high-case growth requirements to 2035 would consume slightly less than 50% of identified resources available at a cost of <USD 130/kgU and 35% of identified resources available at a cost of <USD 260/kgU. Moreover, 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.

As noted in Chapter 1, there are also considerable unconventional resources, including phosphate deposits, that could be utilised to significantly lengthen the time that nuclear energy could supply energy demand using current technologies. However, considerable effort and investment would need to be devoted to better defining the extent of this potentially significant source of uranium.

8. Identified resources include all cost categories of RAR and inferred resources for a total of about 7 096 600 tU (Table 1.2).
9. Uranium usage per TWh is taken from the NEA publication *Trends in the Nuclear Fuel Cycle* (NEA, 2002). These were used to define how much electricity could be generated for the given levels of uranium resources. Years of generation were then developed by factoring in the 2010 generation rate (2 623 TWh net, Table 2.2) and rounding to the nearest five years.
10. Total conventional resources include all cost categories of RAR, inferred, prognosticated and speculative resources for a total of about 17 533 200 tU (Tables 1.2 and 1.14). This total does not include secondary sources or unconventional resources, e.g. uranium from phosphate rocks.

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. In addition, thorium, which is more abundant than uranium in the earth's crust, is also a potential source of nuclear fuel, if alternative fuel cycles are developed and successfully introduced. Thorium-fuelled reactors have been demonstrated and operated commercially in the past.

Thus, 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, research and investment is required, both to develop new mining projects in a timely manner and to facilitate the deployment of promising technologies.

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# *Chapter 3*. National reports on uranium exploration, resources, production, demand and the environment

Chapter 3 of the report presents the national submissions on uranium exploration, resources and production. These reports have been provided by official government organisations (Appendix 2) responsible for the control of nuclear raw materials in their respective countries and 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 deemed helpful to the reader, the Secretariat has provided additional comments or estimates to complete this report. Where utilised, the Secretariat estimates are clearly indicated.

The agencies are aware that exploration activities may be currently proceeding in a number of other countries which are not included in this report. They are also aware that in some of these countries uranium resources have been identified. However, it is believed that the total of these resources would not significantly affect the overall conclusions of this report. Nevertheless, both agencies encourage the governments of these countries to submit an official response to the questionnaire for the next edition exercise.

Finally, it should be noted that the national boundaries depicted on the maps that accompany the country reports are for illustrative purposes and do not necessarily represent the official boundaries recognised by the member countries of the OECD or the member states of the IAEA.

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). A snapshot of this database is published as *World Distribution of Uranium Deposits (UDEPO) with Uranium Deposit Classification*, 2009 Edition (IAEA-TECDOC-1629). 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. The IAEA publication is accompanied with the database as of end of 2008 on a CD-ROM. It may be ordered from:

International Atomic Energy Agency
Sales and Promotion Unit, Division of Publications
P.O. Box 100, Wagramerstrasse 5, A-1400 Vienna, Austria
Telephone: (43) 1-2600-22529 (or 22530)
Facsimile: (43) 1-26007-29302
Electronic mail: sales.publications@iaea.org
Website: www-pub.iaea.org/MTCD/publications/publications.asp

Thirty-four member countries submitted a response to the questionnaire and the Secretariat drafted eight country reports. As a result, there are a total of 42 national reports in the following section. This edition uses the revised format introduced in 2005, where the data tables are provided at the end of each country's report.

# 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 Pre-Cambrian 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 at, and focused on the assessment of reserves and exploitation of these 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, 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 2007 and January 2011.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

Reasonably assured resources (RAR) in Algeria fall into one of two geological categories: upper Proterozoic vein deposits in the western Hoggar and a deposit linked to the Pre-Cambrian 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.

Unconformity related resources are represented by the Tahaggart deposit, which is linked to 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 indications discovered in the Ait Oklan-El Bema (north Hoggar) region have not been assessed in terms of the corresponding 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 today and has not produced uranium in the past.

## Environmental activities and socio-cultural issues

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

- Law No. 01-10 of 3 July 2001 on mining activities.
- Law No. 03-10 of 19 July 2003 on the protection of the environment for sustainable development.
- Environmental issues relating specifically to uranium mining will be regulated by the new nuclear legislation currently under development.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

In order to meet the challenges facing Algeria, namely electricity generation, development of the agricultural sector, use of water resources and improved healthcare services, the country needs to acquire comprehensive scientific knowledge. Its activities in the nuclear sector, in compliance with the Treaty on the Non-proliferation of Nuclear Weapons that it has ratified, will undoubtedly assist it in meeting its objectives in large part.

As an oil and gas producing country, Algeria is well aware of the non-renewable nature of these resources and limited availability of its domestic energy resources. It knows that it absolutely has to diversify its energy resources and examine other sustainable and economically viable options. It is from this perspective that the Algerian government has launched programmes to promote research into alternative energy sources such as solar, wind and biomass, with a particular focus on costs and the environmental issues involved.

The aim is to capitalise on the most innovative technological developments, including the role that nuclear energy should play in the national energy mix.

It is for this reason that the development of programmes to promote nuclear power and improve national planning capacities is currently of particular interest.

### *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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | 2 000 | *In situ* |
| Sandstone | | | | | |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | 24 000 | *In situ* |
| Intrusive | | | | | |
| Volcanic and caldera-related | | | | | |
| Metasomatite | | | | | |
| Other* | | | | | |
| Total | | | | 26 000 | *In situ* |

* 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.

### 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 | 0 | 0 | |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 26 000 | *In situ* |
| Total | 0 | 0 | 0 | 26 000 | *In situ* |

### 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 | 0 | 0 | 0 | 0 | |
| Conventional from UG | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 26 000 | *In situ* |
| Total | 0 | 0 | 0 | 26 000 | *In situ* |

* Also known as stope leaching or block leaching.

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

### Short-term production capability

(tonnes U/year)

| 2011 | | | | 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 |
| 0 | 0 | 0 | 0 | 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 |

### Installed nuclear generating capacity to 2035

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 0 | 0 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 0 | 0 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

### 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 | 0 | 0 | 0 | 0 | 0 |
| Producer | 0 | 0 | 0 | 0 | 0 |
| Utility | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 0 | 0 |

# Argentina

## Uranium exploration and mine development

### *Historical review*

Uranium exploration activities in Argentina began in 1951-1952, leading to the discovery of the Huemul, Don Otto and Los Berthos sandstone deposits. During the late 1950s and the early 1960s, airborne surveys also led to the discovery of the Los Adobes sandstone deposit in Patagonia.

During the 1960s, the Schlagintweit and La Estela vein deposits were discovered and subsequently mined. During the 1970s, follow-up exploration in the vicinity of 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 nation-wide exploration programme was undertaken to evaluate geological units with uranium potential.

### *Recent and ongoing uranium exploration and mine development activities*

In 1990, exploration was initiated in the vicinity of the Cerro Solo deposit in Patagonia and drilling of more than 56 000 m has been completed to test the potential of favourable portions of the paleochannel structure. The results included the localisation and partial evaluation of specific mineralised bodies containing several thousand tonnes of resources. These results allowed conclusion of a prefeasibility study on this U-Mo deposit. The National Atomic Energy Commission (CNEA) then developed a programme to complete a feasibility study of the Cerro Solo deposit, including exploration and evaluation of the surrounding areas. From 2007 to April 2011 a total of 28 431.60 m had been drilling into main bodies and mineralised areas in the Pichiñan district. This includes 4 030 m of core sample collected for hydrometallurgical analyses.

Environmental studies are also being carried out in the Pichiñan district, including the collection of stream water and sediment, soil, vegetation, wildlife and other samples to establish baseline data, along with socio-economic, archaeological and paleontological surveys. In addition, environmental monitoring in the deposit area and surroundings is being carried out, covering a total of 500 $km^2$. The monitoring includes stream, spring, groundwater and potable well water.

The Las Thermas (vein type) uranium exploration project continues with samples obtained during past fieldwork being analysed. However, the Judge of Mines in Catamarca province suspended field exploration activities in October 2007 due to the intervention of a group opposed to uranium mining. This situation continues to the present.

In the east slope of Velasco Hill, La Rioja province, detailed exploration is being carried out on surface and a drilling campaign was begun in 2009 in order to study uranium mineralisation recognised in the contact between granite and metamorphic rocks.

Other areas were selected for more detailed geological studies. These include an examination of the potential of exploiting some favourable sandstone occurrences by

*in situ* leach (ISL) technology and favourability studies in vein and episyenite type granitic environments.

From 2009 to April 2011, the number of exploration permit areas studied by CNEA increased from 50 to 76 as a consequence of the reactivation of the nuclear programme and uranium mining activity by the government of Argentina.

In the past five years, there has also been an increase in exploration activity by the private sector in Argentina. The financial crisis at the end of 2008 caused a temporary slowdown of activities in 2009, which picked up again in 2010. In 2009, a number of companies formed the Argentine Chamber of Uranium Companies (CADEU, in Spanish), in order to share best practices in uranium exploration and to co-operate on joint industry information efforts. Exploration companies have employed a total of about 60 people in their recent activities.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

The identified conventional resources values reported here contain only minor changes compared to those published in 2009. Geological and uranium mineralisation data were loaded and processed in a specific software for mineral resource evaluation, resulting in a decrease of reasonably assured resources and an increase of inferred resources in the higher cost categories, compared to figures reported in 2009.

Additions in identified conventional resources at the Cerro Solo deposit between 2007 and 2011 as result of additional exploration drilling of the "C" and "B" ore bodies amounted to:

- 2007-2009, RAR plus IR (<USD 130/kgU): 1 257 tU;
- 2009-2011, RAR plus IR (<USD 130/kgU): 147 tU.

The results of private sector exploration activities are not included in these figures since these data are not collected by CNEA. This issue is discussed further in Chapter 1.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

The 13 810 tU prognosticated resources reported correspond to five ore bodies of the Cerro Solo, El Ganso, Puesto Alvear, El Molino and Arroyo Perdido deposits. All but two of these deposits are part of the East Pichiñán uraniferous district in Chubut province and occur in the same geological setting. Two other small deposits are located in the provinces of La Rioja and Santa Cruz.

### *Unconventional resources and other materials*

NA.

## Uranium production

### *Historical review*

Argentina produced uranium from the mid-1950s until 1999 from a total of seven commercial scale production centres and a pilot plant that operated from 1953-1970. 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. Since 1996, the uranium mining industry has been wholly owned by CNEA. The last facility that remained in operation at that time, San Rafael, was placed on stand-by in 1999. Between the mid-1950s and 1999, cumulative uranium production totalled 2 582 tU (revised from the previously reported figure of 2 513 tU).

**Uranium production centre technical details**

(as of 1 January 2011)

| | Centre #1 | Centre #2 |
|---|---|---|
| Name of production centre | Complejo Minero Fabríl San Rafael (CMFSR) | |
| Production centre classification | Stand-by | Planned |
| Date of first production (year) | 1976 | 2016 |
| Source of ore: | | |
| Deposit name(s) | Sierra Pintada | Cerro Solo |
| Deposit type(s) | Volcaniclastic | Sedimentary |
| Recoverable resources (tU) | 6 000 | NA |
| Grade (% U) | 0.107 | NA |
| Mining operation: | | |
| Type (OP/UG/ISL) | OP | OP-UG |
| Size (tonnes ore/day) | 550 | NA |
| Average mining recovery (%) | 90 | NA |
| Processing plant: | | |
| Acid/alkaline | Acid | Acid |
| Type (IX/SX) | IX | SX |
| Size (tonnes ore/day) | | |
| Average process recovery (%) | 78 | NA |
| Nominal production capacity (tU/year) | 150 | 100 |
| Plans for expansion (yes/no) | Yes | NA |
| Other remarks | | Preliminary stage |

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

*The production projects*

Argentina produced about 120 tU/year for about 20 years to feed the power plants Atucha I and Embalse, with ore from different sites distributed throughout the national territory. But in the late 1990s, the decline in 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 caused CNEA to review its plans and consider reopening production facilities. These changes include the overall increase in the price of uranium since 2000, uncertainties in future external supply and the impending increase in domestic uranium requirements to 265 tU/yr owing to the completion of the Atucha II reactor. In addition, the potential addition of two new NPPs and the development of the new CAREM 25 reactor will further domestic uranium requirements.

*The San Rafael Mining-Milling Complex Remediation and Reactivation Project*

Once CNEA evaluated the possibility of reopening the productive facilities of San Rafael mining-milling complex (Sierra Pintada mine), it developed an environmental impact assessment (EIA 2004, according to provincial Act No. 5961) and presented it to the authorities in the Province of Mendoza and to the Nuclear Regulatory Authority.

This study evaluated the potential impacts of uranium concentrate and dioxide production and the treatment of the former wastes simultaneously.

This EIA concluded that former operations had not affected the quality of underground and surface waters in the area, or any other environmental component of the surroundings.

Provincial authorities nonetheless rejected this proposal because they maintain that CNEA must first remediate the open-pit water and wastes from the purification process 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. This proposal received technical approval in all instances, but did not receive final approval because it lacked the statutory public hearing.

In all these studies, the use of modern technology to preserve the environment along with additional security measures has always been considered.

A further complication that increases the difficulty of reopening the plant is the approval of Mendoza provincial Act No. 7722 that prohibits the use of sulfuric acid in mining.

Currently CNEA is dealing with two major issues: on one hand, updating the General Environmental Impact Manifestation (MGIA 2006) related to the treatment of open-pit water and solid wastes through a competitive bidding process; on the other hand, preparing for the construction of ponds for evaporation and effluent treatment at the San Rafael complex.

CNEA finally managed to secure sufficient funds for the rehabilitation works of uranium production facilities from the Bank for Investment Projects in the Ministry of Economy. Before beginning the rehabilitation work however, it is necessary to obtain both provincial approval and modification of the law that prevents the use of sulfuric acid. Having secured an approved budget means that greater time and resources can be devoted to addressing the remediation and rehabilitation work. These activities involve the removal of obsolete facilities, construction of effluent ponds, the purchase of equipment and facilities and associated activities.

*The Cerro Solo Project*

CNEA also continues to develop feasibility studies for the proposed mining of the Cerro Solo deposit in Chubut province. At the current stage of development, a laboratory scale sample testing is underway in order to determine the most economically competitive process. Given that the ore contains not only uranium but also molybdenum, finding an appropriate and feasible process is a challenge. For this reason, all these preliminary investigations are critical steps in order to eventually achieve the required change of scale.

Apart from technical considerations, a Chubut provincial law (5001/03), very similar to the previously mentioned legislation in Mendoza, is in effect that prevents open-pit mining. However, Chubut is considering splitting the province into regions that would allow such operations and Cerro Solo is located in one of these proposed regions.

### *Ownership structure of the uranium industry*

In Argentina, all of uranium industry is currently government owned. Private sector participation exists only in the exploration phase, although legislation provides for the participation of both public and private sectors in uranium exploration and development activities.

### *Employment in the uranium industry*

Continued development of the uranium production industry employed 133 people in 2010 and this is expected to increase slightly to a total of 145 in 2011. Most of them (about 90) are working on development of the San Rafael mining-milling complex.

### *Future production centres*

The strategic plan recently submitted by CNEA to national authorities includes development of a new production centre in the province of Chubut in the vicinity of the Cerro Solo deposit. The beginning of operations is targeted in 2016.

## Secondary sources of uranium

### *Production and/or use of mixed oxide fuels*

Argentina neither produces nor uses MOX fuel, re-enriched tails or reprocessed uranium in its NPPs.

## Environmental activities and social cultural issues

A number of Argentina's provinces have legislation in place limiting certain aspects of mining activities (e.g. use of certain substances, open-pit mining). Efforts continue on the part of the public and private sectors to improve communication, information and education about the mining sector in general and uranium mining in particular.

### *The San Rafael Mining-Milling Complex Remediation and Reactivation Project (CMFSR in Spanish)*

Although all activities related to the "Temporary Storage Waste Management" project are not yet authorised, the reconstruction of some effluent treatment ponds has been authorised.

The reconstruction of the ponds, in the same place that those of the former production stage are situated, involves the management of other former wastes such as barren and low-grade mineralised ore that could be used in the stabilisation of solid precipitates and embankment construction.

At this point the construction of an evaporation pond of about three hectares with waterproofed HDPE geo-membrane has been completed. Detailed engineering of two ponds of about five hectares for civil works tender is well advanced. These ponds will have security drainage systems and double waterproofing HDPE geo-membrane in order to control leaks.

Other activities in progress related to waste management include waterproofing of cisterns, recycling of the wastewater neutralisation plant, repair of facilities used for the storage and distribution of sulfuric acid and the installation of pipes for pumping effluent between the quarries and processing and treatment facilities.

Furthermore, modelling studies on the waterproofing behaviour of cohesive material and other hydrogeological studies are being carried out through agreements with the National Institute of Water. Tendering an updated environmental impact assessment for waste management in transient storage is also in process. This update will also include a study related to the socio-economic aspects of the development project.

Also foreseen in 2012 is the development of an EIA on the rehabilitation of uranium concentrate production at CMFSR.

### *Cerro Solo ore deposit*

The environmental authority of the Chubut province has determined that mining projects must complete baseline environmental studies during the exploration stage. This task is being realised by CNEA through cross contract with universities and institutes of investigation since 2009.

The last environmental studies that are being carried out in the Pichiñan district include the collection of environmental data and assessments of archaeological, paleontological and socio-economic impacts.

Also, in the last two years social communication and diffusion of information on mining activities has been intensified in the localities near proposed mining projects and areas of exploration.

## Uranium requirements

Uranium requirements listed below correspond to estimates made in the Strategic Energy Plan 2010-2030 and the revival of the Argentine Nuclear Plan in 2006. The nuclear plan includes:

- completion of the construction of Atucha II NPP (expected in 2011);
- prolonging the life of the Embalse NPP;
- reactivation of production at the heavy water plant;
- reactivation of the development of the nuclear power reactor CAREM;
- reactivation of the uranium enrichment plant.

Also proposed is expansion of the nuclear energy field, including: construction of two 1 100 MW NPP for operation from 2016/7 and 2018/20; completing development and construction of the CAREM (25 MWe) NPP; and finally, completing construction of another CAREM (150 MW) to be located in Formosa Province.

### *Supply and procurement strategy*

Argentina is carrying out an exploration programme and developing projects for restarting domestic uranium production in order 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 the National Atomic Energy Commission (CNEA) and the Nuclear Regulatory Authority (ARN). It also provides for the participation of both public and private sectors in uranium exploration and development activities.

The National Mining Code of 1994 stipulates 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 conform to international standards.

### *Uranium stocks*

As of 31 March 2011, total stocks held by CNEA amounted to 52 tU.

### *Uranium prices*

There is no uranium market in Argentina.

**Uranium exploration and development expenditures and drilling effort – domestic**

(ARS [Argentine pesos])

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 16 116 878.00 | 8 509 440.00 | 21 533 056.00 | 30 805 866.00 |
| Government exploration expenditures | 6 199 000.00 | 17 332 000.00 | 26 500 000.00 | 30 300 000.00 |
| Industry* development expenditures | | | | |
| Government development expenditures | | | | |
| Total expenditures | | | | |
| Industry* exploration drilling (m) | 8 665 | 0 | 5 530 | 11 300 |
| Industry* exploration holes drilled | 219 | 0 | 214 | 276 |
| Government exploration drilling (m) | 3 951.6 | 8 719.75 | 13 314.00 | 6 000.00 |
| Government exploration holes drilled | 38 | 99 | 129 | 53 |
| Industry* development drilling (m) | | | | |
| Industry* development holes drilled | | | | |
| Government development drilling (m) | | | | |
| Government development holes drilled | | | | |
| Subtotal exploration drilling (m) | | | | |
| Subtotal exploration holes drilled | | | | |
| Subtotal development drilling (m) | | | | |
| Subtotal development holes drilled | | | | |
| Total drilling (m) | | | | |
| Total number of holes drilled | | | | |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | |
| Sandstone | | 2 890 | 4 599 | 4 599 | 72 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | |
| Vein | 0 | 0 | 0 | 0 | |
| Intrusive | 0 | 0 | 0 | 0 | |
| Volcanic and caldera-related | | 2 240 | 4 000 | 4 000 | 72 |
| Metasomatite | 0 | 0 | 0 | 0 | |
| Other* | 0 | 0 | 0 | 0 | |
| Total | | 5 130 | 8 599 | 8 599 | |

* 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.

### 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 | 180 | 180 | |
| Open-pit mining (OP) | | 5 130 | 8 419 | 8 419 | 72 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | | 5 130 | 8 599 | 8 599 | 72 |

### 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 | 0 | 0 | |
| Conventional from OP | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | NA | 5 130 | 8 599 | 8 599 | 72 |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | | 5 130 | 8 599 | 8 599 | 72 |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | |
| Sandstone | 1 951 | 2 201 | 3 762 | 4 812 | 72 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | |
| Vein | 0 | 0 | 0 | 0 | |
| Intrusive | 0 | 0 | 0 | 0 | |
| Volcanic and caldera-related | 480 | 1 800 | 6 170 | 6 170 | 72 |
| Metasomatite | 0 | 0 | 0 | 0 | |
| Other* | 0 | 0 | 0 | 0 | |
| Total | 2 431 | 4 001 | 9 932 | 10 982 | 72 |

* 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.

### 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 (%) |
|---|---|---|---|---|---|
| Underground mining (UG) | 0 | 0 | 0 | 0 | |
| Open-pit mining (OP) | 2 431 | 4 001 | 9 932 | 10 780 | 72 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 2 431 | 4 001 | 9 932 | 10 982 | 72 |

### 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 | 0 | 0 | |
| Conventional from OP | 2 431 | 4 001 | 9 932 | 10 980 | 72 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 2 431 | 4 001 | 9 932 | 10 982 | 72 |

* 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 |
| NA | 13 810 | 13 810 |

### 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 2 581.7 | 0 | 0 | 0 | 2 581.7 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 2 581.7 | 0 | 0 | 0 | 2 581.7 | 0 |

* 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.

## Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 1 858.5 | 0 | 0 | 0 | 1 858.5 | 0 |
| Underground mining[1] | 723 | 0 | 0 | 0 | 723 | 0 |
| *In situ* leaching | 0 | 0 | 0 | 0 | 0 | 0 |
| Co-product/by-product | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 2 581.5 | 0 | 0 | 0 | 2 581.5 | 0 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 752.7 | 0 | 0 | 0 | 0 | 0 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** | 1 829 | 0 | 0 | 0 | 0 | 0 |
| U recovered from phosphate rocks | 0 | 0 | 0 | 0 | 0 | 0 |
| Other methods*** | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 2 581.7 | 0 | 0 | 0 | 0 | 0 |

* Also known as stope leaching or block leaching.

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

*** Includes mine water treatment and environmental restoration.

### Uranium industry employment at existing production centres

(person-years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 133 | 133 | 133 | 145 |
| Employment directly related to uranium production | 90 | 90 | 90 | 95 |

### Short-term production capability

(tonnes U/year)

| 2011 | | | | 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 |
| 0 | 0 | 120 | 0 | 0 | 0 | 150 | 0 | 0 | 0 | 150 | 250 |

| 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 |

### Net nuclear electricity generation

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 8.2 | 7.2 |

### Installed nuclear generating capacity to 2035

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 005 | 1 005 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 1 005 | NA | 1 785 | NA | 4 200 | NA | 4 200 | NA | 4 200 | NA | 4 200 | NA |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 140 | 120 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 120 | 120 | 265 | 265 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |

### Total uranium stocks

(tonnes natural U-equivalent)

| Holder | Natural uranium stocks in concentrates | Enriched uranium stocks | Enrichment tails | LWR reprocessed uranium stocks | Total |
|---|---|---|---|---|---|
| Government | 52 | 0 | 0 | 0 | 52 |
| Producer | 0 | 0 | 0 | 0 | 0 |
| Utility | NA | NA | NA | NA | NA |
| Total | NA | NA | NA | NA | NA |

# Armenia

## Uranium exploration and mine development

### *Historical review*

On 23 April 2007, the Director General of Rosatom (a state corporation of the Russian Federation) and the Armenian Minister of Ecology Protection signed the 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 geological exploration, mining and processing of uranium. The founders of ARMC are the government of Republic of Armenia and Atomredmetzoloto of the Russian Federation.

In the frame of this project, the collection and analysis of the archival material relevant to the uranium mining was completed. The document *Geologic Exploration Activity for 2009-2010* aimed at the uranium ore exploration in the Republic of Armenia was developed and approved. According to this document, in the spring of 2009 field work related to uranium ore exploration was started near Lernadzor, in the province of Syunikand and was ongoing as of mid-2011.

## Uranium production

In 2007, the government of Armenia decided that the Republic of Armenia would enter into an agreement with the governments of Kazakhstan and the Russian Federation to establish an international uranium enrichment centre (IUEC) at the Angarsk electrolytic chemical combine in the Russian Federation. The Republic of Armenia completed the legal registration of accession and in 2010 joined the IUEC.

## Uranium requirements

There have been no changes in 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 (Armenia-2). A high-level uranium requirements forecast was done, taking into account the designed lifetime for this reactor, which has an installed capacity of about 407.5 MW(e).

The long-term requirements depend on the country's policy in the nuclear energy sector. According to the Armenian energy sector development plan to 2020, construction of a new nuclear unit with the capacity of about 1 000 MW(e) and second unit of the same capacity is envisaged in 2025, according to the high-level energy forecast option. The Ministry of Energy and Natural Resources released in April 2011 the *Armenia New Nuclear Unit Environmental Report*.

### *Supply and procurement strategy*

Nuclear fuel for the reactor of the Armenian NPP is supplied by the Russian Federation. Armenia's nuclear fuel requirements during the past two years remain unchanged. The procurement strategy has remained the same and the country's uranium supply position continues to be based on the fuel procurement from the Russian Federation.

**Net nuclear electricity generation**

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 2.30 | 2.344 |

**Installed nuclear generating capacity to 2035**

(MWe net)

| 2008 | 2009 | 2010 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 375 | 375 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 375 | 375 | 375 | 375 | 1 000 | 1 000 | 1 000 | 2 000 | 2 000 | 2 000 | 2 000 | 2 000 |

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

(tonnes U)

| 2008 | 2009 | 2010 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 81 | 64 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 64 | 64 | 64 | 64 | 154 | 315 | 154 | 469 | 308 | 308 | 308 | 308 |

# Australia

## Uranium exploration and mine development

### *Historical review*

A review of the history of uranium exploration and mine development in Australia is provided in *Australia's Uranium: Resources, Geology and Development of Deposits*: www.ga.gov.au/image_cache/GA9508.pdf

### *Recent and ongoing uranium exploration and mine development activities*

Uranium exploration expenditure in Australia reached a record high of AUD 220.5 million in 2008 then declined to AUD 179.6 million in 2009 and AUD 190.0 million in 2010.

The main areas where uranium exploration was carried out during recent years were:

- Gawler Craton/Stuart Shelf region (South Australia, SA) – exploration for hematite breccia complex deposits.
- Frome Embayment (SA) – exploration for sandstone uranium deposits.

- Alligator Rivers region (Northern Territory, NT) – exploration for unconformity-related deposits.
- Mount Isa region (Queensland, Qld) – exploration for extensions of metasomatite type deposits.
- Cenozoic palaeochannels sands (Western Australia, WA) – exploration for calcrete deposits.

*Olympic Dam* (SA) – Exploration drilling has outlined significant additional resources in the south-eastern portion of the orebody. Total measured + indicated + inferred resources (JORC Code) amount to 9 075 million tonnes (Mt) averaging 0.87% Cu, 0.27 kg/t $U_3O_8$, 0.32 g/t Au and 1.5 g/t Ag as at June 2010.

*Ranger* (NT) – Exploration drilling in the Ranger 3 Deeps area has defined a zone of contiguous high grade mineralisation east of the current operating pit.

*Four Mile* (SA) – In July 2009, the Australian and South Australian governments formally approved the development of an *in situ* recovery (ISR, otherwise known as ISL) operation and an ion exchange facility to be constructed at Four Mile. Heathgate Resources propose that uranium-bearing resins from this plant will be transported 8 km by road tanker to the Beverley plant where uranium will be recovered to produce uranium hydroxide concentrates. Progress has been delayed until legal issues between the joint venture partners are resolved.

In 2009, Heathgate Resources discovered two new sandstone-hosted uranium deposits in the Frome Embayment (SA) – the Pepegoona and Yadglin deposits, located 12 km north and 16 km north-northeast (respectively) of Beverley mine. This area is referred to as Beverley North project.

Environment impact assessments have commenced on the following deposits which are proposed new uranium mines: *i)* Yeelirrie, WA – BHP Billiton plans for an open-cut pit and ore processing plant; *ii)* Kintyre, WA – Cameco plans for an open-cut, on-site leach and precipitation treatment plant; *iii)* Wiluna project, WA – Toro Energy plans for two open-pits and on-site heap leach.

ISR field leach trials are in progress at Mullaquana deposit, 20 km south-west of Whyalla SA (UraniumSA Ltd) and Oban deposit 100 km north of Broken Hill (Curnamona Energy).

Exploration drilling continued at Carrapateena, a hematite breccia complex deposit hosted by brecciated granites (similar to Olympic Dam and 100 km south-east of it). The deposit is known over a vertical height of 1 000 m and the top of the deposit is 400 m below surface. Total inferred resources are 203 Mt averaging 1.31% Cu, 0.56 g/t Au, 6 g/t Ag and 270 ppm U. Metallurgical test work has shown that uranium recoveries are approximately 75%. The average uranium grade of Carrapateena is the same as the average grade of total resources at Olympic Dam, although Olympic Dam ore reserves are higher grade, averaging 500 ppm U.

### *Uranium exploration and development expenditures – abroad*

During 2009 and 2010, several Australian companies explored for uranium in Namibia and other African countries.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

Australia's total identified resources recoverable at costs of less than USD 80/kg U amounted to 961 500 tU as of 1 January 2010, a decrease of 17% compared with the estimates as of 1 January 2009. Australia's total identified resources of uranium

recoverable at costs of USD 130/kg U amounted to 1 158 000 tU, a decrease of 2% compared with the 2009 estimate. These changes are due to the impacts of increasing costs of mining and milling uranium ores over recent years. As a result, resources in some uranium mines and deposits are now in higher cost categories compared with the estimates for 2009. These increases reflect the overall cost increases in the Australian mining industry due to ongoing expansions and major developments in the industry.

Although there more than 35 deposits with identified resources recoverable at costs of <USD 130/kg U, the vast majority of these resources are within the following 6 deposits:

- Olympic Dam, which is the world's largest uranium deposit.
- Ranger, Jabiluka and Koongarra in the Alligator Rivers region (NT).
- Kintyre and Yeelirrie (WA).

At Olympic Dam, uranium is a co-product of copper mining. Gold and silver are also recovered.

All of Australia's identified resources recoverable at costs of <USD 80/kg U (and 80% of identified resources recoverable at costs of <USD 130/kg U) are tributary to existing and committed production centres.

#### *Undiscovered conventional resources (prognosticated and speculative resources)*

Estimates are not made of Australia's undiscovered resources.

#### *Unconventional resources and other materials*

Estimates are not made for Australia.

### Uranium production

#### *Historical review*

A review of the history of uranium production in Australia is given in *Australia's Uranium Resources, Geology and Development of Deposits*, AGSO-Geoscience Australia: www.ga.gov.au/image_cache/GA9508.pdf

#### *Status of production capability and recent and ongoing activities*

Australia's mine production for 2010 was 5 900 tU, 26% less than for 2009. Production declined at all three operating mines. Ranger was disrupted by heavy rainfall; Olympic Dam was disrupted by damage to the main haulage shaft; and Beverley was lower because of limited resources remaining at Beverley deposit. Mine production has decreased progressively at all three mines since 2007.

*Olympic Dam*

In 2010, production from Olympic Dam was 2 330 tU, 21% lower than the previous year. Mine production for 2009 and 2010 were reduced following damage to the haulage system in the Clark shaft. Following repairs, ore hoisting from the shaft resumed in June 2010.

BHP Billiton has proposed a major expansion of the Olympic Dam operation that would include the development of a large open pit to mine the south-eastern portion of the deposit adjacent to the existing underground mine. The final supplementary environmental impact statement for the Olympic Dam expansion was released in May 2011 and the project was formally approved by the Australian and South Australian governments in October 2011.

At full production, the expanded open-cut and underground operations would mine a total of 80 Mt per annum (Mtpa) of ore with annual production estimated to reach 750 000 t of refined copper, 16 100 tU (19 000 t $U_3O_8$), 800 000 ounces of gold and 2.9 million ounces of silver. The capacity of the existing underground mine would be increased to approximately 20 Mtpa by 2015.

*Ranger*

In 2010, the open-cut Ranger mine produced 3 216 tU, 28% lower than the previous year because mining and milling were disrupted by heavy rainfall in 2010 and early 2011. In January 2011, Energy Resources of Australia suspended metallurgical processing operations until late July. Due to the large volume of water in the operating open cut, mining operations ceased in January and the company did not expect to be able to access the ore in the bottom of the pit before late 2011. In addition, the average mill head grade was lower (0.19% $U_3O_8$ in 2010 compared with 0.26% $U_3O_8$ in 2009) as mining extends to deeper parts of the orebody.

The company investigated a proposal to construct a heap leach facility for the extraction of up to 20 000 t $U_3O_8$ contained in low-grade mineralisation both *in situ* and on stockpiles. The proposal was subsequently rejected for economic reasons.

Exploration drilling in the Ranger 3 Deeps area has defined a zone of contiguous high-grade mineralisation east of the current operating pit. The zone has an estimated 28 800 t contained U and it is proposed to mine this by underground methods.

*Beverley/Beverley North (Pepegoona)*

ISR operations continued at Beverley deposit to mine the remaining resources. During 2010 and 2011 production was mainly from wellfields that were reopened after having been previously shut down. In 2010, the Beverley ISR operation produced 354 tU, 33% lower than the previous year.

In early 2011, commercial ISR operations commenced at the Pepegoona deposit 12 km north of Beverley. Uranium-bearing solutions are pumped to a satellite ion exchange plant at Pepegoona and ion exchange resins containing uranium are trucked to the Beverley plant for processing.

*Honeymoon*

Construction of the wellfields and processing plant at the Honeymoon ISR project continued. The processing plant uses solvent extraction technology and pulse columns. Production of uranium hydroxide concentrates commenced in late 2011 and is anticipated to increase progressively to 340 tU per annum.

### *Ownership of uranium production*

The Ranger mine is owned by Energy Resources of Australia Ltd. which is majority owned by Rio Tinto (68.39%), with the remaining capital held publicly.

The Olympic Dam mine is fully owned by BHP Billiton.

The Beverley mine is fully owned by Heathgate Resources Pty Ltd, a wholly-owned subsidiary of General Atomics (United States).

### *Employment in existing production centres*

Total employment at Australia's three uranium mines increased from 3 830 employees in 2009 to 4 813 employees in 2010. It is anticipated that employment may increase to around 4 888 employees in 2011.

## Uranium industry employment at existing production centres*

(person-years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 4 787** | 3 830 | 4 813 | 4 888 |
| Employment directly related to uranium production | 4 322** | 3 512 | 4 514 | 4 590 |

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

** These figures are approximate only as not all data for 2008 were available.

## Uranium production centre technical details

(as of 1 January 2011)

| | Centre #1 | Centre #2 | Centre #3 | Centre #4 |
|---|---|---|---|---|
| Production centre name | Ranger | Olympic Dam | Beverley | Honeymoon |
| Production centre classification | Existing | Existing | Existing | Existing |
| Start-up date | 1981 | 1988 | 2000 | 2011 |
| Source of ore: | | | | |
| Deposit name(s) | Ranger No. 3 | Olympic Dam | Beverley, Pepegoona | Honeymoon, East Kalkaroo |
| Deposit type(s) | Unconformity-related | Hem. breccia complex | Sandstone | Sandstone |
| Reserves | 22 100 tU | 212 900 tU | 763 tU | 3 230 tU |
| Grade (% U) | 0.10 | 0.05 | 0.10 | 0.17 |
| Mining operation: | | | | |
| Type (OP/UG/ISR) | OP | UG | ISR | ISR |
| Size (tonnes ore/year) | 4.5 Mt[(a)] | 12 Mt | NA | NA |
| Average mining recovery (%) | 100 | 85 | 65[(b)] | 65[(b)] |
| Processing plant: | | | | |
| Acid/alkaline | Acid | Acid | Acid | Acid |
| Type (IX/SX) | SX | FLOT, SX, | IX | SX |
| Size (tonnes ore/year); for ISR (kilo-litre/day or litre/hour) | 2.5 Mt/yr | 12 Mt/yr | 1.62 ML/h | Not reported |
| Average process recovery (%) | 88 | 72 | (b) | (b) |
| Nominal production capacity (tU/year) | 4 660 | 3 820 | 850 | 340 |
| Plans for expansion (yes/no) | | (c) | (d) | |
| Other remarks | (e) | NA | (f) | |

(a) Capacity to mine a total of 4.5 million tonnes per year of ore and waste rock.

(b) Recovery includes combined losses due to ISR mining and hydro-metallurgical processing.

(c) BHP Billiton plans to expand Olympic Dam operations to produce 16 100 tU (19 000 t $U_3O_8$) per year. It is proposed to mine the southern portion of the deposit by a large open pit in conjunction with underground mining in the northern portion of the deposit.

(d) Approval has been granted to extend the capacity of the Beverley plant to produce 1 270 t U (1 500 t $U_3O_8$) per year when the company decides it is commercially viable to do so.

(e) Processing of lateritic ores in a separate plant produces approximately 340 tU (400 t $U_3O_8$) per annum. In addition, a new radiometric ore sorter allows an additional 930 tU (1 100 t $U_3O_8$) to be produced from existing low-grade stockpiles.

(f) In 2011, commercial ISR operations commenced at Pepegoona deposit. Uranium resins from satellite ion exchange plant are trucked to Beverley for further processing.

**Uranium production centre technical details** (*continued*)

(as of 1 January 2011)

| | Centre #5 | Centre #6 | Centre #7 |
|---|---|---|---|
| Production centre name | Four Mile | Yeelirrie | Wiluna |
| Production centre classification | Planned | Planned | Planned |
| Start-up date | Not known | Not known | 2013 |
| Source of ore: | | | |
| Deposit name(s) | Four Mile | Yeelirrie | Lake Way |
| Deposit type(s) | Sandstone | Calcrete | Calcrete |
| Reserves | (g) | 44 500 | (h) |
| Grade (% U) | 0.26 | 0.13 | |
| Mining operation: | | | |
| Type (OP/UG/ISR) | ISR | OP | OP |
| Size (tonnes ore/year) | NA | NA | 2 Mt per year |
| Average mining recovery (%) | 65 | NA | NA |
| Processing plant: | | | |
| Acid/alkaline | Acid | Alkaline | Alkaline |
| Type (IX/SX) | (i) | (j) | Heap leach |
| Size (tonnes ore/year); for ISR (kilo-litre/day or litre/hour) | NA | NA | NA |
| Average process recovery (%) | | | |
| Nominal production capacity (tU/year) | (i) | NA | 850 (k) |
| Plans for expansion (yes/no) | No | No | No |
| Other remarks | (l) | (m) | (m) |

(g) Four Mile West total resources 12 700 tU (15 000 t $U_3O_8$) averaging 0.31% U. Four Mile East inferred resources 3 900 tU (4 627 t $U_3O_8$) averaging 0.14% U.

(h) Total measured plus indicated resources are 5 450 tU averaging 500 ppm U.

(i) Uranium bearing resin from Four Mile will be treated at Beverley plant to recover uranium.

(j) BHP Billiton is investigating several options for processing the ores including tank leaching with ion exchange, and heap leaching with ion exchange.

(k) Production is planned to be 1 200 t per year of $UO_4.2H_2O$ which equates to 850 t U/yr.

(l) Commencement of operations delayed due to legal dispute between joint venture (Heathgate Resources and Alliance Resources).

(m) Company has commenced environmental approvals process.

### *Future production centres*

*Yeelirrie*

BHP Billiton is undertaking drilling at Yeelirrie (WA) to upgrade the resource estimate and has commenced a feasibility study for development of the deposit. Yeelirrie currently has total resources of 52 500 t $U_3O_8$ with an average grade 0.15% $U_3O_8$.

*Wiluna*

The Wiluna project comprises two shallow (less than 8 m deep) calcrete hosted deposits, Lake Way and Centipede, which are 15 km south and 30 km south respectively south of Wiluna (WA). In mid-2010, Toro Energy mined an evaluation pit (45 000 t) at the Centipede deposit to increase confidence in the resource estimates and in the proposed mining method. It is proposed to use alkaline agitated leaching in tanks at elevated

temperatures to process the ore. Production is estimated to be 850 tU/yr. In March 2011, Toro Energy submitted a draft Environmental Review and Management Program which will be the basis for environmental assessment of the project.

*Kintyre*

Cameco proposes to develop the Kintyre deposit (WA). Ore will be mined by open-cut methods and radiometric sorting will be used to separate uranium ore from waste rock. The ore will be processed using conventional solvent extraction techniques and it is proposed that annual production will be between 2 300 tU and 3 000 tU. The company has commenced the environmental impact assessment process to obtain government approvals.

## 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 impact statement*

All new uranium projects and expansion of existing uranium mines are required to go through environmental assessments under the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC). The Olympic Dam expansion project underwent an environmental impact assessment process from 2005 to 2011. The project was approved by both the Australian and South Australian governments in 2011.

The Commonwealth assessment is in addition to state and territory requirements in the assessment of uranium projects, however, the EPBC assessment is undertaken bilaterally with the state and territory jurisdictions.

To assist project proponents and regulators in the assessment of projects the Commonwealth government has developed *Australia's In Situ Recovery Uranium Mining Best Practice Guide: Groundwaters, Residues and Radiation Protection* in consultation with state and territory governments and industry. To view the guide visit: www.ret.gov.au.

### *Regulatory activities*

The Uranium Council (UC), formerly the Uranium Industry Framework, is a joint government/industry initiative established to contribute to national wellbeing through the progressive and sustainable development of the Australian uranium exploration, mining, milling and exporting industry in line with world's best practice standards. The UC deals with four broad strategic themes: competitiveness, sustainability, stewardship, and indigenous communication and economic development. These themes aim to progress initiatives which are consistent with the priorities of industry. Further information on the UC is available at www.ret.gov.au.

## Uranium requirements

Australia has no commercial NPPs and thus has no uranium requirements.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

The Australian government supports the development of a sustainable Australian uranium mining sector in line with world's best practice environmental and safety

standards. In 2008, the government of Western Australia overturned the ban on uranium mining put in place by the previous state government, and it now allows uranium exploration and mining along with South Australia and the Northern Territory.

The Australian government's control over uranium exports reflects both national interest considerations and international obligations. Australia allows uranium exports only to countries which are a party to the Treaty on the Nuclear Non-Proliferation of Nuclear Weapons (NPT) and which are committed to non-proliferation and nuclear safeguards. All states must also have in force an Additional Protocol.

### *Uranium stocks*

For reasons of confidentiality, information on producer stocks is not available.

### *Uranium prices*

The average price of uranium exported from Australia in 2010 was USD 32.30/lb $U_3O_8$. Average export prices for the last five years are as follows:

| | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 |
|---|---|---|---|---|---|---|
| Average export value (AUD/lb $U_3O_8$) | 35.12 | 50.43 | 35.17 | 39.07 | 27.71 | 21.03 |
| (USD/lb $U_3O_8$) | 32.30 | 39.97 | 29.98 | 32.77 | 20.88 | 16.03 |

Note: Average of the daily AUD:USD exchange rates for the calendar year was used as the factor to convert AUD values to equivalent USD values for each year.

Source: Reserve Bank of Australia daily currency exchange rates.

**Uranium exploration and development expenditures and drilling effort – domestic**

(AUD millions)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 220.5 | 179.6 | 190.0 | 190.0 |
| Government exploration expenditures | 0 | 0 | 0 | 0 |
| Industry* development expenditures | NA | NA | NA | NA |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 220.5 | 179.6 | 190.0 | 190.0 |
| Industry* exploration drilling (m) | NA | NA | NA | NA |
| Industry* exploration holes drilled | NA | NA | NA | NA |
| Government exploration drilling (m) | 0 | 0 | 0 | 0 |
| Government exploration holes drilled | 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) | 0 | 0 | 0 | 0 |
| Subtotal exploration holes drilled | 0 | 0 | 0 | 0 |
| Subtotal development drilling (m) | 0 | 0 | 0 | 0 |
| Subtotal development holes drilled | 0 | 0 | 0 | 0 |
| Total drilling (m) | 0 | 0 | 0 | 0 |
| Total number of holes drilled | 0 | 0 | 0 | 0 |

* Non-government.

### Uranium exploration and development expenditures – non-domestic

| | 2008 | 2009 | 2010 | 2011 (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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 44 400 | 141 300 | 144 800 | |
| Sandstone | 0 | 0 | 28 800 | 37 500 | |
| Hematite breccia complex | 0 | 917 100 | 918 500 | 919 200 | |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | |
| Vein | 0 | 0 | 0 | 200 | |
| Intrusive | 0 | 0 | 1 600 | 5 500 | |
| Volcanic and caldera-related | 0 | 0 | 2 700 | 6 000 | |
| Metasomatite | 0 | 0 | 16 600 | 18 400 | |
| Other* | 0 | 0 | 48 400 | 48 400 | |
| Total | 0 | 961 500 | 1 158 000 | 1 180 100 | |

* 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.

### 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 | 78 300 | 80 600 | |
| Open-pit mining (OP) | 0 | 44 400 | 146 000 | 165 800 | |
| *In situ* leaching acid | 0 | 0 | 16 600 | 16 600 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 917 100 | 917 100 | 917 100 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 961 500 | 1 158 000 | 1 180 100 | |

### 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 | 0 | 44 400 | 146 000 | 165 800 | |
| Conventional from UG | 0 | 917 100 | 995 400 | 997 700 | |
| *In situ* leaching acid | 0 | 0 | 16 600 | 16 600 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 961 500 | 1 158 000 | 1 180 100 | |

* 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 |
|---|---|---|---|---|
| Unconformity-related | 0 | 5 200 | 50 000 | 51 700 |
| Sandstone | 0 | 0 | 46 700 | 58 200 |
| Hematite breccia complex | 0 | 382 700 | 397 100 | 402 600 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 1 100 | 4 900 |
| Volcanic and caldera-related | 0 | 0 | 1 000 | 1 500 |
| Metasomatite | 0 | 0 | 2 700 | 14 700 |
| Other* | 0 | 0 | 5 000 | 25 200 |
| Total | 0 | 387 900 | 503 600 | 558 700 |

* 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.

### 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 | 41 500 | 53 400 | |
| Open-pit mining (OP) | 0 | 5 200 | 58 200 | 90 200 | |
| *In situ* leaching acid | 0 | 0 | 21 200 | 26 900 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 382 700 | 382 700 | 388 200 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 387 900 | 503 600 | 558 700 | |

### Inferred conventional resources by processing method

(tonnes U)

| Processing method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Conventional from OP | 0 | 5 200 | 58 300 | 90 200 | |
| Conventional from UG | 0 | 382 700 | 424 100 | 441 600 | |
| *In situ* leaching acid | 0 | 0 | 21 200 | 26 900 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 387 900 | 503 600 | 558 700 | |

* Also known as stope leaching or block leaching.

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

### 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | 93 864 | 4 530 | 4 447 | 3 216 | 106 057 | 3 000 |
| Sandstone | 4 758 | 559 | 531 | 354 | 6 202 | 500 |
| Hematite breccia complex | 41 122 | 3 344 | 2 956 | 2 330 | 49 752 | 3 800 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 | 0 | 0 |
| Intrusive | 721 | 0 | 0 | 0 | 721 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 | 0 |
| Other* | 7 531 | 0 | 0 | 0 | 7 531 | 0 |
| Total | 147 996 | 8 433 | 7 934 | 5 900 | 170 263 | 7 300 |

* 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.

## Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 101 278 | 4 530 | 4 447 | 3 216 | 113 471 | 3 000 |
| Underground mining[1] | 838 | 0 | 0 | 0 | 838 | 0 |
| *In situ* leaching | 4 758 | 559 | 531 | 354 | 6 202 | 500 |
| Co-product/by-product | 41 122 | 3 344 | 2 956 | 2 330 | 49 769 | 3 800 |
| Total | 147 996 | 8 433 | 7 934 | 5 900 | 170 280 | 7 300 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 147 996 | 8 433 | 7 934 | 5 900 | 170 280 | 7 300 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** | 0 | 0 | 0 | 0 | 0 | 0 |
| U recovered from phosphate rocks | 0 | 0 | 0 | 0 | 0 | 0 |
| Other methods*** | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 147 996 | 8 433 | 7 934 | 5 900 | 170 263 | 7 300 |

* 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 2010

| Domestic | | | | Foreign | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | | |
| (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) |
| 0 | 0 | 1 787 | 30.2 | 0 | 0 | 4 131 | 69.8 | 5 900 | 100 |

## Short-term production capability

(tonnes U/year)

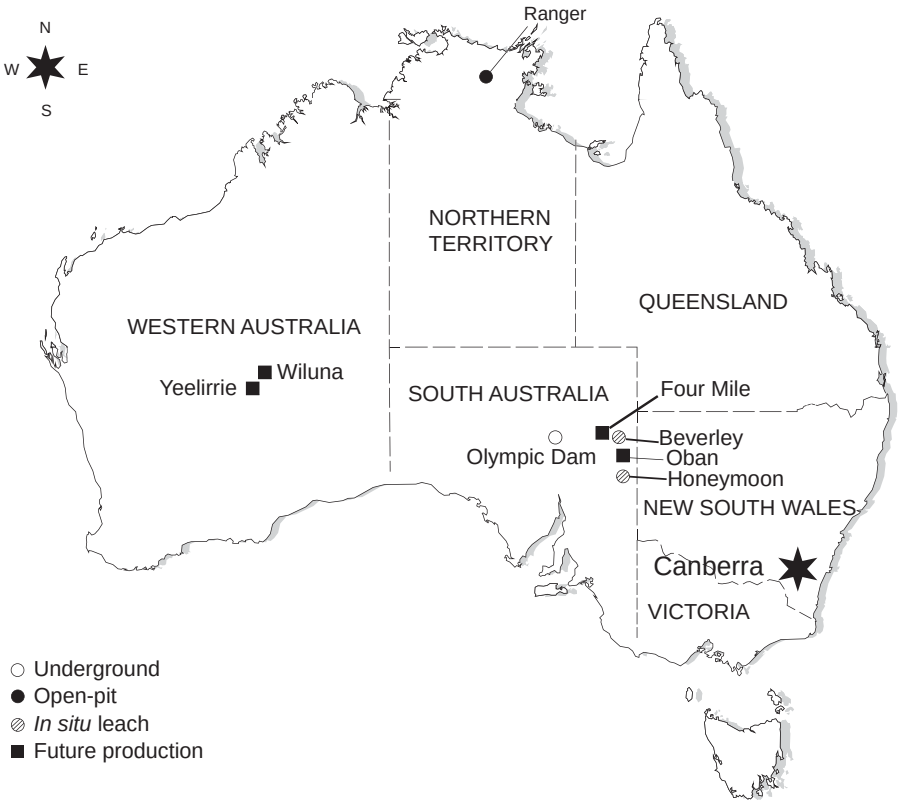
| 2011 | | | | 2015 | | | | 2020 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A-I | B-I | A-II | B-II | A-I | B-I | A-II | B-II | A-I | B-I | A-II | B-II |
| 9 700 | 9 700 | 9 700 | 9 700 | 10 100 | 16 600 | 10 100 | 16 600 | 10 100 | 24 200 | 10 100 | 24 200 |

| 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 |
| 10 100 | 27 900 | 10 100 | 27 900 | 9 800 | 27 600 | 9 800 | 27 600 | 9 800 | 27 600 | 9 800 | 27 600 |

**Uranium industry employment at existing production centres**

(person-years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 4 787 | 3 830 | 4 813 | 4 888 |
| Employment directly related to uranium production | 4 322 | 3 512 | 4 514 | 4 590 |






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# Botswana*

## Uranium exploration

### *Historical review*

The surge in the uranium price in the 1970s led to exploration activities in Botswana by various foreign and local companies. Large airborne radiometric surveys were followed up by ground surveys, soil sampling, trenching and drilling. Thick sand cover in many parts hindered exploration activities. Exploration work effectively ceased in the early 1980s with the slump in uranium prices. No deposits of economic interest were discovered but significant mineralisation was shown to occur in the Karoo sandstones and surficial calcretes, particularly in the central eastern part of the country.

### *Recent and ongoing uranium exploration activities*

The recent rise in uranium prices engendered renewed interest from junior Australian companies. A-Cap Resources followed up on mineralisation discovered by Falconbridge in the 1970s in the Serowe area and is now developing projects around two groups of deposits: Letlhakane and Southern Pans. Four distinct styles of mineralisation are present. The oldest is primary mineralisation in Karoo sandstones and occurs as tabular laterally continuous bodies. This is very similar to sandstone hosted ore bodies found in the Karoo rocks in South Africa, Zimbabwe and Zambia. Primary mineralisation in the active weathering environment becomes oxidised to secondary uranium minerals. Later remobilisation of these two types of mineralisation into crosscutting fractures results in powdery yellow mineralisation along fractures and bedding planes. The youngest style results from the supergene remobilisation and re-precipitation of secondary uranium minerals into surficial pedogenic calcrete.

Intensive drilling resulted in A-Cap reporting Botswana's first JORC compliant uranium resource in 2008. Continued exploration work has substantially increased these resources. The company recently reported JORC compliant indicated and inferred *in situ* resources totalling just over 100 000 tU at an average grade of 129 ppm U (85 ppm U cut-off grade). Although grades are low, tonnages are large and mineralisation occurs near the surface. A bankable feasibility study of the Letlhakane project, including detailed metallurgical test work to optimise the exploitation of the resources, is underway. The Southern Pans project is at early stages of investigation and no resources have yet been determined.

Impact Minerals, another Australian junior company, took up ground around A-Cap's areas in early 2008. Exploration activities in 2009 began with airborne radiometric surveys, followed by field reconnaissance, mapping and drilling, led to the discovery of four prospects in Karoo siltstones and sandstones. The company has a 32 000 $km^2$ exploration portfolio in Botswana and has applied to access an additional 9 000 $km^2$. Additional work, now ongoing, is needed before resources estimates can be reported.

Similar styles of mineralisation to that explored by A-Cap occur in impacts prospect areas and an additional two styles of mineralisation are being investigated: uranium

* Secretariat report based on information in company reports.

bearing alaskitic rocks similar to those found at Rossing in Namibia and mineralisation related to Proterozoic sedimentary and basement rocks with geological similarities to the unconformity related deposits in Canada and Australia. Further work is needed to assess the validity of the model and the potential of this style of mineralisation.

Both companies are fully committed to continuing uranium exploration in Botswana. Australia-based Bannerman Resources also held three prospecting licences for uranium exploration in the Foley and Sua Pan regions of Botswana. However, the Serule South, Serule North and Dukwe licences were not renewed in 2011 and Bannerman is no longer active in Botswana.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

A-Cap Resources is the only company that has reported JORC compliant uranium resources in Botswana. Over 75% of the resources are considered primary-type, occurring in Karoo sandstones and the majority of the remaining mineralisation is considered secondary-type and occurs mainly in the oxide zone. In addition, calcrete mineralisation occurs in the surficial environment. Notably, the secondary-type and calcrete mineralisation makes a very minor contribution to the total reported resources.

About 28% of the total 82 000 tU (recoverable) are classified as reasonably assured with the remaining 72% classified as inferred. Insufficient investigations have been carried out to reliably assign a cost category, but considering the low grade, the nature and location of the deposits, conservative production costs of <USD 260/kgU are considered appropriate at this stage.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

Impact Minerals reports "target conceptual" resources of less than 2 000 tU. However, the uncertainty of the term and small amounts reported do not warrant inclusion as undiscovered resources at this time. Although undiscovered resources no doubt exist, further work is required before they can be reported.

### *Unconventional resources and other materials*

Nil.

## Uranium production

Uranium has never been produced in Botswana.

## Environmental activities and socio-cultural issues

A-Cap has established a Safety, Health, Radiation, Environment and Community Group aimed at informing, educating and involving local communities with regard to their activities. Meetings are held on a regular basis.

A-Cap Resources submitted an environmental and social impact assessment study of the Letlhakane project to the Botswana government in 2011 as part of the application process for a uranium mining licence.

## National policies relating to uranium

National policies regarding uranium exploitation and production are under development. At present, no regulations for uranium mining and milling are in place. However, the government is committed to encouraging private investment in exploration and new mine development and the fiscal, legal and policy framework for mineral

exploration, mining and mineral processing in Botswana is continuously being reviewed to make it more competitive. Amendments made to the Mines and Minerals Act in 1999 and the Income Tax Act in 2006 streamlined licensing, enhanced security of tenure and reduced royalty payments and tax rates. From 2009 to 2010, the number of prospecting licences for radioactive minerals had increased by 38%.

**Uranium exploration and development expenditures and drilling effort – domestic**

(AUD thousands)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 216.8 | 4 629 | 6 202 | 7 171 |
| Government exploration expenditures | 0 | 0 | 0 | 0 |
| Industry* development expenditures | 0 | 0 | 0 | 0 |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 216.8 | 4 629 | 6 202 | 7 171 |
| Industry* exploration drilling (m) | 1 393 | 12 358 | 26 475 | 30 000 |
| Industry* exploration holes drilled | 34 | 384 | 589 | 650 |
| Government exploration drilling (m) | 0 | 0 | 0 | 0 |
| Government exploration holes drilled | 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) | NA | NA | NA | NA |
| Subtotal exploration holes drilled | NA | NA | NA | NA |
| Subtotal development drilling (m) | 0 | 0 | 0 | 0 |
| Subtotal development holes drilled | 0 | 0 | 0 | 0 |
| Total drilling (m) | 1 393 | 12 358 | 26 475 | 30 000 |
| Total holes drilled | 34 | 384 | 589 | 650 |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | | | | 23 105 | 80 |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | | | | |
| Metasomatite | | | | | |
| Other* | | | | | |
| Total | | | | 23 105 | 80 |

* 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.

### 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) | | | | | |
| Open-pit mining (OP) | | | | 23 105 | 80 |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| Co-product and by-product | | | | | |
| Unspecified | | | | | |
| Total | | | | 23 105 | 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 | | | | | |
| Conventional from UG | | | | | |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| In-place leaching* | | | | | |
| Heap leaching** from OP | | | | 23 105 | 80 |
| Heap leaching** from UG | | | | | |
| Unspecified | | | | | |
| Total | | | | 23 105 | 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | | | | 59 090 | 80 |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | | | | |
| Metasomatite | | | | | |
| Other* | | | | | |
| Total | | | | 59 090 | 80 |

* 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.

**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) | | | | | |
| Open-pit mining (OP) | | | | 59 090 | 80 |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| Co-product and by-product | | | | | |
| Unspecified | | | | | |
| Total | | | | 59 090 | 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 | | | | | |
| Conventional from UG | | | | | |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| In-place leaching* | | | | | |
| Heap leaching** from OP | | | | 59 090 | 80 |
| Heap leaching** from UG | | | | | |
| Unspecified | | | | | |
| Total | | | | 59 090 | 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.

# Brazil

## Uranium exploration and mine development

### *Historical review*

Beginning in 1952, systematic prospecting for radioactive minerals by the Brazilian National Research Council led to the discovery of the first uranium occurrences at Poços de Caldas (State of Minas Gerais) and Jacobina (State of Bahia). Exploration continued through the 1970s, initially by the National Nuclear Energy Commission and later by NUCLEBRAS, an organisation created in 1974 for the purpose of uranium exploration and production, leading to the discovery and development of the Osamu Utsumi deposit on the Poços de Caldas plateau and the identification of eight areas hosting uranium resources. The 2007 edition of the Red Book provides additional information on uranium exploration.

### *Recent and ongoing uranium exploration and mine development activities*

No exploration work was done in 2009 and 2010. The work scheduled for the Cachoeira deposit was suspended due to interruptions in the ramp-up of construction activities due to regulatory requirements. Planned exploration in the Rio Cristalino area was also postponed. However, geological mapping of new targets in the north area of the Caetité province is underway.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

Brazil's conventional identified and undiscovered 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 (metasomatic);
- Lagoa Real, Espinharas and Campos Belos (metasomatic-albititic);
- others including the Quadrilátero Ferrifero with the Gandarela and Serra des Gaivotas deposits (quartz pebble conglomerate).

No additional resources were identified during the 2009-2010 period.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

Exploration activities in the Rio Cristalino (south of Pará State) area and additional resources at the Pitinga site, *in situ* prognosticated resources are estimated to amount to 300 000 tU.

## Uranium production

### *Historical review*

The Poços de Caldas uranium facility was closed in 1997 and a remediation/restoration study is being carried out. This industrial facility was used to produce rare earth compounds from monazite treatment until 2006, but is now closed 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 expansion of Lagoa Real, Caetité unit is on course to be doubled to 670 tU/year by 2015. In addition to increased production, the current heap leaching process will be replaced by conventional agitated leaching and other detailed changes in the milling process will be carried out. The overall investment in this expansion is estimated to amount to USD 90 million.

After surpassing the nominal capacity in 2009, the 2010 production was dramatically reduced due to the need to address regulatory requirements related to the tailings ponds.

Pilot tests have been carried out for phosphate and uranium production at the Santa Quitéria project and the operator is applying for local/construction licences, now under the new guidelines imposed by Brazil's federal environmental regulatory authority,

IBAMA (the Brazilian Institute of Environment and Renewable Natural Resources). Project design is in progress and at the end of construction in 2015, production is planned to begin with an initial capacity of 970 tU/year.

**Uranium production centre technical details**

(as of 1 January 2011)

| | Centre #1 | Centre #2 |
|---|---|---|
| Name of production centre | Caetité | Santa Quitéria |
| Production centre classification | Existing | Committed |
| Start-up date | 1999 | 2015 |
| Source of ore: | | |
| Deposit name(s) | Cachoeira | Santa Quitéria |
| Deposit type(s) | Metasomatite | Metamorphic/phosphorite |
| Resources (tU) | 10 700 | 76 100 |
| Grade (% U) | 0.3 | 0.08 |
| Mining operation: | | |
| Type (OP/UG/ISL) | OP | OP |
| Size (tonnes ore/day) | 1 000 | 6 000 |
| Average mining recovery (%) | 90 | 90 |
| Processing plant: | | |
| Acid/alkaline | | |
| Type (IX/SX) | HL/SX | AL/SX |
| Size (tonnes ore/day) | 1 000 | 6 000 |
| Average process recovery (%) | 80 | 75 |
| Nominal production capacity (tU/year) | 340 | 970 |
| Plans for expansion (yes/no) | Yes | Yes |
| Other remarks | (a) | By-product phosphoric acid |

(a) INB plans to expand the Caetité production centre to produce a total of 670 tU by 2015, including mining the nearby Engenho deposit (16 000 tU with a grade of 0.02% U) to provide additional feed.

### *Ownership structure of the uranium industry*

The Brazilian uranium industry is 100% government-owned through Indústrias Nucleares do Brasil S/A (INB).

### *Future production centres*

As noted above, development of the Santa Quitéria project is in progress. A partnership agreement with a Brazilian fertiliser producer was signed in 2009 to extract uranium from the Itataia phosphate/uranium deposit.

The Engenho deposit, located 2 km from the Cachoeira deposit currently being mined, is under study and is currently expected to provide additional feed to the Caetité mill after 2015.

## Environmental activities and socio-cultural issues

Government policies and regulations established by Comissão Nacional de Energia Nuclear (CNEN) include a standard *Diretrizes Básicas de Radioproteção* (NE-3.01 – Radioprotection Basic Directives), standards for licensing uranium of mines and mills (NE-1.13 – *Licenciamento de Minas e Usinas de Beneficiamento de Minérios de Urânio ou Tório*) and decomissioning 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, ICRP and IAEA recommendations are used.

Licences are issued by IBAMA, according to Brazilian environment law and CNEN regulations.

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. Specific closure, remediation and restoration actions remain under development. Several studies have been carried out to characterise geochemical and hydrochemical aspects of the waste rock and tailings dam in order to better establish the impact they may have had on the environment and to develop the necessary mitigation measures. Alternatives for remediation/restoration are expected to be presented at the end of 2011.

The licensing of Santa Quitéria uranium/phosphate project is split into a non-nuclear part involving milling and phosphate production. INB is now applying for local construction and environmental licences for uranium production under new guidelines established by IBAMA. Regarding licensing nuclear aspects of this production centre, INB is discussing its terms with the federal regulatory body CNEN.

## Uranium requirements

Brazil's present uranium requirements for the Angra I NPP, a 630 MWe PWR, are about 150 tU/year. The Angra II NPP, a 1 245 MWe PWR, requires 300 tU/year. In addition, start-up of the Angra III NPP (a similar design to Angra II) is scheduled to 2016, adding another 300 tU/year to annual domestic demand.

The long-term electricity energy supply plan includes 4 000 MW generated from nuclear sources by 2030. The first unit of this longer term plan is expected to be in operation in 2020. Siting studies for this unit, to be situated in the northeast region of Brazil, were completed in 2010.

### *Supply and procurement strategy*

All domestic production is destined for internal requirements. The shortfall between demand and production is met through market purchases. The planned production increases are intended to meet all reactor requirements, including the Angra III unit and all units foreseen in the long-term planned expansion of nuclear energy for electricity generation.

## Uranium policies, uranium stocks and uranium prices

INB, a 100% government-owned company, is in charge of fuel cycle activities and is currently working to increase production in order to meet future domestic uranium demand.

### *Uranium stocks*

The Brazilian government does not maintain stocks of uranium concentrate or enriched uranium product.

### *Uranium prices*

NA.

**Uranium exploration and development expenditures and drilling effort – domestic**

(BRA thousands [Brazilian real])

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 0 | 0 | 0 | 0 |
| Government exploration expenditures | 0 | 0 | 400 | 400 |
| Industry* development expenditures | 0 | 0 | 0 | 0 |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 0 | 0 | 400 | 400 |
| Industry* exploration drilling (m) | 0 | 0 | 0 | 0 |
| Industry* exploration holes drilled | 0 | 0 | 0 | 0 |
| Government exploration drilling (m) | 0 | 0 | 0 | 0 |
| Government exploration holes drilled | 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) | 0 | 0 | 0 | 0 |
| Subtotal exploration holes drilled | 0 | 0 | 0 | 0 |
| Subtotal development drilling (m) | 0 | 0 | 0 | 0 |
| Subtotal development holes drilled | 0 | 0 | 0 | 0 |
| Total drilling (m) | 0 | 0 | 0 | 0 |
| Total number of holes drilled | 0 | 0 | 0 | 0 |

* Non-government.

**Reasonably assured conventional resources by deposit type**

(tonnes U)

| Deposit type | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | |
| Sandstone | 0 | 0 | 0 | 0 | |
| Hematite breccia complex | 0 | 0 | 0 | 0 | |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | |
| Vein | 0 | 0 | 0 | 0 | |
| Intrusive | 0 | 0 | 0 | 0 | |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | |
| Metasomatite | 84 300 | 102 100 | 102 100 | 102 100 | |
| Other* | 53 600 | 53 600 | 53 600 | 53 600 | |
| Total | 137 900 | 155 700 | 155 700 | 155 700 | |

* 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.

### 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) | 58 300 | 58 300 | 58 300 | 58 300 | 80 |
| Open-pit mining (OP) | 8 500 | 8 500 | 8 500 | 8 500 | 80 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 71 100 | 88 900 | 88 900 | 88 900 | 70 |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 137 900 | 155 700 | 155 700 | 155 700 | - |

### 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 | 58 300 | 58 300 | 58 300 | 58 300 | 80 |
| Conventional from OP | 6 500 | 6 500 | 6 500 | 6 500 | 80 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 2 000 | 2 000 | 2 000 | 2 000 | 80 |
| Unspecified*** | 71 100 | 88 900 | 88 900 | 88 900 | 70 |
| Total | 137 900 | 155 700 | 155 700 | 155 700 | - |

* Also known as stope leaching or block leaching.

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

*** Includes production from phosphoric acid – Santa Quiteria project.

### Inferred conventional resources by deposit type

(tonnes U)

| Deposit type | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | |
| Sandstone | 0 | 7 600 | 7 600 | 7 600 | 70 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | |
| Quartz-pebble conglomerate | 0 | 8 900 | 8 900 | 8 900 | 70 |
| Vein | 0 | 600 | 600 | 600 | 70 |
| Intrusive | 0 | | | | |
| Volcanic and caldera-related | 0 | | | | |
| Metasomatite | 0 | 6 000 | 53 400 | 53 400 | 70 |
| Other* | 0 | 50 500 | 50 500 | 50 500 | 70 |
| Total | 0 | 73 600 | 121 000 | 121 000 | |

* 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.

### 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 | 0 | 0 | |
| Open-pit mining (OP) | 0 | 2 400 | 2 400 | 2 400 | 70 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 31 200 | 78 600 | 78 600 | 70 |
| Unspecified | 0 | 40 000 | 40 000 | 40 000 | 70 |
| Total | 0 | 73 600 | 121 000 | 121 000 | |

### Inferred conventional resources by processing method

(tonnes U)

| Processing method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Conventional from UG | 0 | 0 | 0 | 0 | |
| Conventional from OP | 0 | 2 400 | 2 400 | 2 400 | 70 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | 0 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | 0 |
| Unspecified*** | 0 | 71 200 | 118 600 | 118 600 | 70 |
| Total | 0 | 73 600 | 121 000 | 121 000 | |

* 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 production from phosphoric acid – Santa Quiteria project.

### 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 80/kgU | <USD 130/kgU | <USD 260/kgU |
| NA | NA | 500 000 |

## Historical uranium production by deposit type

(tonnes U in concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 1 097 | 0 | 0 | 0 | 1 097 | 0 |
| Metasomatite | 1 412 | 330 | 347 | 148 | 2 237 | 360 |
| Other* | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 2 509 | 330 | 347 | 148 | 3 334 | 360 |

* 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.

## Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 2 509 | 330 | 347 | 148 | 3 334 | 360 |
| Underground mining[1] | 0 | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching | 0 | 0 | 0 | 0 | 0 | 0 |
| Co-product/by-product | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 2 509 | 330 | 347 | 148 | 3 334 | 360 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 1 097 | 0 | 0 | 0 | 1 097 | 0 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** | 1 412 | 330 | 347 | 148 | 2 237 | 360 |
| U recovered from phosphate rocks | 0 | 0 | 0 | 0 | 0 | 0 |
| Other methods*** | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 2 509 | 330 | 347 | 148 | 3 334 | 360 |

* 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 2010

| Domestic | | | | Foreign | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | | |
| (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) |
| 148 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 148 | 100 |

### Uranium industry employment at existing production centres

(person-years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 640 | 620 | 620 | 620 |
| Employment directly related to uranium production | 340 | 340 | 340 | 340 |

### Short-term production capability

(tonnes U/year)

| 2011 | | | | 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 |
| 340 | 340 | 340 | 340 | 1 600 | 1 600 | 1 600 | 1 600 | 2 000 | 2 000 | 2 000 | 2 000 |

| 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 |
| 2 000 | 2 000 | 2 000 | 2 000 | NA | NA | NA | NA | NA | NA | NA | NA |

### Net nuclear electricity generation

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 12.975 | 14.544 |

### Installed nuclear generating capacity to 2035

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 875 | 1 875 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 1 875 | 1 875 | 1 875 | 3 120 | 3 120 | 4 120 | 3 120 | 5 120 | 3 120 | 7 120 | NA | NA |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 450 | 450 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 450 | 450 | 450 | 750 | 750 | 1 000 | 750 | 1 250 | 750 | 1 750 | NA | NA |




# Canada

## Uranium exploration and mine development

### *Historical review*

Uranium exploration in Canada began in 1942, with the focus of activity first at Great Bear Lake 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 2009 and 2010, 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 lesser extent, similar geologic settings in the Thelon Basin of Nunavut and the Northwest Territories. Uranium exploration also remained active in the Otish Mountains of Québec where Strateco Resources Inc. has applied for a licence to conduct underground exploration on the Matoush deposit. Very little exploration activity occurred in other areas of Canada in 2009 and 2010.

Surface drilling, geophysical surveys and geochemical surveys continued to be the main tools used to identify new uranium occurrences, define extensions of known mineralised zones and to reassess deposits which were last examined in the 1970s and 1980s.

Recent exploration activity has led to new uranium discoveries in the Athabasca Basin. Notable high-grade uranium mineralisation discoveries include Centennial (UEM Inc.), Shea Creek (AREVA Resources Canada Inc.), Wheeler River (Denison Mines Inc.), Midwest A (AREVA Resources Canada Inc.) and Roughrider (Hathor Exploration Ltd.).

Domestic uranium exploration expenditures were CAD 355 million in 2010, down 5.1% from 2009 exploration expenditures of CAD 374 million. Uranium exploration and development drilling totalled 373 900 m in 2010, compared with 447 900 m reported in 2009. Over 70% of the combined exploration and development drilling in 2010 took place in Saskatchewan.

In 2010, overall Canadian uranium exploration and development expenditures amounted to CAD 605 million. Less than one-third of the overall exploration and development expenditures in 2010 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 2011, Canada's total identified conventional uranium resources recoverable at a cost of <USD 80/kgU amounted to 416 800 tU, a decrease of 7% from the 2009 estimate of 447 400 tU. Canada's total identified uranium resources recoverable at a cost of <USD 130/kgU were 468 600 tU as of 1 January 2011, a decrease of 3.5% compared to the 2009 estimate of 485 600 tU. These decreases are primarily due to resources being reclassified into higher cost categories as mining costs increase. 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 (~20%) 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 81%, 75% and

68%, respectively. Less than 8% of the identified conventional uranium resources recoverable at <USD 260/kgU are currently not available for mining due to a three-year moratorium that was enacted in 2008 by the Nunatsiavut Assembly, the legislative branch of Labrador's regional aboriginal government.

### *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 by British and United States defence programmes. A ban on private exploration and development was lifted in 1947, and by the late 1950s some twenty 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 mine 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*

*Overview*

Since the last Elliot Lake production facility closed in 1996, all active uranium production centres are located in northern Saskatchewan. Current Canadian uranium production remains below full production capability. Production in 2010 was 9 775 tU, 4% below 2009 production of 10 174 tU, due primarily to the depletion of the ore stockpile at the McClean Lake mill. Canadian uranium production is forecast to decrease to 8 600 tU in 2011 but will increase significantly in 2013 when the Cigar Lake mine begins production.

Cameco Corporation is the operator of the McArthur River mine, a Cameco (70%), AREVA (30%) joint venture. Production at this, the world's largest high-grade uranium mine, was 7 273 tU and 7 594 tU in 2009 and 2010, respectively. After raise bore mining of the high-grade ore behind a freeze curtain created to control groundwater inflow, high-grade ore slurry is produced by underground crushing, grinding and mixing facilities. The slurry is then pumped to the surface and loaded on specially designed containers that are trucked 80 km to Key Lake, where all McArthur River ore is milled.

The Key Lake mill is a Cameco (83%) and AREVA (17%) joint venture operated by Cameco. Although mining at Key Lake was completed in 1997, the mill maintained its standing as the world's largest uranium production centre by producing 7 339 tU and 7 654 tU in 2009 and 2010, respectively. These totals represent a combination of high-grade McArthur River ore slurry and stockpiled, mineralised Key Lake special waste rock that is blended with the slurry to produce a mill feed grade of about 3.4% U.

The McClean Lake production centre, operated by AREVA, is a joint venture between AREVA (70%), Denison Mines Inc. (22.5%), and OURD (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 1 388 tU and 657 tU, respectively, and was obtained from processing the higher grade ore from the stockpile. The lower grade ore remaining in the stockpile was not economic to process so the mill was placed into care and maintenance in July 2010. Production is expected to resume in 2013 when high-grade ore from Cigar Lake becomes available for processing. Modifications to the mill to increase capacity to 4 615 tU/yr and to process ore from the Cigar Lake mine have been completed. The environmental assessment of a proposal to mine the Caribou deposit was completed in April 2010, however, AREVA has decided to postpone mining the deposit until market conditions improve.

The Rabbit Lake production centre, wholly owned and operated by Cameco, produced 1 447 tU and 1 463 tU in 2009 and 2010, respectively. Exploratory drilling in the Eagle Point mine during the last several years has delineated additional assured resources, extending the life of the mine to at least 2017. Cameco has indicated that it intends to conduct underground exploratory drilling at the Eagle Point mine in 2012 to evaluate an ore body that was discovered by the latest phase of surface drilling.

Cigar Lake, with identified resources of 81 000 tU at an average grade of approximately 14% U, is the world's second-largest high-grade uranium deposit. The mine is a Cameco (50.025%), AREVA (37.1%), Idemitsu (7.875%) and TEPCO (5%) joint venture operated by Cameco. When completed, the mine is expected to have a full annual production capacity of 5 000 tU. Cigar Lake ore will be shipped to the McClean Lake mill for processing.

Construction of the Cigar Lake mine began on 1 January 2005 with completion originally expected in 2007. During October 2006, construction was halted due to a major inflow of groundwater that could not be controlled and the mine became flooded. Cameco conducted work to seal off the breach, however when dewatering the mine in 2008, a second inflow of groundwater occurred and operations were halted. The second breach was sealed and dewatering of the mine was completed in February 2010. Restoration of the underground development is currently underway and production from the mine is expected in mid 2013.

### *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. AREVA is the majority owner and operator of the McClean Lake production centre in which Denison Mines Inc. and OURD (Canada) Co. Ltd. have minority ownership.

### *Employment in the uranium industry*

Direct employment in Canada's uranium industry totalled 1 379 in 2009 and 1 305 in 2010. Total employment, including head office and contract employees, was 2 205 in 2009 and 2 399 in 2010.

## Uranium production centre technical details

(as of 1 January 2011)

| | Centre #1 | Centre #2 | Centre #3 | Centre #4 | Centre #5 | Centre #6 | Centre #7 |
|---|---|---|---|---|---|---|---|
| Name of production centre | McArthur River /Key Lake | McClean Lake | Rabbit Lake | Cigar Lake | Midwest | Millennium | Kiggavik |
| Production centre classification | Existing | Existing | Existing | Committed | Planned | Planned | Planned |
| Start-up date | 1999/1983 | 1999 | 1975 | 2013 | NA | NA | NA |
| Source of ore: | | | | | | | |
| Deposit name(s) | P2N et al. | JEB, McClean, Sue A-E, Caribou | Eagle Point | Cigar Lake | Midwest | Millennium | Kiggavik, Andrew Lake, End Grid |
| Deposit type(s) | Unconformity | Unconformity | Unconformity | Unconformity | Unconformity | Unconformity | Unconformity |
| Resources | 135 500 tU | 4 400 tU | 11 300 tU | 81 000 tU | 13 300 tU | 19 600 tU | 44 000 tU |
| Grade (% U) | 12.2 | 1.96 | 0.61 | 14.0 | 4.68 | 3.8 | 0.47 |
| Mining operation: | | | | | | | |
| Type (OP/UG/ISL) | UG | OP/UG | UG | UG | OP | UG | OP/UG |
| Size (tonnes ore/day) | NA | NA | NA | ~200 | NA | ~500 | ~1 500 |
| Average mining recovery (%) | NA | NA | NA | NA | NA | NA | NA |
| Processing plant: | | | | To be processed at McClean Lake and Rabbit Lake | To be processed at McClean Lake | To be processed at Key Lake | |
| Acid/alkaline | Acid | Acid | Acid | | | | Acid |
| Type (IX/SX) | SX | SX | SX | | | | SX |
| Size (tonnes ore/day) | 750 | 300 | 2 300 | | | | NA |
| Average process recovery (%) | 98 | 97 | 97 | NA | NA | NA | NA |
| Nominal production capacity (tU/year) | 7 200 | 4 615 | 6 500 | ~5 000 | ~2 300 | ~2 750 | ~3 000 |
| Plans for expansion | Relates to Millennium | Relates to Cigar Lake | Relates to Cigar Lake | | | | |

### *Future production centres*

Three uranium mining projects in Saskatchewan could enter into production within a few years, extending the lives of existing production centres. The Cigar Lake mine, which is scheduled to begin production in 2013, will provide feed for the McClean Lake and Rabbit Lake mills. Ore from the proposed Midwest mine will also provide additional feed for the McClean Lake mill. Ore from the proposed Millennium mine will processed at the Key Lake mill. There are several other exploration projects in the Athabasca Basin which have identified significant high-grade uranium mineralisation that may develop into proposals for new mines.

There is also the possibility of mines being developed outside of Saskatchewan. A proposal by AREVA to develop the Kiggavik and Sissons deposits in Nunavut is currently undergoing an environmental assessment as well as a feasibility study. Strateco Resources Inc. has applied for a licence to conduct underground exploration at the Matoush deposit in Québec. There is also a proposal to develop the Michelin and Jacques Lake deposits in Labrador which is currently on hold due to a three-year moratorium that was enacted in 2008 by the Nunatsiavut Assembly.

## Secondary sources of uranium

Canada reported that there was no production or use of mixed acid fuels nor any production or use of re-enriched tailings.

## Environmental activities and socio-cultural issues

### *Environmental impact assessments*

The environmental assessment for the Midwest project began on 2 March 2006. The Midwest project is a joint venture between AREVA (69.16%), Denison Mines Inc. (25.17%) and OURD (Canada) Co. Ltd. (5.67%). The proposal is to mine the Midwest deposit (13 300 tU averaging 4.68% U) by open pit and to transport the ore to McClean Lake for milling. In 2008, AREVA announced a decision to postpone development of the project due to low uranium prices. AREVA is continuing with the environmental assessment process which has been ongoing since March 2006. If the project receives regulatory approval, and the economics of the project improve, it would take two years to develop the mine and a further two years to mine the ore. Milling of the Midwest ore is expected to take from five to seven years.

On 3 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-Sissons project in Nunavut. The deposits have an estimated 44 000 tU with an average grade of 0.47% U. An environmental assessment of the project will be submitted to the Nunavut Impact Review Board as part of the Canadian Nuclear Safety Commission (CNSC) licensing process.

The environmental assessment for the Matoush Exploration Project began in November 2008. The proposal from Strateco Resources Inc. is to conduct underground exploration on the Matoush deposit which is located in the Otish Mountains of Québec. The Matoush deposit has identified resources of 6 500 tU with an average grade of 0.42% U. The environmental impact assessment was submitted for regulatory review in November 2009 and a decision is expected in 2011.

In August 2009, Cameco submitted a proposal to the CNSC to develop the Millennium deposit which is located 35 km north of Key Lake. The proposed underground mine would produce 150 000 to 200 000 t of ore annually for six to seven years. Ore and associated waste materials, other than clean waste rock, would be transported to the Key Lake mill along a new 21 km access road. In addition to an environmental assessment, Cameco is conducting an economic feasibility study of the project.

A proposal to extend the lifespan and increase the annual production capacity of the Key Lake milling operation by 33% (from 7 200 tU/yr to 9 600 tU/yr) was submitted to the federal nuclear regulator, the CNSC in May 2010. The proposal includes increasing the storage capacity of the Deilmann Tailings Management Facility and modifications to the mill to allow treatment of a wider range of ore and waste rock from other deposits.

In February 2010, AREVA submitted a proposal to transport uranium ore slurry from the McArthur River mine to the McClean Lake mill for processing. The primary purpose of this project, which is undergoing an environmental assessment, is to optimise the high-grade circuit at the mill in anticipation of the eventual receipt of similar high-grade ore from Cigar Lake.

### *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 2009 and 2010. 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 study environmental assessment. Decommissioning was essentially completed by 2006 and AREVA continues to work on site restoration activities such as the planting of over 800 000 tree seedlings. A follow-up monitoring programme is in place to confirm that the objectives of the decommissioning plan are met.

On 2 April 2007, the government of Canada and the government of Saskatchewan announced funding for the first phase of the cleanup of uranium mining sites (principally the Gunnar and Lorado mines) that operated in northern Saskatchewan from the late 1950s to early 1960s. The private sector companies that operated these facilities no longer exist. When the sites were closed, there was no regulatory framework in place to appropriately contain and treat the waste, which has led to environmental impacts on local soils and lakes. The projects to decommission the Gunnar and Lorado sites are currently undergoing environmental assessments.

In Elliot Lake, Ontario, the major uranium mining centre in Canada for over 40 years, uranium mining companies have committed well over CAD 75 million to decommission all mines, mills and waste management areas. These companies continue to commit some CAD 2 million each year for treatment and monitoring activities.

## Uranium requirements

Nuclear energy represents an important component of Canada's electricity sources. In 2010, nuclear energy provided 15% of Canada's total electricity needs (over 50% in Ontario) and should continue to play an important role in supplying Canada with power in the future. Canada has 22 CANDU reactors operated by public utilities and private companies in Ontario (20), Québec (1) and New Brunswick (1). Of these 22 reactors, 17 were in full commercial operation in 2010. Of the five reactors which were not operating, two are shut down and three are being refurbished.

The construction of new nuclear power reactors has been considered by some public and private companies in Canada over the past years. The actual number of new reactor units to be built hinges largely on refurbishment plans for existing units, demand for electricity and economics. Although there are currently no firm commitments from any province or territory within Canada to build a new nuclear power reactor, the

government of Ontario has expressed interest in building at least two new reactors at the Darlington Nuclear Generating Station.

Refurbishment projects are currently underway or have been announced in Ontario, New Brunswick and Québec. In Ontario, Bruce Power's restart and refurbishment programme of Bruce A units 1 and 2 at the Bruce Nuclear Generating Station has been underway for a few years. Both units are scheduled to return to service in 2012. Bruce Power is also examining the life extension of other units. New Brunswick Power began the refurbishment of the Point Lepreau Generating Station in March 2008 and is expected to be returned to service by the end of 2012. In August 2010, Hydro-Québec decided to postpone its decision to proceed with the refurbishment of the Gentilly-2 Nuclear Generating Station. The refurbishment projects currently underway are progressing, although they have encountered some technical delays and cost overruns.

In 2010, Ontario Power Generation (OPG) announced a two-part investment strategy for its Pickering and Darlington nuclear generating stations. First, OPG announced that it will proceed with a detailed planning phase for the mid-life refurbishment of its four nuclear power reactors at the Darlington Nuclear Generating Station, with construction expected to start in 2016. This will enable the station to operate for an additional 25-30 years. Second, OPG also announced that it will invest USD 300 million to ensure the continued safe and reliable performance of the Pickering Nuclear Generating Station (the two Pickering A units and the four Pickering B units) up until 2020 when it will reach the end of its operating life. Then, OPG will begin the long-term decommissioning process of the facility.

In June 2011, the government of Canada announced that it had reached an agreement with SNC-Lavalin Group Inc. (SNC) under which they will acquire the CANDU Reactor Division of AECL. Under the terms of the agreement, SNC, through its wholly-owned subsidiary CANDU Energy Inc., will take over the CANDU Reactor Division's three business lines: services to the existing fleet, life-extension projects and reactor new builds.

### *Supply and procurement strategy*

Ontario Power Generation fills its uranium requirements through long-term contracts with a variety of suppliers, as well as periodic spot market purchases. Since becoming a partner in Bruce Power in 2001, Cameco provides all uranium and uranium conversion services, and contracts all required fuel fabrication services for all of Bruce Power's fuel procurement needs.

## 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. Under the NFWA, the NWMO is required to submit a study to the government on the options for the long-term management of nuclear fuel waste.

On 3 November 2005, the NWMO submitted its report to the federal government for review and consideration. The NWMO recommended adaptive phased management (APM) which involves centralised containment and isolation of nuclear fuel waste in a deep geological repository. On 14 June 2007, the federal government announced its acceptance of the recommendation of the NWMO and selected APM as the preferred approach. Pursuant to the NFWA, the NWMO is responsible for implementing the approach, with government oversight. In May 2011, the NWMO initiated a site selection process to find a suitable site in a community willing to host a nuclear fuel waste facility. It is expected to take a decade or more before a site is identified.

The Nuclear Liability Act (NLA) sets out a comprehensive scheme of liability for civil injury and damage arising from nuclear accidents, and a compensation system for victims. It 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 75 million. All other contractors or suppliers are thereby indemnified. Previous parliaments have considered, but not passed bills, to update the NLA in order to better addresses public interests and reflect international standards. Key among the proposed amendments was an increase in the operator liability limit to CAD 650 million. The current session of parliament will provide an opportunity for the government to make a renewed attempt to modernise Canada's nuclear civil liability regime.

### *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)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 378 | 374 | 355 | 387 |
| Government exploration expenditures | 0 | 0 | 0 | 0 |
| Industry* development expenditures | 128 | 154 | 250 | 124 |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 506 | 528 | 605 | 511 |
| Industry* exploration drilling (m) | 725 400 | 409 800 | 317 200 | NA |
| Industry* exploration holes drilled | NA | NA | NA | NA |
| Government exploration drilling (m) | 0 | 0 | 0 | 0 |
| Government exploration holes drilled | 0 | 0 | 0 | 0 |
| Industry* development drilling (m) | 95 900 | 37 500 | 56 700 | NA |
| Industry* development holes drilled | NA | NA | NA | NA |
| Government development drilling (m) | 0 | 0 | 0 | 0 |
| Government development holes drilled | NA | NA | NA | |
| Subtotal exploration drilling (m) | 725 400 | 409 800 | 317 200 | NA |
| Subtotal exploration holes drilled | NA | NA | NA | NA |
| Subtotal development drilling (m) | 95 900 | 37 500 | 56 700 | NA |
| Subtotal development holes drilled | NA | NA | NA | NA |
| Total drilling (m) | 821 300 | 447 300 | 373 900 | NA |
| Total number of holes drilled | 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 237 927 | 292 524 | 305 201 | 380 880 | |
| Sandstone | | | | | |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | 5 255 | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | | 10 540 | 31 818 | |
| Metasomatite | | | | | |
| Other* | | | 3 934 | 3 934 | |
| Total | 237 927 | 292 524 | 319 675 | 421 887 | |

* 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.

### 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) | 237 667 | 292 264 | 296 198 | 336 244 | |
| Open-pit mining (OP) | 260 | 260 | 23 477 | 85 643 | |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| Co-product and by-product | | | | | |
| Unspecified | | | | | |
| Total | 237 927 | 292 524 | 319 675 | 421 887 | |

### 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 | 260 | 260 | 23 477 | 85 643 | |
| Conventional from UG | 237 667 | 292 264 | 296 198 | 330 989 | |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| In-place leaching* | | | | 3 153 | |
| Heap leaching** from OP | | | | | |
| Heap leaching** from UG | | | | 2102 | |
| Unspecified | | | | | |
| Total | 237 927 | 292 524 | 319 675 | 421 887 | |

* 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 |
|---|---|---|---|---|
| Unconformity-related | 112 857 | 124 297 | 134 514 | 142 604 |
| Sandstone | | | 2 840 | 2 840 |
| Hematite breccia complex | | | | |
| Quartz-pebble conglomerate | | | | 18 947 |
| Vein | | | | |
| Intrusive | | | | |
| Volcanic and caldera-related | | | 3 993 | 20 531 |
| Metasomatite | | | | |
| Other* | | | 7 627 | 7 627 |
| Total | 112 857 | 124 297 | 148 974 | 192 549 |

* 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.

### 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) | 112 857 | 124 297 | 144 981 | 177 779 | |
| Open-pit mining (OP) | 0 | 0 | 3 993 | 14 770 | |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| Co-product and by-product | | | | | |
| Unspecified | | | | | |
| Total | 112 857 | 124 297 | 148 974 | 192 549 | |

### Inferred conventional resources by processing method

(tonnes U)

| Processing method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Conventional from OP | 0 | 0 | 3 993 | 14 770 | |
| Conventional from UG | 112 857 | 124 297 | 144 981 | 158 832 | |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| In-place leaching* | | | | 11 368 | |
| Heap leaching** from OP | | | | | |
| Heap leaching** from UG | | | | 7 579 | |
| Unspecified | | | | | |
| Total | 112 857 | 124 297 | 148 974 | 192 549 | |

* 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | 238 574 | 9 000 | 10 174 | 9 775 | 267 523 | 8 600 |
| Sandstone | | | | | | |
| Hematite breccia complex | | | | | | |
| Quartz-pebble conglomerate | 144 182 | | | | 144 182 | |
| Vein | 26 630 | | | | 266 630 | |
| Intrusive | | | | | | |
| Volcanic and caldera-related | | | | | | |
| Metasomatite | 8 284 | | | | 8 284 | |
| Other* | | | | | | |
| Total | 417 670 | 9 000 | 10 174 | 9 775 | 446 619 | 8 600 |

* 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.

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 115 203 | 1 307 | 1 454 | 716 | 118 680 | 60 |
| Underground mining[1] | 302 467 | 7 693 | 8 720 | 9 059 | 327 939 | 8 540 |
| *In situ* leaching | | | | | | |
| Co-product/by-product | | | | | | |
| Total | 417 670 | 9 000 | 10 174 | 9 775 | 446 619 | 8 600 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 416 670 | 9 000 | 10 174 | 9 775 | 445 619 | 8 600 |
| In-place leaching* | 1 000 | | | | 1 000 | |
| Heap leaching** | | | | | | |
| U recovered from phosphate rocks | | | | | | |
| Other methods*** | | | | | | |
| Total | 417 570 | 9 000 | 10 174 | 9 775 | 446 619 | 8 600 |

* Also known as stope leaching or block leaching.

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

*** Includes mine water treatment and environmental restoration.

### Ownership of uranium production in 2010

| Domestic | | | | Foreign | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | | |
| (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) |
| 0 | 0 | 6 955 | 71.2 | 2 771 | 28.3 | 49 | 0.5 | 9 775 | 100 |

### Uranium industry employment at existing production centres

(person-years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 1 984 | 2 205 | 2 399 | 2 400 |
| Employment directly related to uranium production | 1 416 | 1 379 | 1 305 | 1 300 |

### Short-term production capability

(tonnes U/year)

| 2011 | | | | 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 |
| 16 430 | 16 430 | 16 430 | 16 430 | 17 730 | 17 730 | 17 730 | 17 730 | 17 730 | 19 000 | 17 730 | 19 000 |

| 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 |
| 17 730 | 19 000 | 17 730 | 19 000 | 17 730 | 19 000 | 17 730 | 19 000 | 17 730 | 19 000 | 17 730 | 19 000 |

### Installed nuclear generating capacity to 2035

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 12 000 | 12 000 | 12 000 | 12 000 | 13 300 | NA | 10 800 | NA | NA | NA | NA | NA | NA | NA |



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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 1 600 | 1 600 | 1 550 | 1 650 | 1 750 | NA | 1 500 | NA | NA | NA | NA | NA | NA | NA |

**Total uranium stocks**

(tonnes natural U-equivalent)

| Holder | Natural uranium stocks in concentrates | Enriched uranium stocks | Enrichment tails | LWR reprocessed uranium stocks | Total |
|---|---|---|---|---|---|
| Government | 0 | 0 | 0 | 0 | 0 |
| Producer | NA | 0 | 0 | 0 | NA |
| Utility | NA | 0 | 0 | 0 | NA |
| Total | NA | 0 | 0 | 0 | NA |



# 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 United States Atomic Energy Commission. Following a delay of about ten years, activities were renewed in 1970 by the Spanish Nuclear Energy Organization (JEN), 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 (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, spehne, 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 U-REO of the Cerro Carmen prospect (2000-2002), located in Region III (Atacama), was completed as part of the specific co-operation agreement between CCHEN and ENAMI. Geophysical exploration work was undertaken (magnetometry, resistivity and chargeability), defining targets with metallic sulphurs 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*

In 2008, CCHEN signed a broad scope co-operation agreement with the National Copper Corporation (CODELCO Norte) for geological and metallurgical investigation of natural atomic material occurrences and in 2009 a second agreement to carry out a programme of activities aimed at extracting uranium and molybdenum was signed.

**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: | -- | -- | 500 |
| 1. Surface deposits, Cenozoic | -- | -- | 500 |
| 2. Metasomatic deposits, Cretaceous | -- | -- | 250 |
| 3. Magmatic deposits, Cenozoic | | | |
| 4. Polymtallic deposts, 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 |

(*) SR. 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.

### 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 | | |

### 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 | | |

### 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 | | | |


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## 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.

**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$^3$<br>Oxide plants gravel<br>Cu silicate and oxides, 20-70 ppm<br>Sulphurs oxides 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, 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 (subeconomic) 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. 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. The production of copper oxide minerals has continued to grow over the last two years.

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 occurrence:

**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 t U.

## Uranium production

Outside of trial production mentioned above, no uranium has been produced in Chile.

## Environmental activities and socio-cultural issues

The Chilean Nuclear Energy Commission 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 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 the Russian Federation, enriched to 19.75% in $U_{23,}$ 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 (HFR), which ended in November 2004.

### *Supply and procurement strategy*

Should other loads of combustible elements be required, consideration will be given to obtaining enriched metallic uranium.

## National policies relating to uranium

There have been no changes in legislation relating to uranium in Chile.

### *Uranium stocks*

There are no uranium stocks.

## Uranium exploration and development expenditures and drilling effort – domestic

(CLP [Chilean pesos])

| | | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|---|
| Wages | | 101 238 349 | 105 539 586 | 115 336 870 | 141 467 564 |
| Operational expenses | CCHEN | 48 300 746 | 33 732 089 | 11 594 613 | 6 300 000 |
| | CODELCO | 25 536 989 | 91 483 943 | 495 919 607 | 277 824 106 |
| Management CCHEN[1] | | 50 619 175 | 52 769 793 | 57 668 435 | 70 733 782 |
| Total | | 225 695 259 | 283 525 411 | 680 519 525 | 496 325 452 |

Note: Exploration expenses incurred in the country, by the state of Chile, expressed in national currency of the indicated year.

1. Wages account for 50% of expenditure.

## 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 PLIO – 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 | | |

(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 were 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 PLIO – 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.

# China (People's Republic of)

## Uranium exploration and mine development

### *Historical review*

Before 1990s, China's uranium resource exploration activities were mainly carried out on hydrothermal related granite type and volcanic type uranium deposits in the Jiangxi, Hunan and Guangdong provinces and the Guangxi Autonomous Region of southern China. With decades of exploration experience, the Bureau of Geology (BOG), China National Nuclear Corporation (CNNC), had been successful in discovering some significant uranium deposits such as the Xiangshan and Xiazhuang ore fields and the Chengxian deposit in the Southern China Fold Belt. These deposits mainly occur in intermediate to acid magmatic rocks (such as granitoid) and volcanic rocks. As a number of these deposits are of relatively small size, low to middle grade, and their transportation and power supply are not easily accessible, the mining cost turned out to be much higher than those that could be accepted by the commercial nuclear reactor operators. At the beginning of 1990s, when China initiated its nuclear energy programme, the demand for uranium from China's NPPs was not so urgent. And in the mid-1990s, China experienced relatively high currency inflation, resulting in a decrease in uranium exploration activities in China from the mid to the end of 1990s.

Facing financial difficulties, as well as the challenge of meeting demand for economic uranium resources for China's mid-term and long-term nuclear energy development plan, the BOG made the decision of changing its prospecting direction from the "hard rock" types to *in situ* leach (ISL) amenable deposits in northern and north-west China. From the mid-1990s, the pace of construction of NPPs in coastal areas increased, and accordingly the demand of uranium increased steadily. As the low-cost identified uranium resources declined, the BOG initiated in the early 1990s with limited funding some regional geological reconnaissance projects and drilling survey projects in the Yili, Turpan-Hami, Junggar, Er'lian and Songliao basins in northern and north-west China. Due to limited funding from the government, the average annual drilling footage was just maintained at about 40 000 m. In 1999, the government conducted a significant structural reform in China's mineral exploration sector, during which a large part of the personnel who had been involved in geological exploration were transferred to local governments. After the transfer of most of the geological organisations, the staff of BOG was reduced from more than 45 000 to near 5 500. At the end of 1990s, the government gradually became aware of the importance of increasing uranium resources of economic interest to meet rising demand from the domestic nuclear power industry. Beginning in 2000, investment in uranium exploration steadily increased and drilling rebounded from 40 000 m to 70 000 m in 2000, gradually increasing to 130 000 m in 2003 and 140 000 m in 2004. All this drilling was directed at identifying ISL amenable sandstone type uranium deposits in northern China, with important target areas including the Yili, Erdos, Turpan-Hami, Er'lian, Junggar and Songliao basins.

***Recent and ongoing uranium exploration and mine development activities***

The domestic uranium prospecting and exploration has been intensified and increased due to more financial input and an increase in the work undertaken during 2009-2010. The scope of work has been expanded to potential prospects selected after regional prognosis and assessment has been completed, apart from the continued prospecting and exploration on areas with known mineralisation and belts related to previously discovered uranium deposits. The exploration focus is the sedimentary basin in northern China and granite and volcanic metallogenetic belts in southern China.

The exploration, including regional uranium potential assessment and further works on previously discovered mineralisation and deposits in northern China, spanned the Yili, Turpan-Hami, Junggar and Tarim basins of Xinjiang Autonomous Region, the Erdos, Erlian, Songliao, Badanjili and Bayingebi basins of Inner Mongolia, the Caidaum basin in Qinghai province and the Jiuquan Basin in Gansu province, etc. Different methods, such as EH-4, CSMT, etc, combined with some drilling are used in these assessments, followed by further drilling in mineralised areas in order to identify ISL amendable sandstone deposits and conventional hard rock sandstone and mudstone deposits.

The exploration work in southern China is directed at identifying hydrothermal vein-type uranium deposits related to volcanics and granites in the Xiangshan and Taoshan uranium fields in Jiangxi province, the Xiazhuang, Zhuguang uranium fields in Guangdong province, the Ziyuan field in the Guangxi Autonomous Region, the Lujing field in Hunan province and the Daqiaowu field of Zhejiang province and the Ruoergai area of Sichuan province. Potential deposits in Carbonaceous and siliceous mudstones are secondary targets in this exploration campaign.

The total drilling footage completed in the last two years amounted to 1 150 000 m (550 000 m in 2009 and 600 000 m in 2010). As a result, uranium resources in northern China such as those contained in the Yili, Erlian, Turpan-Hami, Erdos, Songliao basins and the Guyuan uranium field have been increased dramatically. In addition, some potential areas for future targets and prospects were identified such as the Badanjili, Bayingebin and north Erdos basins. Meanwhile, important progress has been achieved in old mining areas of southern China, such as the Taoshan, Zhuguangnanbu, Heyuan, Lujing and Dazhou uranium fields.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

As a result of the exploration in 2009 and 2010, a total of about 50 000 tU, categorised RAR and IR, have been added to China's uranium resource base. These additional resources are distributed in northern China (a total of 20 000 tU in the Yili, Erlian, Turpan-Hami, Erdos and Songliao basins) and in southern China (a total of 30 000 tU in the Taoshan, Zhuguangnanbu, Heyuan, Lujing and Dazhou uranium fields). As of 1 January 2011, uranium resources in China total 221 500 tU according to this latest data, as listed in the following table.

| No. | Location (provinces + places/name) | | tU |
|---|---|---|---|
| 1 | Jiangxi | Xiangshan | 29 000 |
| | | Ganzhou | 12 000 |
| | | Taoshan | 10 500 |
| 2 | Guangdong | Xiazhuang | 12 000 |
| | | Zhuguangnanbu | 20 000 |
| | | Heyuan | 4 000 |
| 3 | Hunan | Lujing | 9 000 |
| 4 | Guangxi | Ziyuan | 11 000 |
| 5 | Xinjiang | Yili | 28 000 |
| | | Turpan-Hami | 10 000 |
| 6 | Inner Mongolia. | Erdos | 23 000 |
| | | Erlian | 33 000 |
| | | Songliao | 2 000 |
| 7 | Hebei | Qinglong | 8 000 |
| 8 | Yunnan | Tengchong | 6 000 |
| 9 | Shanxi | Lantian | 2 000 |
| 10 | Zhejiang | Dazhou | 2 000 |
| Total | | | 221 500 |

### *Undiscovered conventional resources (prognosticated and speculative resources)*

China has great potential for uranium resources. According to statistical study conducted by several institutes in China, 2 million tones of potential uranium resources are predicted. Favourable areas in the Er'lian Basin of the Inner Mongolia Autonomous Region have been identified in the last two years and 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 potential target areas. More uranium resources may also be added to the known uranium deposits in southern China as prospecting and exploration works continue.

### *Unconventional resources and other materials*

No systematic appraisal of unconventional uranium resources has been conducted in China.

## Uranium production

### *Historical review*

During the more than 50-year history of China's uranium industry, both a boom in activities during the first two decades and a decline in late 1980s and 1990s have been experienced. In the early years of the new century a surge in activities has taken place, 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 has once again become a focus of attention. As uranium demand from NPPs is increasing rapidly in the coming decade, China has accelerated the pace of domestic uranium exploitation. Several uranium production centres are being developed and put into construction, such as Fuzhou and Yining. Some uranium deposits with potential reserves, such as Tongliao and Guyuan, are the subject of technical and economical feasibility studies in order to expand uranium production rapidly. Other uranium deposits with abundant reserves but with complicated mining and milling technologies are the subject of pilot tests and feasibility studies, such as Dongsheng and Erlian.

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

There are total six production centres in China now: Fuzhou and Chongyi in Jiangxi, east China; Lantian in Shaanxi, central China; Benxi in Liaoning, north-east China; Shaoguan in Guangdong, south China; and Yining in Xinjiang, north-west China. Uranium production centre technical details are shown in the following table.

The Qinglong uranium mine, a conventional underground mine associated with the Benxi uranium production centre, has attained full design capability through the installation of covers to keep heaps warm in the cold winter of north-east China and the strengthening of applied heap leaching technology to shorten the leach cycle. The Yining ISL uranium production centre also achieved design capability following pilot tests and hydro-geological research. Construction was completed and operations commenced at a new mine at the Fuzhou uranium production centre at the end of 2010. Although the ore body occurrences have proven to change sharply, the new mine has reached the designed capacity of ore extraction, offsetting reduced capacity of other mines and keeping capacity in balance at the Fuzhou production centre.

The status of other production centres in China mainly remains the same as reported in 2009. No production centre has been shut down in the last two years.

China uranium production was 1 200 tU and 1 350 tU in 2009 and 2010 respectively and is expected to increase to 1 500 tU in 2011.

### *Ownership structure of the uranium industry*

The uranium industry in China is 100% owned by state companies.

### *Employment in the uranium industry*

With a new mine of Fuzhou uranium production centre being put into operation, new employees were required. Hence, employment in the industry will slightly increase in 2011.

## Uranium production centre technical details

(as of 1 January 2011)

| | Centre #1 | Centre #2 | Centre #3 | Centre #4 | Centre #5 | | Centre #6 |
|---|---|---|---|---|---|---|---|
| Name of production centre | Fuzhou | Chongyi | Yining | Lantian | Benxi | | Shaoguan |
| Production centre classification | Existing | Existing | Existing | Existing | Existing | Existing | Existing |
| Date of first production | 1966 | 1979 | 1993 | 1993 | 1996 | 2007 | |
| Source of ore: | | | | | | | |
| Deposit name(s) | | | Dep 512 | Lantian | Benxi | Ginglong | |
| Deposit type(s) | Volcanic | Granite | Sandstone | Granite | Granite | Volcanic | Granite |
| Resources (tU) | | | | | | | |
| Grade (% u) | | | | | | | |
| Mining operation: | | | | | | | |
| Type (OP/UG/ISL) | UG | UG | ISL | UG | UG | UG | UG |
| Size (tonnes ore/day) | 700 | 400 | NA | 200 | 100 | 200 | 500 |
| Average mining recovery (%) | 92 | 90 | NA | 80 | 85 | 85 | 90 |
| Processing plant: | | | | | | | |
| Acid/alkaline | Conventional | Heap leach | | Heap leach | Heap leach | Heap leach | Heap leach |
| Type (IX/SX/AL) | IX, AL | IX, AL | IX, AL | IX, AL | SX, AL | IX | SX, AL |
| Size (tonnes ore/day); for ISL (l/day or l/h) | 700 | 350 | NA | NA | NA | NA | NA |
| Average process recovery (%) | 90 | 84 | NA | 90 | 90 | 96 | 90 |
| Nominal production capacity (tU/year) | 350 | 150 | 330 | 100 | 120 | 100 | 200 |
| Plans for expansion | Expansion to 500 tU/yr | Expansion to 300 tU/yr | Expansion to 500 tU/yr | NA | NA | NA | NA |
| Other remarks | | | | | | | |

### *Future production centres*

The new uranium mine of Chongyi uranium production centre remains under construction and is on schedule to begin production by the end of 2011.

ISL pilot tests at the Shihongtan deposit of the Yining uranium production centre are ongoing. The pilot test in Dongsheng uranium deposit is also ongoing but only in the western portion of the field. Owing to low permeability, the eastern part of the deposit proven to be unsuitable for ISL extraction and pilot tests of conventional underground mining are being conducted.

Pilot tests and construction are being carried out on several other deposits, such as the Tongliao sandstone deposit and the Guyuan granite deposit. The Erlian uranium deposit, the recently identified large sandstone uranium deposit in Inner Mongolia, has proven not to be suitable for ISL technology due to its low permeability. Other mining methods are being evaluated, such as open-pit and underground mining. Pilot tests on milling technology of ores from this deposit are also ongoing.

Driven by China's active strategies in developing NPPs, some uranium mines currently on stand-by are expected to be put into operation again.

## Secondary sources of uranium

### *Production and/or use of mixed oxide fuels*

MOX fuels are not produced or used.

### *Production and/or use of re-enriched tails*

Re-enriched tails are not used.

### *Production and/or use of reprocessed uranium*

There is no production or use of reprocessed uranium.

## Uranium requirements

As of 1 January 2011, the total installed capacity of NPPs is 10 800 MWe (gross). Annual uranium requirements amount to about 3 900 tU.

According to the government's nuclear power programme, the total capacity of NPPs will reach between 40 GWe and 58 GWe by the end of 2020.

Based on the preliminary calculation, the uranium requirements will amount to 6 450 tU and 8 200 tU at the year of 2015 and 2020, respectively. The projection of low and high uranium requirements for the year of 2020, 2025, 2030 and 2035 will range from 10 100-12 000 tU, 12 300-16 200 tU, 12 300-16 200 tU and 14 400-20 500 tU respectively.

### *Supply and procurement strategy*

In order to meet the demand of NPPs with the development programme approved by the central government, the policy "Facing Two Markets and Using of Two kinds of Resources" has been adopted. This means that China will actively develop domestic uranium resources, make the full use of non-domestic resources and mine development in advance of requirements. Uranium supply will be guaranteed through a combination of domestic production, development of non-domestic resources and international trade to ensure a stable supply of nuclear fuel to NPPs. As a supplement to balance uranium supply, international supply will be acquired through different channels in order to reduce market risks, ensure stable supply and to realise reasonable prices.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

In order to meet the demand driven by increasing rate of domestic nuclear power development, the Chinese government has given greater importance to uranium fuel supply. Measures taken by the central government include intensification of uranium exploration in China, promotion of domestic production, introduction of regulations to allow non-government organisations to explore for uranium in China, and further development of the "two markets and two resources" policy, including overseas purchases and production.

### *Uranium stocks*

NA.

### *Uranium prices*

The uranium price is gradually streamlined with the international market price in order to follow the trend of the development of uranium price in the world, so it is purchased in China following on the fluctuation of international market accordingly.

**Uranium exploration and development expenditures and drilling effort – domestic**

(USD millions)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 0 | 0 | 8 | 8 |
| Government exploration expenditures | 44 | 55 | 69 | 69 |
| Industry* development expenditures | 0 | 0 | 8 | 8 |
| Government development expenditures | | | | |
| Total expenditures | 44 | 55 | 77 | 77 |
| Industry* exploration drilling (m) | 0 | 0 | 70 000 | 70 000 |
| Industry* exploration holes drilled | 0 | 0 | 140 | 140 |
| Government exploration drilling (m) | 500 000 | 550 000 | 530 000 | 530 000 |
| Government exploration holes drilled | 1 590 | 1 550 | 1 600 | 1 600 |
| Industry* development drilling (m) | 0 | 0 | NA | NA |
| Industry* development holes drilled | 0 | 0 | NA | NA |
| Government development drilling (m) | 0 | 0 | 0 | 0 |
| Government development holes drilled | 0 | 0 | 0 | 0 |
| Subtotal exploration drilling (m) | 500 000 | 550 000 | 600 000 | 600 000 |
| Subtotal exploration holes drilled | 1 590 | 1 550 | 1 740 | 1 740 |
| Subtotal development drilling (m) | 0 | 0 | 0 | 0 |
| Subtotal development holes drilled | 0 | 0 | 0 | 0 |
| Total drilling (m) | 500 000 | 550 000 | 600 000 | 600 000 |
| Total number of holes drilled | 1 590 | 1 550 | 1 740 | 1 740 |

Note: USD 1 = CNY 6.47 (Yuan renminbi) as of November 2011.

* Non-government.

### Uranium exploration and development expenditures – non-domestic

(USD millions)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | | | | |
| Government exploration expenditures | | 5.45 | 8.84 | 13.50 |
| Industry* development expenditures | | | | |
| Government development expenditures | 220 | 187.57 | 85.77 | 80.69 |
| Total expenditures | 220 | 193.02 | 94.61 | 94.19 |

Note: USD 1 = CNY 6.47 as of November 2011.

* 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 |
|---|---|---|---|---|
| Unconformity-related | NA | NA | NA | NA |
| Sandstone | NA | NA | NA | NA |
| Hematite breccia complex | NA | NA | NA | NA |
| Quartz-pebble conglomerate | NA | NA | NA | NA |
| Vein | NA | NA | NA | NA |
| Intrusive | NA | NA | NA | NA |
| Volcanic and caldera-related | NA | NA | NA | NA |
| Metasomatite | NA | NA | NA | NA |
| Other* | NA | NA | NA | NA |
| Total | 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.

### 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) | 20 000 | 49 000 | 70 000 | 70 000 | *In situ* |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | |
| *In situ* leaching | 41 000 | 69 000 | 76 000 | 76 000 | *In situ* |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 61 000 | 118 000 | 146 000 | 146 000 | |

### Reasonably assured conventional resources by processing method

(tonnes U)

| Processing method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Conventional from UG | 20 000 | 49 000 | 70 000 | 70 000 | *In situ* |
| Conventional from OP | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 41 000 | 69 000 | 76 000 | 76 000 | *In situ* |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 61 000 | 118 000 | 146 000 | 146 000 | *In situ* |

* 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 |
|---|---|---|---|---|
| Unconformity-related | NA | NA | NA | NA |
| Sandstone | NA | NA | NA | NA |
| Hematite breccia complex | NA | NA | NA | NA |
| Quartz-pebble conglomerate | NA | NA | NA | NA |
| Vein | NA | NA | NA | NA |
| Intrusive | NA | NA | NA | NA |
| Volcanic and caldera-related | NA | NA | NA | NA |
| Metasomatite | NA | NA | NA | NA |
| Other* | NA | NA | NA | NA |
| Total | 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.

### 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) | 5 400 | 41 000 | 49 500 | 49 500 | *In situ* |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 12 500 | 21 000 | 26 000 | 26 000 | *In situ* |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 17 900 | 62 000 | 75 500 | 75 500 | *In situ* |

### 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 | 20 000 | 49 000 | 70 000 | 70 000 | *In situ* |
| Conventional from OP | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 12 500 | 21 000 | 26 000 | 26 000 | *In situ* |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 17 900 | 62 000 | 75 500 | 75 500 | *In situ* |

* 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 concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | NA | NA | 0 | 0 | | 0 |
| Sandstone | NA | NA | 300 | 330 | | 400 |
| Hematite breccia complex | NA | NA | 0 | 0 | | 0 |
| Quartz-pebble conglomerate | NA | NA | 0 | 0 | | 0 |
| Vein | NA | NA | 0 | 0 | | 0 |
| Intrusive | NA | NA | 0 | 0 | | 0 |
| Volcanic and caldera-related | NA | NA | 400 | 450 | | 450 |
| Metasomatite | NA | NA | 0 | 0 | | 0 |
| Other* | NA | NA | 500 | 570 | | 650 |
| Total | NA | NA | 1 200 | 1 350 | NA | 1 500 |

* 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.

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | NA | NA | 0 | 0 | | 0 |
| Underground mining[1] | NA | NA | 900 | 1 020 | | 1 100 |
| *In situ* leaching | NA | NA | 300 | 330 | | 400 |
| Co-product/by-product | NA | NA | 0 | 0 | | 0 |
| Total | NA | NA | 1 200 | 1 350 | | 1 500 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | NA | NA | 300 | 350 | | 350 |
| In-place leaching* | NA | NA | 300 | 330 | | 400 |
| Heap leaching** | NA | NA | 600 | 670 | | 750 |
| U recovered from phosphate rocks | NA | NA | 0 | 0 | | 0 |
| Other methods*** | NA | NA | 0 | 0 | | 0 |
| Total | NA | NA | 1 200 | 1 350 | | 1 500 |

* 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 2010

| Domestic | | | | Foreign | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | | |
| (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) |
| 1 350 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 1 350 | 100 |

### Uranium industry employment at existing production centres

(person-years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 7 450 | 7 500 | 7 560 | 7 650 |
| Employment directly related to uranium production | 6 740 | 6 800 | 6 860 | 6 950 |

### Short-term production capability

(tonnes U/year)

| 2010 | | | | 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 |
| 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 |

### Mixed oxide fuel production and use

(tonnes natural U equivalent)

| Mixed oxide (MOX) fuel | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (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 |

### Re-enriched tails production and use

(tonnes natural U equivalent)

| Re-enriched tails | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Production | 0 | 0 | 0 | 0 | 0 | 0 |
| Use | 0 | 0 | 0 | 0 | 0 | 0 |

### Reprocessed uranium use

(tonnes natural U equivalent)

| Reprocessed uranium | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Production | 0 | 0 | 0 | 0 | 0 | 0 |
| Use | 0 | 0 | 0 | 0 | 0 | 0 |

### Net nuclear electricity generation

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 70.05 | 76.82 |

### Installed nuclear generating capacity to 2035

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 9 070 | 10 800 | 11 880 | 11 880 | 25 000 | 35 000 | 40 000 | 58 000 | 58 000 | 71 300 | 71 300 | 83 800 | 83 800 | 108 800 |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 3 300 | 3 900 | 4 150 | 4 150 | 4 600 | 6 450 | 6 450 | 8 200 | 10 100 | 12 000 | 12 300 | 16 200 | 14 400 | 20 500 |

### 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 | NA | NA | NA | NA | NA |
| Producer | NA | NA | NA | NA | NA |
| Utility | NA | NA | NA | NA | NA |
| Total | NA | NA | NA | NA | NA |




# Czech Republic

## Uranium exploration and mine development

### *Historical review*

Uranium exploration began in 1946 in Czechoslovakia and developed rapidly 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 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 on vein deposits located in metamorphic complexes of the Bohemian massif and around the sandstone-hosted deposits in northern and north-western Bohemia.

In 1989, the decision was made to reduce all uranium related activities. No field exploration has been carried out since the beginning of 1994.

### *Recent and ongoing uranium exploration and mine development activities*

In 2008 and 2009, underground exploration (drilling) has been carried out in the deeper parts of the nearly depleted Rozna deposit to specify and verify resources. This work was funded by the state-owned company DIAMO s.e.

Other 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 2011. Expenditures in 2008 reflect government contributions to the costs of processing the previously collected data.

## 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 Rozna is being mined. Other deposits have resources that are not recoverable because of environmental protection.

Undiscovered uranium resources are believed to occur in the Rozna and Brzkov vein deposits in the metamorphic complex of Western Moravia, as well as in the sandstone deposits of the Straz block, Tlustec block and Hermanky region in the Northern Bohemian Cretaceous basin.

### *Identified conventional resources (reasonably assured and inferred resources)*

As of 1 January 2011, identified conventional resources amounted to 374 tU, a decrease of 128 tU in comparison with the 2009 estimate. These resources are located in the deepest and peripheral parts of the Rozna mine and, because of increased mining costs, have been transferred into a higher cost category (from <USD 80/kgU to <USD 130/kgU). Another 116 000 tU of identified resources are located in the Straz bloc (the Straz, Hamr, Oscena-Kotel and Brevniste deposits), but these are not reported because mining costs are >USD 260/kgU and current policy and environmental considerations make these resources inaccessible to further development.

In detail, reasonably assured conventional resources recoverable at a cost of <USD 130/kgU decreased by 128 tU, and the RAR recoverable at a cost of >USD 130/kgU are no longer registered. The decrease in RAR was the combined result of depletion (a total of 482 tU was mined in 2009 and 2010) and the re-evaluation of the Rozna resources during underground exploration in 2009 and 2010 (adding 354 tU).

Inferred conventional resources at a cost of <USD 130/kgU are unchanged and those available at a cost of >USD 130/kgU are no longer reported. All the identified conventional resources recoverable at <USD 130/kgU are tributary to the existing Rozna and Straz production centres. Mining losses of 5% have been taken into account in estimating RAR and IR.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

The speculative resources at a cost of about or more than USD 260/kgU are estimated to amount to 179 000 tU and are reported in the unassigned cost category. Since these resources are situated in sandstone deposits of the Northern Bohemian Cretaceous basin in a groundwater source protection zone, further exploration and evaluation is prohibited.

## Uranium production

### *Historical review*

Between 1946 and the dissolution of the Soviet Union, all uranium produced in Czechoslovakia was exported to the Soviet Union. The first production came from Jachymov and Horni Slavkov mines, which completed operations in the mid-1960s. Pribram, the main vein deposit, was mined between 1950 and 1991. The Hamr and Stráz production centres started operation in 1967 and peak production from these sandstone deposits of about 3 000 tU was achieved around 1960. A cumulative total of 110 939 tU was produced in the Czech Republic during the period 1946-2010, of which about 85% was produced by underground and open-pit mining methods and the remainder was recovered by *in situ* leaching (ISL).

### *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 Rozna in the Dolni Rozinka uranium production centre (Western Moravia) and the second is a chemical mining centre in Straz pod Ralskem (Northern Bohemia). Both the Dolni Rozinka and Straz pod Ralskem production centres are wholly operated by the state-owned enterprise DIAMO.

The Dolni Rozinka production centre (Rozna vein deposit, with reserves of 374 tU, stoping c. 1 100 m underground) produced 218 tU in 2009 and 224 tU in 2010. Expected production from this centre is 200 tU in 2011 (these figures do not include U recovered from mine water treatment). Currently the resources are located in the deepest and boundary parts of the mine and therefore are expected to be recovered at a higher cost and will result in a gradual decrease in production.

At the Straz pod Ralskem chemical mining centre (Straz sandstone deposit, with reserves of 1 089 tU recoverable at costs >260 kgU), the former acid ISL (c. 180 m underground) production centre, 25 tU and 13 tU were recovered in 2009 and 2010, respectively. Uranium production at this centre results from environmental remediation activities at the Straz deposit that began in 1996. Production capability during remediation (without acid) has decreased due to lower uranium concentration in solutions. Expected production amounts to 12 tU in 2011, and is expected to decrease thereafter.

Uranium is also obtained from mine water treatment (at existing and former facilities), with total expected production of 14 tU in 2011 (not including U recovery from mine 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, s.p., a mining and environmental engineering company, based in Straz pod Ralskem.

### *Employment in the uranium industry*

Total employment in Czech uranium production centres was 2 248 workers in 2009 and 2 164 workers in 2010 (i.e. employment related to production including head-office, laboratory, mining emergency services, etc.).

Employment directly related to uranium production at Dolni Rozinka and Straz pod Ralskem centres was 1 122 in 2009 and 1 118 in 2010, however some uranium production is associated with remediation.

### *Future production centres*

No other production centres are committed or planned in the near future.

## Secondary resources of uranium

### *Production and/or use of mixed oxide fuels*

The Czech power company CEZ, a.s., operator of all six nuclear power reactors in the Czech Republic, does not use MOX fuel in its reactors.

### *Production and/or use of re-enriched tails*

CEZ does not use re-enriched tails for fuel purposes.

### *Production and/or use of reprocessed uranium*

CEZ does not use reprocessed uranium in its reactors.

**Uranium production centre technical details**

(as of 1 January 2011)

| | Centre #1 | Centre #2 |
|---|---|---|
| Name of production centre | Dolni Rozinka | Straz pod Ralskem |
| Production centre classification | Existing | Existing |
| Start-up date | 1957 | 1967 |
| Source of ore: | | |
| Deposit name(s) | Rozna | Straz |
| Deposit type(s) | Vein | Sandstone |
| Resources (tU) | 374 | 1 089 |
| Grade (% U) | 0.291 | 0.030 |
| Mining operation: | | |
| Type (OP/UG/ISL) | UG | ISL |
| Size (tonnes ore/day) | 550 | - |
| Average mining recovery (%) | 92.0 | 50.0 (estimated) |
| Processing plant: | | |
| Acid/alkaline | Alkaline | Acid |
| Type (IX/SX) | IX, CWG | IX |
| Size (tonnes ore/day);<br>for ISL (kilolitre/day) | 530<br>- | -<br>500 |
| Average process recovery (%) | 90.4 | - |
| Nominal production capacity (tU/year) | 400 | 100 |
| Plans for expansion (yes/no) | No | No |
| Other remarks | - | Production under remediation process |

## Environmental activities and socio-cultural issues

Both environmental remediation activities and the resolution of social issues are the responsibility of 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, 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 ISL used in Straz pod Ralskem that impacted a total of 266 million $m^3$ of groundwater and an enclosure of 600 ha surface area.
- Rehabilitation of the tailings impoundments in Mydlovary, Pribram, Straz pod Ralskem and Rozna (a total of 19 ponds with a total area of 576 ha).
- Rehabilitation (incl. reprocessing) of waste rock dumps in Pribram, Hamr, Rozna, Western Bohemia and other sites (a total of 68 dumps with a capacity 38.9 million $m^3$).
- Mine water treatment from former uranium facilities in Pribram, Straz, Horni Slavkov, Licomerice, Olsi, and others, amounting to a total of approximately 14 million $m^3$/year which, results in the recovery of about 15 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%). The projects, expected to continue until approximately 2040, are expected to cost in total more than CZK 60 000 million.

The social part of the programme (obligatory spending, compensation, damages, rent etc.) is financed entirely by the state budget.

**Expenditures related to environmental activities and social issues**

(CZK millions)

| | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Uranium environmental remediation | 23 884 | 2 015 | 2 921 | 2 460 | 31 280 | 3 106 |
| Social programme and social security | 6 890 | 467 | 442 | 408 | 8 187 | 405 |
| Total | 30 774 | 2 482 | 3 363 | 2 868 | 39 467 | 3 511 |

## Uranium requirements

The average annual uranium requirements for the Dukovany NPP and the Temelin NPP are about 670 tU in the long term.

The temporary increase in the uranium needs in 2009-2010 was caused by replacement of all fuel assemblies in the entire core of Temelin Unit 1 by new fuel supplied by the Russian fabricator TVEL. The same scope of fuel replacement will be carried out at Temelin Unit 2 in 2011 with the same impact on the increase in uranium needs. Two following transitional reloads at each of these Units will have 48 and 42 assemblies, respectively. When the 12 months cycle is stabilised, a typical fuel reload will require 36 assemblies. This is reflected in the total annual uranium needs stated for 2015 and onwards.

Two new units at the Temelin site, to be put in operation around 2025 and one additional unit after 2030 are currently under consideration. An 18-month fuel cycle is considered for these new units. However, a decision about the installed capacity of these new units has not been made yet; since it will stem from a successful bidder for the new units. Note: In comparison with previous announcements and reports, possible delays in putting the new units into operation have been taken into consideration in this report.

The projected uranium requirements for 2035 are mainly influenced by a lifespan of operation of the Dukovany NPP. The low case projection assumes 40 years of lifetime operation for the reactors and the high case assumes 50 years (in this case, the Dukovany reactors would be the first to close in 2035).

### *Supply and procurement strategy*

The Czech power utility CEZ, a.s. procures uranium for its NPPs Dukovany and Temelin on mid- and long-term contractual basis. The main portion of total uranium requirements was covered from domestic sources in the past. As Czech uranium production was continuously decreased during the previous decade, increased quantities of uranium have to be purchased on the world market (an existing contract with DIAMO, s.p. covers about 30% of national needs). A portion of uranium requirements (mainly for the Dukovany NPP) are covered by purchases of uranium together with conversion and enrichment services (i.e. as a "package") under existing fabrication contracts with TVEL. CEZ maintains strategic and working inventories of nuclear materials in different stages of processing and also fabricated fuel (Dukovany NPP).

## 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 and new uranium mining activities have not been developed.

On the base of the government decision (Government Decree No. 565/2007 Coll.) the existing Rozna uranium deposit will be mined by DIAMO as long as it can be done profitably with no government financial assistance.

The government of the Czech Republic maintains a positive nuclear energy policy. Political support for the completion of the Temelin NPP is important and is a groundbreaking decision for possible future development of nuclear power.

### *Uranium stocks*

CEZ maintains uranium stocks (pipeline and strategic) on a level sufficient for about two years of annual needs. Such stocks are held in all forms of processed uranium: U-concentrates ($U_3O_8$), $UF_6$, EUP and fabricated fuel.

### *Uranium prices*

Uranium prices are not available as they are commercially confidential. In general, uranium prices in supply contracts between DIAMO and CEZ reflect price indicators of the world market incorporated according to agreed formulas.

### Uranium exploration and development expenditures and drilling effort – domestic

(CZK millions)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 5.2 | 2.1 | 0.1 | 0.1 |
| Government exploration expenditures | 0.8 | 0 | 0 | 0 |
| Industry* development expenditures | 0 | 0 | 0 | 0 |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 6 | 2.1 | 0.1 | 0.1 |
| Industry* exploration drilling (m) | 0 | 0 | 0 | 0 |
| Industry* exploration holes drilled | 0 | 0 | 0 | 0 |
| Government exploration drilling (m) | 0 | 0 | 0 | 0 |
| Government exploration holes drilled | 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) | 0 | 0 | 0 | 0 |
| Subtotal exploration holes drilled | 0 | 0 | 0 | 0 |
| Subtotal development drilling (m) | 0 | 0 | 0 | 0 |
| Subtotal development holes drilled | 0 | 0 | 0 | 0 |
| Total drilling (m) | 0 | 0 | 0 | 0 |
| Total number of holes drilled | 0 | 0 | 0 | 0 |

* Non-government.

### Reasonably assured conventional resources by deposit type

(tonnes U)

| Deposit type | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 304 | 304 | 90 |
| Intrusive | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 304 | 304 | 90 |

* 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.

### 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 | 304 | 304 | 90 |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | 0 |
| *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 | 0 | 0 | 304 | 304 | 90 |

### 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 | 304 | 304 | 90 |
| Conventional from OP | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | 0 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | 0 |
| Unspecified | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 304 | 304 | 90 |

* 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 |
|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 70 | 70 |
| Intrusive | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 70 | 70 |

* 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.

### 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 | 70 | 70 | 90 |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | 0 |
| *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 | 0 | 0 | 70 | 70 | 90 |

### 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 | 70 | 70 | 90 |
| Conventional from OP | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | 0 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | 0 |
| Unspecified | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 70 | 70 | 90 |

* 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 concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 32 749 | 35 | 25 | 13 | 32 822 | 12 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 | 0 |
| Vein | 77 403 | 240 | 233 | 241 | 78 117 | 214 |
| Intrusive | 0 | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 110 152 | 275 | 258 | 254 | 110 939 | 226 |

* 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.

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 0 | 0 | 0 | 0 | 0 | 0 |
| Underground mining[1] | 92 737 | 240 | 233 | 241 | 93 451 | 214 |
| *In situ* leaching | 17 415 | 35 | 25 | 13 | 17 488 | 12 |
| Co-product/by-product | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 110 152 | 275 | 258 | 254 | 110 939 | 226 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 107 640 | 226 | 218 | 224 | 108 308 | 200 |
| In-place leaching* | 3 | 0 | 0 | 0 | 3 | 0 |
| Heap leaching** | 125 | 0 | 0 | 0 | 125 | 0 |
| U recovered from phosphate rocks | 0 | 0 | 0 | 0 | 0 | 0 |
| Other methods*** | 2 384 | 49 | 40 | 30 | 2 503 | 26 |
| Total | 110 152 | 275 | 258 | 254 | 110 939 | 226 |

* 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.

### Prognosticated conventional resources

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 80/kgU | <USD 130/kgU | <USD 260/kgU |
| 0 | 180 | 180 |

### Speculative conventional resources

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 130/kgU | <USD 260/kgU | Unassigned |
| 0 | 0 | 179 000 |

### Ownership of uranium production in 2010

| Domestic | | | | Foreign | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | | |
| (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) |
| 254 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 254 | 100 |

### Uranium industry employment at existing production centres

(person-years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 2 287 | 2 248 | 2 164 | 2 140 |
| Employment directly related to uranium production | 1 122 | 1 122 | 1 118 | 1 118 |

### Short-term production capability

(tonnes U/year)

| 2011 | | | | 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 |
| 0 | 0 | 500 | 500 | 0 | 0 | 50 | 50 | 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 |

### Net nuclear electricity generation

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 25.7 | 26.4 |

### Installed nuclear generating capacity to 2035

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 3.60 | 3.70 | 3.73 | 3.75 | 3.81 | 3.82 | 3.83 | 3.85 | 3.85 | 5.92 | 5.92 | 6.13 | 5.1 | 7.25 |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 1 039 | 885 | 840 | 842 | 650 | 680 | 655 | 680 | 680 | 850 | 850 | 900 | 910 | 1 300 |

### Total uranium stocks

(tonnes natural U-equivalent)

| Holder | Natural uranium stocks in concentrates | Enriched uranium stocks | Enrichment tails | LWR reprocessed uranium stocks | Total |
|---|---|---|---|---|---|
| Government | 0 | 0 | 0 | 0 | 0 |
| Producer | <200 | 0 | 0 | 0 | <200 |
| Utility | NA | NA | 0 | 0 | NA |
| Total | <200 | 0 | 0 | 0 | <200 |




# Ethiopia

## Uranium exploration and mine development

### *Historical review*

Ethiopia reported limited uranium exploration activity in the Red Book in 1979, 1983 and 1986 but has not been active in this programme since. Uranium exploration activities began in the 1950s and information on airborne radiometer surveys and relevant ground prospecting during 1954-1964 are provided in a number of diverse sources (Jelenc D.A [1966], *Mineral Resources of Ethiopia*, Ministry of Mines). As a result of these early exploration activities, many localities are reported to indicate uranium-bearing mineral manifestations, though their specific locations are not well presented and recognised.

Between 1968 and 1970, airborne geophysical surveys in southern and western Ethiopia were conducted as part of the United Nations Development Program (UNDP).

Accordingly 13 anomalies in southern Ethiopia, 8 of which were checked by ground survey and 6 anomalous bodies out of 36 in western Ethiopia were investigated and none were found to support the existence of proper uranium mineralisation.

In addition to this, the 1993-1994 airborne geophysical survey of southern basement rocks under the Ethiopia-UNDP programme, as well as a similar type of survey by the Ethio-Nor Program in western Ethiopia in 1997-2001, failed to identify significant radiometric anomalies related to radioactive mineral resources.

Based on an interest in diversifying energy resources, the Ethiopian government initiated in 2006 the Uranium Resource Exploration Project. However, these activities only detected some radiometric anomalous spots related to localised pegmatite bodies hosting only minerals accessory to uranium.

Since recent uranium exploration in Ethiopia is based on limited information and little knowledge, the efforts to discover uranium deposits in all favourable geological terrains in the country need a highly experienced expertise and capacity-building approach that overcomes past difficulties in exploration for uranium resources.

Ethiopia does not currently produce uranium. However, efforts are being made in order to define possible targets of interest. In the first quarter of 2010, the Geological Survey of Ethiopia (GSE) signed a Uranium Resource Assessment Agreement with Zarubezhgeologia (JSC), and accordingly a specialist has been employed for a specific period to conduct an overall assessment of favourable geological settings with uranium mineral resource potential.

### *Recent and ongoing uranium exploration and mine development activities*

Previous and current exploration detected insignificant radiometric anomalies that are mainly related to variation in the background values of rocks or accessory minerals in localised targets. With demand for a capacity-building programme to solve challenges associated with the identification of uranium metallogenic provinces, Ethiopia strongly encourages uranium mineral exploration in order to diversify the energy mix.

At present, the assessment of possible uranium related areas has been launched under an expert assisted programme with the support of radiometric equipment from sister countries.

In 2011, co-operative assessment activities have been continuing. This work is concentrated on characterising U-enriched granitoids that could be possible uranium ore sources to help narrow the search in surrounding areas for possible uranium concentrations of economic interest. In addition to this, proposals for an airborne survey and for the application of remote sensing technology are being pursued under the co-operation programme with sister institutions from abroad.

## National policies relating to uranium

### *Mining and radiation protection proclamations*

Ethiopia's first mining laws and regulations were enacted in 1971. The military government of Ethiopia modified these laws in 1975 to totally close off foreign investment. A fundamental shift in policy was made after the fall of the military regime, and a Mining Law No. 52/1993 and an Income Tax Law No. 182/1994 was enacted to guarantee the rights of the private national and international investors. With the intention of further increasing attractiveness to foreign investors, the mining law has been reviewed and endorsed by the Ethiopian government with the goal of further developing an enabling environment for investment.

Nevertheless, these laws apply to the ownership of mineral deposits and do not specifically address safety and environmental protection of uranium and related

radioactive minerals during exploration and mining (both surface and underground), including mine development, production and decommissioning as well as rehabilitation.

On the other hand, the government of Ethiopia issued the Radiation Protection Proclamation No. 571/2008 to protect the risk of damage to health, property and the environment from radiation and radioisotopes generated by radioactive material under only the influence of human intervention. In accordance with this proclamation, the Ethiopian Radiation Protection Authority (ERPA) was established with powers and duties to issue, renew, suspend and revoke licences to perform any of the activities related to the mining of radioactive materials. Nevertheless, both administrative and technical regulatory requirements specific to the uranium production cycle (exploration, development, production and remediation) have not yet been developed.

Since the Ethiopian government has been encouraging domestic uranium exploration and many companies are interested in participating in uranium resource investment, the general legislation so far established likely needs to be augmented by specific uranium-related regulation and standards owing to the radioactive nature of uranium and its ores and the potential creation of hazards caused during exploration, mine development and production. In these respects, relevant regulations related to mining, environmental protection, occupational health and safety and radiation protection should be developed and put into action.

**Uranium exploration and development expenditures and drilling effort – domestic**

(ETB [Ethiopian birr])

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | | | | |
| Government exploration expenditures | 208 341 | - | | 250 000 |
| Industry* development expenditures | | | | |
| Government development expenditures | | | | |
| Total expenditures | 208 341 | - | | 250 000 |
| Industry* exploration drilling (m) | | | | |
| Industry* exploration holes drilled | | | | |
| Government exploration drilling (m) | | | | |
| Government exploration holes drilled | | | | |
| Industry* development drilling (m) | | | | |
| Industry* development holes drilled | | | | |
| Government development drilling (m) | | | | |
| Government development holes drilled | | | | |
| Subtotal exploration drilling (m) | | | | |
| Subtotal exploration holes drilled | | | | |
| Subtotal development drilling (m) | | | | |
| Subtotal development holes drilled | | | | |
| Total drilling (m) | | | | |
| Total number of holes drilled | | | | |

* Non-government.

# Finland

## Uranium exploration and mine development

### *Historical review*

Uranium exploration was carried out in Finland from 1955 to 1989, first by several organisations but from the late-1970s mainly by the Geological Survey. Since beginning in the early-1970s, regional aero-geophysical and geochemical mapping programmes have played an important role in uranium exploration. The 2007 edition of the Red Book contains additional information on the history of uranium exploration in Finland.

### *Recent and ongoing uranium exploration and mine development activities*

Accepted by the parliament on 15 March 2011, a new Mining Act, with amendments to the Nuclear Act at the same time, superseding the Mining Act of 1965. The Mining Act of 2011 and amendments to Nuclear Act entered into force on 1 July 2011.

The delay in the handling of all applications for exploration and mining licences at the Ministry of Employment and the Economy (MEE) continued through 2009 and 2010, partly as a consequence of increased exploration and mining activity in the country.

The number of exploration licences for uranium was reduced from 1 claim reservation, 18 claim applications (pending), and 2 accepted claims (1 in force) in early 2009 to 1 claim reservation, 6 claim applications (pending) and 4 accepted claims (3 in force) in late 2010. The number of companies involved decreased from four to two. The pending claim applications were filed in 2007, 2008 and 2009, with three additional applications for one of the target areas in 2010. The uranium exploration licences are subject to more extensive hearings than those for other commodities. The licensing procedure for uranium claim decisions by the MEE in 2009 and 2010 took two to three years.

Only minor field activities were carried out by the companies in 2009. Namura Finland relinquished uranium exploration in Finland and cancelled all its licences and applications at the end of 2009. AREVA NC decided to run down its subsidiary AREVA Resources Finland (ARF) and sold the Finnish uranium exploration portfolio and a database to Vancouver-based Mawson Resources Ltd in April 2010 but became a significant Mawson shareholder (11%). For the moment, Mawson Energi AB, the Swedish subsidiary of Mawson Resources Ltd, is the only active uranium exploration company in Finland. A Finnish junior company, Karelian Resource Services was granted three claims in 2009 but gave up two of these claims in 2010, retaining the third which is not yet in force because of court appeals.

Discovered by ARF in 2008, the Rompas Au-U prospect at Ylitornio, northern Finland, is the main target of Mawson Energi. Structurally-hosted hydrothermal style gold and uranium mineralisations occur in Paleoproterozoic rocks in an area exceeding 6 km by 200 m. Native gold and uraninite are identified generally at limonitic fractures within metavolcanic host rocks. Following the transaction of AREVA's properties, Mawson determined Rompas as its key project, launching a field campaign including geological mapping and geochemical sampling, followed by airborne geophysics in 2010. The Rompas prospect is secured by exploration licence applications; diamond drilling and

trenching however will not be permitted until the licences are in force. In addition, Mawson registered new claim reservations east and west of the Rompas prospect that are valid until May 2011. Mawson also holds two claims on previously known targets of Paleoproterozoic uraniferous phosphorites, expiring in 2012 and 2013, and one claim (Riutta, expiring in 2011) with pitchblende veins close to the Paleoproterozoic/Archean unconformity, drilled by ARF.

Operated by Talvivaara Mining Company Plc., the Talvivaara Ni-Zn-Cu-Co mine in Sotkamo, eastern Finland, is one of the largest sulphide nickel deposits in Europe. The company applies bioheapleaching to extract the metals from black schist-hosted ore. Although the average uranium grade is very low (0.0017%), the pregnant leach solution contains 15 to 25 mg/l U, sufficient for exploitation. Talvivaara released its plans to build a solvent extraction circuit for by-product recovery of uranium in February 2010. Annual uranium production is expected to be 350 tU. Proceeding with construction and operation of the uranium circuit requires a number of permits from the regulators. Planning, environmental impact assessment (EIA) and licensing have been ongoing since early 2010. The EIA procedure was completed in March 2011.

Cameco Corporation is providing technical assistance to Talvivaara in the design, construction, commissioning and operation of the uranium extraction circuit. Talvivaara and Cameco signed a uranium off-take agreement in February 2011 which will be in effect until 2027.

## 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 and other materials*

Finland has previously reported unconventional resources in Paleoproterozoic black schist and phosphorite in a Paleozoic carbonatite.

The Talvivaara open-cut Ni-Zn-Cu-Co mine in eastern Finland began production in 2008. The metals are extracted by bioheapleaching from black schist-hosted ore. Updated in October 2010, the total resources amount to 1 550 Mt with 1 121 Mt in measured and indicated categories at average metal contents (nickel cut off 0.07%) 0.23% Ni, 0.50% Zn, 0.13% Cu and 0.02% Co. The estimated lifetime of the mine is 46 years.

Since the IUREP mission's first estimate 30 years ago, Finland has reported Talvivaara as a potential unconventional resource in the Red Book. According to the recent update, the ore contains 0.0017% U on average, and the calculated total uranium content (*in situ*) in the two Talvivaara deposits Kuusilampi and Kolmisoppi is now given as 20 000 tU (measured and indicated resources) to 26 000 tU (including inferred resources).

Another potential by-product uranium target is the Sokli carbonatite in northern Finland, presently under development by Yara International for the beneficiation of the regolith phosphate ore on top of the magmatic carbonatite. In the hardrock carbonatite, uranpyrochlore occurs in specific zones which at a grade of 0.01% U have been evaluated to contain 2 500 tU.

Finland reported previously 2 900 tU of reasonably assured conventional resources in the cost range USD 130 or more/kgU, included in several deposits. This cost category was

not used in the Red Book for some time and these resources were excluded from the estimates. Extensions of national parks, mine closure and other such reasons still exclude most of these resources from being classified as mineable deposits. Presently, Mawson Energi holds exploration licences on two previous discoveries, of which the Nuottijärvi deposit with its historic resource of 1 000 tU can be reported in the cost category USD 130-260/kgU. Because the ore is of low-grade uraniferous phosphorite, this deposit is classified as an unconventional resource.

## Uranium production

### *Historical review*

Uranium production in Finland has been confined only to the now restored Paukkajanvaara mine that operated as a pilot plant between 1958 and 1961. A total of 40 000 t of ore was hoisted, and the concentrates produced amounted to about 30 tU. As listed in the Red Book retrospective, the total historical production calculated from the mining register statistics is no more than 41 tU from 1958 to 1961.

**Uranium production centre technical details**

(as of 1 January 2011)

| | Centre #1 |
|---|---|
| Name of production centre | Talvivaara |
| Production centre classification | Planned |
| Date of first production (year) | 2012 |
| Source of ore: | |
| Deposit name(s) | Kuusilampi |
| Deposit type(s) | Black schist |
| Recoverable resources (tU) | 8 700* |
| Grade (% U) | 0.0017 |
| Mining operation: | |
| Type (OP/UG/ISL) | OP |
| Size (tonnes ore/day) | NA |
| Average mining recovery (%) | NA |
| Processing plant: | |
| Acid/alkaline | Acid |
| Type (IX/SX) | SX |
| Size (tonnes ore/day);<br>for ISL (mega or kilolitre/day or litre/hour, specify) | NA |
| Average process recovery (%) | NA |
| Nominal production capacity (tU/year) | 350 |
| Plans for expansion (yes/no) | Yes |
| Other remarks | Heap leaching by-product |

* Overall recovery factor 65% (by-product) used in the estimate.

### *Future production centres*

The Talvivaara Mining Company released its plans for by-product recovery of uranium in February 2010. The company applies bioheapleaching to extract metals from the black schist-hosted ore. Uranium dissolves in the pregnant leach solution along with base metals, ending up partly in the Ni-Co sulphide concentrate and partly in the waste gypsum tailings.

As an impurity in the Ni-Co sulphide product, uranium disturbs the processes at the Norilsk Nickel Harjavalta refinery (in SW Finland) which is presently licensed by the Radiation and Nuclear Safety Authority to extract uranium up to a limit of 10 tU/a.

The company is planning to build a solvent extraction circuit for uranium recovery at the Talvivaara mill in Sotkamo, with expected annual production of 350 tU. Planning, EIA and licensing have been ongoing since early 2010. If the licensing and construction proceed as the company expects, production could start as early as 2012.

## Secondary sources of uranium

Finland does not produce or use mixed oxide fuels. Re-enriched tails were not used in 2009 and 2010.

## Environmental activities and socio-cultural issues

Mine developments with environmental impact assessments (EIA) relating to uranium have been carried out at the Sokli phosphate project and at the Talvivaara nickel mine. The EIA report on by-product uranium extraction at Talvivaara was released in December 2010 and a radiological baseline study is underway.

The development of the Sokli phosphate deposit in northern Finland by Yara International ASA is at the mining licence application stage. The phosphate ore is a soft regolith lying on top of a Paleozoic hardrock magmatic carbonatite. The phosphate ore contains niobium, thorium and uranium derived from the primary pyrochlore mineral in the carbonatite, and hence the mining would be regulated under the Radiation Act and supervised by the Radiation and Nuclear Safety Authority. In the EIA procedure, finished in 2009, the radioactive impacts of phosphate, iron and niobium production have been described, and a radiological base line study was compiled in 2010. There is potential for by-product uranium extraction from the phosphate and niobium ores although no plans for this have been presented at this stage. Yara's new policy for strengthening the option of transporting the phosphate ore some 50 km across the Finnish border to the Kovdor mill in the Russian Federation requires supplements to the existing EIA reports.

The construction of the EPR unit Olkiluoto 3, the political decisions on new power plants, disposal of spent fuel, uranium exploration, the planned by-product extraction of uranium at the Talvivaara nickel mine and the renewal of the Mining Act have sustained an extensive dialogue on nuclear power and uranium production cycle at all levels of society since 2008.

## Uranium requirements

At the beginning of 2011, four reactors were in operation: Olkiluoto 1 and 2, owned by the Finnish private utility TVO (Teollisuuden Voima Oyj) and Loviisa 1 and 2, owned by Fortum Power and Heat Oy (the former IVO). The installed capacity totals about 2.7 GWe net. Uranium requirements are 460 tU/year for the four reactors.

In October 2003, TVO selected Olkiluoto as the location of the new unit and the consortium Framatome ANP-Siemens, now AREVA, was selected as the main supplier. The construction licence for Olkiluoto 3 pressurised water reactor (type EPR, European

pressurised water reactor) was granted in 2005. The reactor's thermal output is 4 300 MW and electric output about 1 600 MW. The construction of the plant has been delayed by approximately four years. The new unit is planned to start commercial operation in 2013. The uranium requirements for this new unit will range from 200 to 300 tU/year.

In May 2010, the government approved two decisions-in-principle for the construction of additional NPPs. The approved applications were filed by TVO and Fennovoima Oy. An application by Fortum was rejected.

On 1 July 2010, the Finnish parliament ratified decisions-in-principle for the construction of a new power plant, Olkiluoto 4 (TVO) and Fennovoima's application to construct a new NPP in either Simo or Pyhäjoki.

Construction licences and the operating licences submitted in due course will be considered by the government. Such consideration will include the broad-based comment and hearing procedure required under law. At the earliest, the new plants will be ready for commissioning around 2020.

### *Supply and procurement strategy*

TVO procures natural uranium, enrichment services and fuel fabrication from several countries. Fortum Power and Heat Oy purchases fuel assemblies from the Russian Federation and until now, all the uranium.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

Licences for mining, enrichment, possession, fabrication, production, transfer, handling, use and transport of nuclear materials and nuclear wastes may be granted only to natural persons, corporations or authorities under the jurisdiction of a member state of the European Union. However, under special circumstances, foreign organisations or authorities may be granted a licence to transport nuclear material or nuclear waste within Finland. No significant changes to Finnish uranium policy are reported.

*Legislation*

EIA procedure is applied to all uranium mining projects, without any limitations on the annual amount of the extracted resource or on the area of an opencast mine.

In addition to the licensing based on the Mining Act and on other legislation (environmental protection, nature conservation, protection of wilderness reserves, land use and building, occupational safety and health, radiation), production of uranium or thorium also needs a licence from the government according to the Nuclear Energy Act.

The Ministry of Employment and the Economy promotes the use of mineral resources by securing a favourable operating environment for mineral exploration and mining activities. The Ministry has been responsible for the revision of the mining legislation in recent years. The new Mining Act was accepted by the parliament on 15 March 2011, to enter into force on 1 July 2011. An amendment of the Nuclear Energy Act was included.

While securing the preconditions for mining and exploration, the Mining Act of 2011 takes account of environmental issues, citizens' fundamental rights, landowners' rights and municipalities' opportunities to influence decision-making. One of the changes is that the duties of the mining authority are transferred from the ministry to a lower administrative level, the Safety Technology Authority (Tukes). Responsible for granting permits and supervising compliance with legislation, this new mining authority office of Tukes will be based at Rovaniemi, northern Finland.

In the Mining Act of 2011, exploration licence is required for uranium exploration (e.g. drilling, trenching). Permit applications concerning a uranium mine under the Mining Act and 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 project activities are aligned with the overall interests of the society, the municipality in question has given its consent, and safety requirements are being complied with.

*Nuclear waste management*

The Finnish nuclear waste management is guided by the Nuclear Energy Act and Decree. All nuclear waste generated in Finland must be handled, stored and permanently disposed of in Finland. The act also prohibits the import of nuclear waste. Responsibility for nuclear waste remains with the power companies until its final disposal. Contributions are being accumulated annually in the State Nuclear Waste Management Fund by the companies. These fund contributions also cover the decommissioning of the plants. The low- and intermediate-level waste repositories are in operation both at Loviisa (Fortum) and Olkiluoto (TVO) sites at the depth of 60-100 m in bedrock.

The spent fuel of the NPP units of Fortum and TVO will be packed in copper canisters and disposed of in the bedrock of Olkiluoto by Posiva Oy, a company owned by these power companies. An underground rock characterisation facility (ONKALO) is under construction at Olkiluoto. The construction of ONKALO started in 2004 and the access tunnel reached the planned final disposal depth 420 m in 2010.

On 1 July 2010, together with the decisions on two new reactor units, the Finnish parliament approved a separate DIP for an extended final disposal repository for spent nuclear fuel in Olkiluoto. This extension will enable Posiva to dispose of the spent fuel also from the new Olkiluoto 4 unit of TVO.

Posiva is preparing to submit an application for the construction licence in 2012. Construction of the encapsulation plant and geologic repository is expected to commence in 2015. The disposal operations are planned to start in 2020.

The DIP approved for the new NPP of Fennovoima is conditional. Upon submitting its construction licence application, Fennovoima must also provide a detailed report on its plans for nuclear waste management. Furthermore, the company must develop its plan for the final disposal of spent nuclear fuel. Within six years, Fennovoima is obliged to present the Ministry of Employment and the Economy with either an agreement on a nuclear waste disposal partnership with TVO and Fortum (Posiva), or, under the Environmental Impact Assessment Act, its own environmental assessment programme on the final disposal repository for nuclear waste.

### *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)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 1 575 000 | 360 000 | 1 820 000 | NA |
| Government exploration expenditures | 0 | 0 | 0 | 0 |
| Industry* development expenditures | 0 | 0 | 100 000 | 0 |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 1 575 000 | 360 000 | 1 920 000 | NA |
| Industry* exploration drilling (m) | 1 060 | 0 | 0 | 0 |
| Industry* exploration holes drilled | 10 | 0 | 0 | 0 |
| Government exploration drilling (m) | 0 | 0 | 0 | 0 |
| Government exploration holes drilled | 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) | 1 060 | 0 | 0 | 0 |
| Subtotal exploration holes drilled | 10 | 0 | 0 | 0 |
| Subtotal development drilling (m) | 0 | 0 | 0 | 0 |
| Subtotal development holes drilled | 0 | 0 | 0 | 0 |
| Total drilling (m) | 1 060 | 0 | 0 | 0 |
| Total holes drilled | 10 | 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 |
|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 500 | 500 |
| Intrusive | 0 | 0 | 1 000 | 1 000 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 1 500 | 1 500 |

* 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.

### Reasonably assured conventional resources by production method

(tonnes U)

| Production method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Underground mining (UG) | 0 | 0 | 500 | 500 | *In situ* |
| Open-pit mining (OP) | 0 | 0 | 1 000 | 1 000 | *In situ* |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | 0 |
| *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 | 0 | 0 | 1 500 | 1 500 | *In situ* |

### Reasonably assured conventional resources by processing method

(tonnes U)

| Processing method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Conventional from UG | 0 | 0 | 500 | 500 | *In situ* |
| Conventional from OP | 0 | 0 | 1 000 | 1 000 | *In situ* |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | 0 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | 0 |
| Unspecified | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 1 500 | 1 500 | *In situ* |

* 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 concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 30 | 0 | 0 | 0 | 30 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 30 | 0 | 0 | 0 | 30 | 0 |

* 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.

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining* | 15 | 0 | 0 | 0 | 15 | 0 |
| Underground mining* | 15 | 0 | 0 | 0 | 15 | 0 |
| *In situ* leaching | 0 | 0 | 0 | 0 | 0 | 0 |
| Co-product/by-product | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 30 | 0 | 0 | 0 | 30 | 0 |

* Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 30 | 0 | 0 | 0 | 30 | 0 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** | 0 | 0 | 0 | 0 | 0 | 0 |
| U recovered from phosphates | 0 | 0 | 0 | 0 | 0 | 0 |
| Other methods*** | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 30 | 0 | 0 | 0 | 30 | 0 |

* Also known as stope leaching or block leaching.

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

*** Includes mine water treatment and environmental restoration.

### Short-term production capability

(tonnes U/year)

| 2011 | | | | 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 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 350* | 0 | 0 | 0 | 350* |

| 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 | 350* | 0 | 0 | 0 | 350* | 0 | 0 | 0 | 350* |

* By-product of nickel production.

### Re-enriched tails production and use

(tonnes natural U equivalent)

| Re-enriched tails | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Production | 0 | 0 | 0 | 0 | 0 | 0 |
| Use | 843 | 0 | 0 | 0 | 843 | 0 |

**Net nuclear electricity generation**

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 22.7 | 21.9 |

**Installed nuclear generating capacity to 2035**

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 730 | 2 730 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 2 730 | 2 770 | 4 360 | 4 360 | 4 360 | 4 540 | 4 360 | 4 540 | 3 870 | 4 050 | 3 380 | 3 560 |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 640 | 457 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | NA | NA | 700 | 760 | 700 | 760 | 700 | 760 | 520 | 560 | 520 | 560 |

# 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.

During 2009 and 2010 AREVA and its subsidiaries have been active abroad, focusing on targets aimed at the discovery of exploitable resources in Australia, Canada, the Central Africa Republic, Finland, Gabon, Jordan, Kazakhstan, Mongolia, Namibia, Niger and South Africa. In Canada, Namibia, Niger and Kazakhstan, AREVA is involved in uranium mining operations and other related projects. In addition, without being the project operator, it holds shares in several mining operations and research projects in different countries.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

The last uranium mine (Le Bernardan) was closed in 2001. However, known resources on French territory were reassessed in 2009. This reassessment produced new figures of 11 451 tU RAR and 139 tU inferred, all recoverable at costs >USD 130/kgU, of which 9 000 tU are recoverable by open-pit mining.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

No systematic appraisal is made of undiscovered resources.

## Uranium production

### *Status of production capability*

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 Malvesi refinery, where the uranium is recovered.

### *Future production centres*

There are no plans to develop new production centres in the near future.

## Secondary sources of uranium

### *Production and/or use of mixed oxide fuels*

The annual licensed production capacity of MOX fuel in France is about 195 tHM, roughly corresponding to 1 560 tU equivalent 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 (for a total of about 120 t yearly or 960 tNatU equivalent) and the remainder is delivered abroad under long-term contract arrangements.

### *Production and/or use of re-enriched tails*

Until 2009, a fraction of the depleted $UF_6$ flow generated through enrichment activities was sent to the Russian Federation for re-enrichment. This fraction was limited to materials with mining origins that would allow their transfer (in accordance with international and bilateral agreements dealing with the exchange of nuclear materials). The return flow was exclusively used to over-feed the enrichment plant in France (the Georges Besse gaseous diffusion plant run by EURODIF, an AREVA subsidiary).

In addition, in 2008 and 2009, a few thousand tonnes of depleted uranium were removed from storage, converted to $UF_6$ and enriched to natural uranium grade at the Georges Besse gaseous diffusion plant, thanks to the then prevailing economic conditions (primarily high uranium spot prices).

### *Production and/or utilisation of reprocessed uranium*

Production of reprocessed uranium in France results from the activity of the la Hague reprocessing plant. The annual production from Électricité de France (EDF) spent fuel is around 1 000 tU. In France since 2010, around 600 tNatU equivalent are recycled every year in four reactors (EDF reactors at the Cruas power plant).

## Uranium requirements

The total number of nuclear power reactors is expected to increase slightly with the addition of one 1 600 MWe EPR expected to be put into operation at Flamanville in 2016, and possibly a second EPR at Penly before 2020. Nonetheless, uranium requirements should not change significantly since no reactors are expected to be shut down in the near future.

### *Supply and procurement strategy*

Since France is a net importer of uranium, its policy towards procurement is one of supply diversification. French operators 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 operators have shareholdings or from mines operated by third parties.

## Uranium stocks

EDF possesses strategic uranium inventories, the minimum level of which has been fixed at the equivalent of three 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)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 56 | 55 | 50 | NA |
| Government exploration expenditures | | | | |
| Industry* development expenditures | NA | NA | NA | NA |
| Government development expenditures | | | | |
| 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | | | | | |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | | | | |
| Metasomatite | | | | | |
| Other* | | | | | |
| Total | | | | 11 451 | |

* 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.

### 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) | | | | | |
| Open-pit mining (OP) | | | | 9 000 | |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| Co-product and by-product | | | | | |
| Unspecified | | | | 2 451 | |
| Total | | | | 11 451 | |

### 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 | | | | | |
| Conventional from OP | | | | 9 000 | |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| In-place leaching* | | | | | |
| Heap leaching** from UG | | | | | |
| Heap leaching** from OP | | | | | |
| Unspecified | | | | 2 451 | |
| Total | | | | 11 451 | |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | | | | | |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | | | | |
| Metasomatite | | | | | |
| Other* | | | | | |
| Total | | | | 139 | |

* 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.

### 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) | | | | | |
| Open-pit mining (OP) | | | | | |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| Co-product and by-product | | | | | |
| Unspecified | | | | 139 | |
| Total | | | | 139 | |

### 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 | | | | | |
| Conventional from OP | | | | | |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| In-place leaching* | | | | | |
| Heap leaching** from UG | | | | | |
| Heap leaching** from OP | | | | | |
| Unspecified | | | | 139 | |
| Total | | | | 139 | |

* 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 concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | | 0 | 0 | 0 | | 0 |
| Sandstone | | 0 | 0 | 0 | | 0 |
| Hematite breccia complex | | 0 | 0 | 0 | | 0 |
| Quartz-pebble conglomerate | | 0 | 0 | 0 | | 0 |
| Vein | | 0 | 0 | 0 | | 0 |
| Intrusive | | 0 | 0 | 0 | | 0 |
| Volcanic and caldera-related | | 0 | 0 | 0 | | 0 |
| Metasomatite | | 0 | 0 | 0 | | 0 |
| Other* | | 5 | 8 | 9 | | 0 |
| Total | 75 965 | 5 | 8 | 9 | 75 987 | 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.

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | | 0 | 0 | 0 | | 0 |
| Underground mining[1] | | 0 | 0 | 0 | | 0 |
| *In situ* leaching | | 0 | 0 | 0 | | 0 |
| Co-product/by-product | | 5 | 8 | 9 | | 0 |
| Total | 75 965 | 5 | 8 | 9 | 75 987 | NA |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | | 0 | 0 | 0 | | 0 |
| In-place leaching* | | 0 | 0 | 0 | | 0 |
| Heap leaching** | | 0 | 0 | 0 | | 0 |
| U recovered from phosphate rocks | | 0 | 0 | 0 | | 0 |
| Other methods*** | | 5 | 8 | 9 | | 0 |
| Total | 75 965 | 5 | 8 | 9 | 75 987 | 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.

*** 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Production | 13 030 | 1 008 | 1 560 | 1 560 | 17 158 | 1 560 |
| Use | NA | 800 | 800 | 880 | NA | 960 |
| Number of commercial reactors using MOX | | 20 | 20 | 21 | | 22 |

### Reprocessed uranium production and use

(tonnes natural U equivalent)

| Reprocessed uranium | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Production | 12 200 | 800 | 800 | 1 000 | 14 800 | 1 000 |
| Use | 2 300 | 300 | 300 | 600 | 3 500 | 600 |

### Net nuclear electricity generation

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 390 | 407.9 |

**Installed nuclear generating capacity to 2035**

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 130 | 63 130 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 63 130 | 63 130 | 63 130 | 63 130 | 64 690 | 65 210 | NA | NA | NA | NA | NA | NA |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 000 | 8 000 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 8 000 | 8 000 | 7 500 | 8 500 | 7 500 | 8 500 | NA | NA | NA | NA | NA | NA |

# Germany

## Uranium exploration and mine development

### *Historical review*

Exploration for uranium in Germany occurred in the two separate countries prior to reunification in 1990. In the former German Democratic Republic (GDR), uranium exploration and mining began in 1946 and by the end of the 1950s was concentrated in eastern Thuringia. Uranium exploration using a variety of ground-based and aerial techniques was undertaken over an extensive area of about 55 000 $km^2$.

Uranium exploration in the Federal Republic of Germany began in 1956. An initial phase including hydrogeochemical surveys, car borne surveys, field surveys, and, to a lesser extent, airborne prospecting. Was followed by geochemical stream sediment surveys, radon surveys, and detailed radiometric work, including drilling and trenching in promising areas. Although both federal and state geological surveys were involved, the work was carried out mainly by industrial companies.

There have been no exploration activities in Germany since the end of 1990. Several German mining companies continued exploration abroad, mainly in Canada, but these activities came to an end in 1997. The 2007 edition of the Red Book provides additional historical information on uranium exploration in Germany.

### *Recent and ongoing uranium exploration and mine development activities*

There are no current exploration activities in Germany.

## 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 which 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.

## Uranium production

### *Historical review*

A total of over 200 000 tU was produced in the GDR between 1950 and 1989. A plant at Crossen in Saxony, with a maximum capacity of 2.5 million tonnes of ore per year, began operations in 1950. It was permanently closed on 31 December 1989. A second plant at Seelingstadt, Thuringia, with a maximum capacity of 4.6 million tonnes of ore per year, began operations in 1960. After 1989, Seelingstadt's operations were limited to the treatment of slurry produced at the Königstein mine.

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. The 2007 edition of the Red Book provides additional historical information on uranium production in Germany.

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

There is no commercial production of uranium in Germany. Decommissioning of the German production facilities started in 1989 (former Federal Republic of Germany) and 1990 (former German Democratic Republic). Since 1991 and 2010, uranium recovery from mine water treatment and environmental restoration totalled 2 439 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 German Democratic Republic 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 of the production facilities and remediation activities. 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 1 835 (2006) to 1 489 (2010).

### *Future production centres*

None reported.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

According to the energy concept 2010, the federal government decided to phase-out use of nuclear power for commercial electricity generation at the earliest possible time – on a staggered schedule. However, in the aftermath of the accident at the Fukushima NPP the German Bundestag (parliament) passed on 30 June 2011 the Thirteenth Act amending the Atomic Energy Act (*Dreizehntes Gesetz zur Änderung des Atomgesetzes*) accelerating the planned phase-out. This amendment to the Atomic Energy Act entered into force on 6 August 2011.

Germany plans to phase out nuclear power use for commercial electricity generation gradually and completely by no later than the end of 2022. The country's seven oldest NPPs, which had already been shut down during a provisional three-month period immediately after the Fukushima accident, as well as the Krümmel NPP, are now permanently shut down. The final dates for end of operations of the other NPPs are as follows: 2015, Grafenrheinfeld; 2017, Gundremmingen B; 2019, Philippsburg 2; 2021, Grohnde, Gundremmingen C and Brokdorf; and 2022, the three youngest nuclear power stations, Isar 2, Emsland and Neckarwestheim 2.

**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 (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | | | | | |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | | | | |
| Metasomatite | | | | | |
| Other* | | | | | |
| Total | | | | | |

* 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.

**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 | 0 | 0 | |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 3 000 | |
| Total | 0 | 0 | 0 | 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 (%) |
|---|---|---|---|---|---|
| Conventional from UG | 0 | 0 | 0 | 0 | |
| Conventional from OP | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Heap leaching**from OP | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 3 000 | |
| Total | 0 | 0 | 0 | 3 000 | |

* 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 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 | 0 | 0 | |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 4 000 | |
| Total | 0 | 0 | 0 | 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 (%) |
|---|---|---|---|---|---|
| Conventional from UG | 0 | 0 | 0 | 0 | |
| Conventional from OP | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 4 000 | |
| Total | 0 | 0 | 0 | 4 000 | |

* 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 concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | | | | | | |
| Sandstone | | | | | | |
| Hematite breccia complex | | | | | | |
| Quartz-pebble conglomerate | | | | | | |
| Vein | | | | | | |
| Intrusive | | | | | | |
| Volcanic and caldera-related | | | | | | |
| Metasomatite | | | | | | |
| Other* | | | | | | |
| Total | | | | | | |

* 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.

## Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | NA | 0 | 0 | 0 | NA | 0 |
| Underground mining[1] | NA | 0 | 0 | 0 | NA | 0 |
| *In situ* leaching | 0 | 0 | 0 | 0 | 0 | 0 |
| Co-product/by-product | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 0 | 0 | 0 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | NA | 0 | 0 | 0 | NA | 0 |
| In-place leaching* | NA | 0 | 0 | 0 | NA | 0 |
| Heap leaching** | NA | 0 | 0 | 0 | NA | 0 |
| U recovered from phosphate rocks | 0 | 0 | 0 | 0 | 0 | 0 |
| Other methods*** | 2 341 | 0 | 0 | 8 | 2 439 | 80 |
| Total | 219 517 | 0 | 0 | 8 | 219 525 | 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.

*** Includes mine water treatment and environmental restoration.

## Prognosticated conventional resources

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 80/kgU | <USD 130/kgU | <USD 260/kgU |
| 0 | 0 | 0 |

### Speculative conventional resources

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 130/kgU | <USD 260/kgU | Unassigned |
| 0 | 0 | 74 000 |

### Ownership of uranium production in 2010

| Domestic | | | | Foreign | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | | |
| (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) |
| 7.5 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 7.5 | 100 |

### Uranium industry employment at existing production centres

(person-years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 1 770 | 1 638 | 1 489 | 1 452 |
| Employment directly related to uranium production | NA | NA | NA | NA |

### Mixed oxide fuel production and use

(tonnes natural U equivalent)

| Mixed oxide (MOX) fuel | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Production | 0 | | | | | |
| Use | 6 070 | 250 | 210 | 100 | 6 630 | 100 |
| Number of commercial reactors using MOX | | 4 | 5 | 3 | | 2 |

### Re-enriched tails production and use

(tonnes natural U equivalent)

| Re-enriched tails | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Production | NA | NA | NA | NA | NA | NA |
| Use | 0 | 0 | 0 | 0 | 0 | 0 |

### Reprocessed uranium use

(tonnes natural U equivalent)

| Reprocessed uranium | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Production | NA | NA | 0 | 0 | 0 | 0 |
| Use | NA | 950 | NA | NA | NA | NA |

**Net nuclear electricity generation**

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 128 | 133 |

**Installed nuclear generating capacity to 2035**

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 500 | 20 500 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 12 100 | 12 100 | 10 800 | 10 800 | 8 100 | 8 100 | 0 | 0 | 0 | 0 | 0 | 0 |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 400 | 2 800 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | NA | NA | NA | NA | NA | NA | 0 | 0 | 0 | 0 | 0 | 900 |

**Total uranium stocks**

(tonnes natural U-equivalent)

| Holder | Natural uranium stocks in concentrates | Enriched uranium stocks | Enrichment tails | LWR reprocessed uranium stocks | Total |
|---|---|---|---|---|---|
| Government | NA | NA | NA | NA | NA |
| Producer | NA | NA | NA | NA | NA |
| Utility | NA | NA | NA | NA | NA |
| Total | NA | NA | NA | NA | NA |

# Greenland

## Uranium exploration and mine development

### *Historical review*

From 1955 to 1984, uranium exploration activities were undertaken in south, east and west Greenland, including exploration of the Kvanefjeld U-Th deposit in south Greenland, a large rare earth element (REE) deposit associated with alkaline intrusive rocks.

Additional activities in south Greenland included a regional exploration programme during the 1979-1986 period. Three prospects were found: *i)* uraninite in mineralised fractures and veins; *ii)* uranium rich pyrochlore mineralisation in alkaline rocks; and, *iii)* uraninite in hydrothermally mineralised metasediments.

In east Greenland, additional exploration activities were undertaken between 1972 and 1977. The exploration programme concluded with no major discovery. Reconnaissance airborne gamma spectrometry with ground follow-up performed in west Greenland also resulted in no major discovery.

In 1995, a stream sediment survey including analysis for uranium and thorium, with scintillometer readings, covered 7 000 $km^2$ in north-west Greenland, but no prospects were recorded.

### *Recent and ongoing uranium exploration and mine development activities*

Uranium exploration is no longer permitted in Greenland. Companies which have found and demarcated mineral resources containing radioactive elements can however apply for a licence to prepare assessments of the environmental impact and social sustainability to better inform government.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

An inferred resource has been determined at the Kvanefjeld REE-deposit in south Greenland. As the REE resource has been re-evaluated, so too has the uranium resource. The complex composition and processing of the ore mean that the resource is best placed in the high cost category (<260 USD/kg U). The deposit is of 619 Mt ore at a cut-off grade of 260 ppm $U_3O_8$, (0.022%U) equivalent to an inferred uranium resource of 158 757 t $U_3O_8$ (134 654 tU).

### *Undiscovered conventional resources (prognosticated and speculative resources)*

Unknown.

### *Unconventional resources and other materials*

Unknown.

## Uranium production

No uranium has been produced in Greenland.

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

Uranium production is not permitted in Greenland. Licence applications, including assessments of the environmental impact and social sustainability, can be applied for by companies that have demarcated mineral resources containing radioactive elements. This will provide government with increased knowledge of health and safety issues associated with radioactive elements in occurrences where the actual goal is the mining of other metals. A licence to complete such environmental impact assessments, etc., does not give right to a licence to explore for or exploit radioactive elements.

### *Employment in the uranium industry*

None.

### *Future production centres*

No plans.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

In Greenland there is a zero-tolerance policy regarding exploration and exploitation of uranium and other radioactive elements.

An addition to the rules which regulate exploration for mineral resources was made on 9 September 2010. The addition was a clarification of the rules and statutes that companies which have found and demarcated mineral resources containing radioactive elements can apply for a licence to prepare assessments of the environmental impact and social sustainability.

In making this addition to the standard terms, the hope is to increase knowledge about health and safety issues regarding radioactive elements in occurrences where the actual goal is the production of other, non-radioactive metals.

The addition to the rules explicitly states that a licence to complete such environmental impact assessments, etc., does not give right to a licence to explore for or exploit radioactive elements.

**Uranium exploration and development expenditures and drilling effort – domestic**

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 0 | 0 | 0 | 0 |
| Government exploration expenditures | 0 | 0 | 0 | 0 |
| Industry* development expenditures | 0 | 0 | 0 | 0 |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 0 | 0 | 0 | 0 |
| Industry* exploration drilling (m) | 0 | 0 | 0 | 0 |
| Industry* exploration holes drilled | 0 | 0 | 0 | 0 |
| Government exploration drilling (m) | 0 | 0 | 0 | 0 |
| Government exploration holes drilled | 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) | 0 | 0 | 0 | 0 |
| Subtotal exploration holes drilled | 0 | 0 | 0 | 0 |
| Subtotal development drilling (m) | 0 | 0 | 0 | 0 |
| Subtotal development holes drilled | 0 | 0 | 0 | 0 |
| Total drilling (m) | 0 | 0 | 0 | 0 |
| Total number of holes drilled | 0 | 0 | 0 | 0 |

* Non-government.

### Inferred conventional resources by deposit type

(tonnes U)

| Deposit type | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 134 654 | 65 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 134 654 | 65 |

* 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.

### 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 | 0 | 0 | 0 |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | 0 |
| Co-product and by-product | 0 | 0 | 0 | 134 654 | 65 |
| Unspecified | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 134 654 | 65 |

### 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 |

# Hungary

## Uranium exploration and mine development

### *Historical review*

The first reconnaissance for uranium started in 1952 when, with participation by the Soviet Union, 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, leading to the discovery of the Mecsek deposit in 1954.

### *Recent and ongoing uranium exploration and mine development activities*

Since 2006, there are four uranium ore exploration project areas covered by seven exploration licences. The 2009 edition of the Red Book contains an overview of the technical details of these exploration programmes.

In 2009-2010, a total of five holes were drilled, logged and core samples were tested on non-mined portions of the Mecsek deposit in the Mecsek exploration project area.

## Uranium resources

Hungary's reported uranium resources are limited to those of the Mecsek deposit.

This ore deposit 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 occurs in the upper 200 m of the unit. It 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)*

Parallel the recent Mecsek exploration programme, resources were re-estimated and recategorised in 2007-2008. As a result, 11 500 tU is now reported as *in situ* high-cost inferred resources.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

Speculative resources are not estimated. Uranium resources classified as prognosticated amount to a total of 12 800 tU recoverable at costs of USD 130-260/kgU. These resources are tributary to the former Mecsek production centre.

## Uranium production

### *Historical review*

The Mecsek underground mine was the only producing mine in Hungary. The complex was in operation between 1956 and 1997. The nominal annual production capacity was about 700 tU. Initially, raw ore was exported to Sillimae metallurgy plant in

Estonia, but with the opening of an ore processing plant in 1963, uranium concentrates were produced on site and shipped to the Soviet Union. Total production from site, including heap leaching, was about 21 000 tU. The 2007 edition of the Red Book provides some additional information on past uranium production.

### *Status of production capability*

Since the closure of the Mecsek mine, uranium has been produced only as a result of water treatment activities, amounting to about 1-6 tU/year.

## Environmental activities and socio-cultural issues

In 1998, after the closure of the mines, stabilisation and remediation work began, following development of a conceptual plan by staff and acceptance by competent authorities in Hungary. The government accepted the financial requirement and determined the time of completion to be the end of 2002. This deadline was modified several times because of financial issues. The final deadline was the end of 2008, when the project finished successfully. The project included:

- closing down underground mines;
- remediating waste rock piles, heap-leaching sites, tailings ponds and contaminated water flows;
- decommissioning the milling plant and open-pit sites.

After the successful remediation programme, the following activities have to be continued:

- operating a monitoring system on the uranium-mining legacy sites;
- treating contaminated water both on the mining and the tailings ponds area.

The legal successor of the former Mecsek mine (as 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 of environmental management**

(HUF thousands [Hungarian forints])

| | Pre-1998 | 1998 to 2008 |
|---|---|---|
| Closing of underground spaces | NA | 2 343 050 |
| Reclamation of surficial establishments and areas | NA | 2 008 403 |
| Reclamation of waste rock piles and their environment | NA | 1 002 062 |
| Reclamation of heap leaching piles and their environment | NA | 1 898 967 |
| Reclamation of tailings ponds and their environment | NA | 8 236 914 |
| Water treatment | NA | 1 578 040 |
| Reconstruction of electric network | NA | 125 918 |
| Reconstruction of water and sewage system | NA | 100 043 |
| Other infrastructural service | NA | 518 002 |
| Other activities including monitoring, staff, etc. | NA | 2 245 217 |
| Total | 5 406 408 | 20 056 615 |

The annual cost of the long-term activity (water treatment, environmental monitoring, maintaining the remediated sites) amounts to HUF 500-700 million.

### Uranium requirements

The Paks NPP generated 15 760.6 GWh of power (gross) in 2010, which represents 42.09% of gross domestic electricity production. Since the date of the first connection to the grid of unit 1 in 1982 to the end of 2010, the total of all electricity generated by the Paks NPP amounts to 351.1 TWh.

As far as the amount of the energy production is concerned, 2010 was an outstanding year since the best ever production result in the history of the power plant was achieved. This was primarily due to the completion of power uprates. The Paks NPP consists of four VVER-440/213 type reactor units, originally designed to produce 1 375 MWth and 440 MWe each. Earlier upgrades of the secondary circuit and turbine increased electrical output to about 470 MWe in each unit, with no change to thermal capacity. Recently an upgrade of the primary side has been completed, increasing nominal power by 8% to 1 485 MWth, resulting in about 500 MWe of power generation by each unit.

A new type of fuel assembly with improved parameters is being introduced at the Paks NPP. The enrichment of the new fuel has been increased and it contains burnable poison (Gd isotope). The increased enrichment enhances the economic efficiency of the fuel cycles, while the application of the burnable poison compensates for the negative effects of the increased enrichment on the safety features of the reactors and the transport and storage devices. This change conforms to a worldwide trend and at Paks the power up-rates of the units made it necessary. In 2010, test operation of 18 assemblies was completed following licensing in 2009. The preliminary use of the test assemblies was necessary for the validation of the reload design computer codes. When the test programme was finished successfully, the Hungarian Atomic Energy Authority issued a licence for the general use of the new fuel. On this basis the first batch of the new fuel assemblies was loaded at unit 4 in 2010. The results of a special inspection programme showed that the behaviour of the fuel assemblies agrees with the preliminary estimates and design requirements. The general use of the new fuel will be phased-in gradually during the next four to five years.

In order to enhance its economic and operational efficiency and to improve its position in the market, Paks NPP began an Economic Efficiency Enhancement Programme (EEP), the principal elements of which are enhancing human resource efficiency, power uprating, optimising maintenance and initiating service life extension. The objectives of EEP were accomplished as planned in 2010.

The Interim Spent Fuel Storage Facility (designed by GEC Alsthom, UK) at the Paks site is a “modular vault dry storage” type spent fuel storage facility, which has been receiving irradiated fuel assemblies from the Paks NPP since 1997. At present, 16 storage modules are ready (each with the capacity of 450 assemblies). The stepwise enlargement of the facility is an ongoing task, with the construction of as many as 33 vaults planned. In 2009, the necessary subsoil stabilisation was carried out and construction of four additional modules began in 2010, with operation of modules 17-20 planned by the end of 2011. The construction of vaults 17-20 is basically being done according to the technical solutions already used in case of vaults 12-16, although minor technical changes for operational and manufacturing reasons were employed that do not affect the environmental impact of the facility. A more significant change however, is the number of spent fuel assemblies stored in the new vaults, which, in turn, is well covered by safety analyses.

On 14 November 2008, Paks NPP submitted its service life extension programme (LEP) licence application to the nuclear regulator, the Hungarian Atomic Energy Authority (HAEA). In the resolution of the Nuclear Safety Directorate of HAEA issued in June 2009, the conditions for implementing the LEP were approved and further actions and tasks

were identified. In accordance with the resolution, preparation for a 20-year service life extension, beyond the original design lifetime of 30 years, continued through 2010.

The nuclear power plant with its shareholder, Hungarian Power Companies Ltd. (MVM Zrt.), established the Lévai Project to carry out tasks to commence the extension of the Paks NPP in accordance with provisions of the resolution of parliament in 2009. Within this project, preparation for the construction of new units, in the form of site activities undertaken in 2010 to obtain an environmental licence, as well as engineering, analysis, legal, communication and financial tasks, have been ongoing.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

Since the shutdown of the Hungarian uranium mining industry in 1997, there are no uranium related policies.

### *Uranium stocks*

The by-product of the water treatment activities ($UO_4.2H_2O$) – until export – is stored in the mine water treatment facility. At the end of 2010 the inventory was 4 512 kg.

### *Uranium prices*

Uranium prices are not available as they are commercially confidential.

**Uranium exploration and development expenditures and drilling effort – domestic**

(HUF millions)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 37.087 | | NA | |
| Government exploration expenditures | | | | |
| Industry* development expenditures | | | | |
| Government development expenditures | | | | |
| Total expenditures | 37.087 | | NA | |
| Industry* exploration drilling (m) | 950 | | 2 422 | |
| Industry* exploration holes drilled | 5 | | 5 | |
| Government exploration drilling (m) | | | | |
| Government exploration holes drilled | | | | |
| Industry* development drilling (m) | | | | |
| Industry* development holes drilled | | | | |
| Government development drilling (m) | | | | |
| Government development holes drilled | | | | |
| Subtotal exploration drilling (m) | 950 | | 2 422 | |
| Subtotal exploration holes drilled | 5 | | 5 | |
| Subtotal development drilling (m) | | | | |
| Subtotal development holes drilled | | | | |
| Total drilling (m) | 950 | | 2 422 | |
| Total number of holes drilled | 5 | | 5 | |

* Non-government.

### Inferred conventional resources by deposit type

(tonnes U)

| Deposit type | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU |
|---|---|---|---|---|
| Unconformity-related | | | | |
| Sandstone | | | | 11 500 |
| Hematite breccia complex | | | | |
| Quartz-pebble conglomerate | | | | |
| Vein | | | | |
| Intrusive | | | | |
| Volcanic and caldera-related | | | | |
| Metasomatite | | | | |
| Other* | | | | |
| Total | | | | 11 500 |

* 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.

### 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) | | | | | |
| Open-pit mining (OP) | | | | | |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| Co-product and by-product | | | | | |
| Unspecified | | | | 11 500 | *In situ* |
| Total | | | | 11 500 | |

### 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 | | | | | |
| Conventional from UG | | | | 11 500 | *In situ* |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| In-place leaching* | | | | | |
| Heap leaching** from OP | | | | | |
| Heap leaching** from UG | | | | | |
| Unspecified | | | | | |
| Total | | | | 11 500 | |

* 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 |
| | | 12 799 |

### Historical uranium production by deposit type

(tonnes U in concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | | | | | | |
| Sandstone | 21 051 | 1 | 1 | 6 | 21 059 | 2 |
| Hematite breccia complex | | | | | | |
| Quartz-pebble conglomerate | | | | | | |
| Vein | | | | | | |
| Intrusive | | | | | | |
| Volcanic and caldera-related | | | | | | |
| Metasomatite | | | | | | |
| Other* | | | | | | |
| Total | 21 051 | 1 | 1 | 6 | 21 059 | 2 |

* 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.

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | | | | | | |
| Underground mining[1] | 21 000 | | | | 21 000 | |
| *In situ* leaching | | | | | | |
| Co-product/by-product | 51 | 1 | 1 | 6 | 59 | 2 |
| Total | 21 051 | 1 | 1 | 6 | 21 059 | 2 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 20 475 | | | | 20 475 | |
| In-place leaching* | | | | | | |
| Heap leaching** | 525 | | | | 525 | |
| U recovered from phosphate rocks | | | | | | |
| Other methods*** | 51 | 1 | 1 | 6 | 59 | 2 |
| Total | 21 051 | 1 | 1 | 6 | 21 059 | 2 |

* 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 2010

| Domestic | | | | Foreign | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | | |
| (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) |
| 6 | 100 | | | | | | | 6 | 100 |

### Net nuclear electricity generation*

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 14.6 | 14.8p |

* *Nuclear Energy Data*, OECD, Paris, 2011.

P = Provisional data.

### Installed nuclear generating capacity to 2035

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 1.86 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 423 | 435 | 435 | 435 | 435 | 435 | 435 | 435 | 435 | 435 | 435 | 435 | 218 | 435 |

### 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 | 5 | | | | 5 |
| Utility | NA | NA | NA | NA | NA |
| Total | 5 | | | | 5 |

# 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 known uranium provinces in the Singhbhum, Jharkhand and Umra-Udaisagar belt in Rajasthan where vein-type mineralisation was already known. Subsequently, investigations were expanded to other geologically favourable areas, based on conceptual models and an integrated exploration approach.

During the early-1990s, a near surface deposit was discovered adjacent to the unconformity contact between basement granites with overlying Proterozoic Srisailam Quartzite at Lambapur in Nalgonda district, Andhra Pradesh. These and others showings were further investigated and by 1996 a number of areas were identified on the basis of favourable geological criteria and promising exploration results. The 2007 edition of the Red Book provides further information on the history of uranium exploration.

### *Recent and ongoing uranium exploration and mine development activities*

In recent years, exploration activities have been concentrated in the following areas:

- Meso-Neo-Proterozoic Cuddapah basin of Andhra Pradesh.
- Meso-Proterozoic Delhi basin of Rajasthan and Haryana.
- Neo-Proterozoic Bhima – Kaladgi basins of Karnataka.
- Cretaceous sedimentary basin of Meghalaya.

*Meso-Neo-Proterozoic Cuddapah basin of Andhra Pradesh*

Three types of uranium mineralisation/deposits – unconformity related, stratabound type and fracture controlled – have been identified in the Cuddapah basin.

- Unconformity related uranium deposits

Exploratory and evaluation drilling in parts of the Chitrial outlier in the Srisailam Sub-basin of the Cuddappah basin have resulted in substantial augmentation of the existing resources, associated with the unconformity between the basement granitoids and overlying Srisailam formation. In the Peddagattu area, evaluation drilling has added additional uranium resources along the unconformity between the basement granite and overlying Srisailam formation.

Geological and geophysical surveys carried out in the Amrabad outlier in the Srisailam sub-basin, further west of Chitrial have indicated the presence of a number of uranium occurrences in the vicinity of the unconformity surface between the basement granite and overlying Cuddappah sediments. These occurrences, confined to the unconformity proximity, further enhance the uranium potential of the Srisailam sub-basin, an area currently under exploration.

- Stratabound uranium deposits

The southern part of the basin holds the largest uranium deposit at Tummallapalle hosted in the Dolostone of the Srisailam Formation of the Papaghni Group. Evaluation drilling has added additional uranium resources. The 160 km long belt extending from Reddipalle in the north to Maddinadugu in the south-east has significant potential to yield substantial uranium resources.

- Fracture controlled uranium mineralisation

The Gulcheru quartzite overlying the basement granitoids in the southern parts of Cuddappah basin, is highly deformed, intensely fractured, faulted and intruded by east-west trending basic dykes. Uranium mineralisation associated with the quartz-chlorite-breccia occurs all along the contact between the Gulcheru quartzite and the basic dykes both in the northern and southern contacts, which are being explored in the Gandi-Madyalabodu area.

*Meso-Proterozoic Delhi basin*

The Meso-Proterozoic Delhi Group of metasediments in parts of Rajasthan and Haryana holds potential for metasomatic and unconformity type uranium mineralisation. The potential of the Malani Igneous province spreading over 55 000$^2$ km, comprising predominantly acid volcanics, as a source and host for uranium mineralisation has since been realised and the current exploration in parts of Rajasthan has been formulated with this concept. Noteworthy uranium mineralisation associated with brecciated quartzites overlying the basement Malanis in the Neo-Proterozoic Sindreth basin, have come to light.

*Neo-Proterozoic Bhima basin, Karnataka*

The Bhima basin comprising arenaceous and calcareous metasediments of the Bhima Group deposited over basement granite has been affected by a number of major east-west trending fault zones. A small-sized medium-grade uranium deposit has been established in one such fault – the Gogi-Kurlagare fault. The Fatahabad fault zone which has geological signatures identical to Gogi is currently under exploration.

*Neo-Proterozoic Kaladgi basin, Karnataka*

In the Neo-Proterozoic Kaladgi basin, significant uranium mineralisation hosted in the Badami arenites and conglomerates have been established in Deshnur area, which is under further exploration for possible augmentation of uranium mineralisation. The northern parts of this basin is covered by Cretaceous Deccan volcanic rocks, which warrants subsurface exploration through drilling to probe the subsurface geological features in order to assess the possibility of locating uranium mineralisation.

*Cretaceous sedimentary basin, Meghalaya*

Exploration carried out in Meghalaya has resulted in the identification of the Upper Cretaceous, lower Mahadeks as potential host for uranium mineralisation. At Umthongkut, about 20 km west of the Wakhyn deposit, subsurface exploration has identified significant mineralisation. Ground geophysical surveys revealed positive signatures between Balphakram and Wakhyn, which are to be explored in future.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

India's known conventional uranium resources (RAR and inferred) are estimated to contain 139 800 tU hosted in the following deposit types.

| | |
|---|---|
| Vein type | 38.39% |
| Unconformity type | 12.29% |
| Sandstone type | 11.84% |
| Metasomatite | 0.48% |
| QPC | 0.25% |
| Others (stratabound) | 36.75% |

As of 1 January 2011, the known conventional *in situ* resources established so far include 102 600 tU of reasonably assured resources (RAR) and 37 200 tU of inferred resources (IR). This amounts to a substantial increase in RAR and a marginal increase in IR, compared to figures in the 2009 Red Book. These changes are mainly due to appreciable resource additions in extensions of one of the stratabound deposits in the southern part of the Cuddapah basin.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

In parts of Andhra Pradesh, Meghalaya, Rajasthan, Jharkhand and Karnataka, potential areas for uranium resources were firmed up with enhanced degrees of confidence. As of 1 January 2011, undiscovered resources remained at 63 600 tU under the prognosticated category and 17 000 tU under the speculative category, both as *in situ* resources.

## 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. UCIL is now operating five underground uranium mines at Jaduguda, Bhatin, Narwapahar, Turamdih and Bagjata, and one opencast mine at Banduhurang in the Singhbhum East district of Jharkhand State. The ore produced from these mines is processed in two plants located at Jaduguda and Turamdih. All these units fall within a multi-metal mineralised sector called the Singhbhum Shear Zone in the eastern part of India.

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

*Status of production capability*

The total installed capacity of Jaduguda plant is about 2 500 t ore/day and the capacity of the Turamdih plant is about 3 000 t ore/day.

*Recent and ongoing activities*

- Jaduguda mine

The Jaduguda uranium deposit lies within meta-sediments of the Singhbhum Shear Zone. The host rocks are of Proterozoic age. There are two prominent parallel ore lenses – the Footwall lode (FWL) and the Hangwall lode (HWL). These lodes are separated by a 100 m thick barren zone. The FWL extends over a strike length of about 600 m in the southeast-northwest direction. The strike length of the 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 northeast. Of the two lodes, the FWL is better mineralised. The Jaduguda deposit has been explored to a depth of 880 m.

Entry to the Jaduguda 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. A cut-

and-fill stoping method is practiced in this mine, with about 80% ore recovery. De-slimed mill tailings are used as backfill. Broken ore is hoisted by the skip in stages through shafts to the surface and sent to the mill by conveyor for further processing.

- Bhatin mine

Located 4 km north-west of Jaduguda, Bhatin has a similar geological set-up as that of Jaduguda. A major strike-slip fault lies between these two deposits. The ore lens in this mine has a thickness of 2 m to 10 m with an average 35 degree dip. Entry to the mine is through an adit and deeper levels are accessed by inclines. Cut-and-fill stoping is followed at Bhatin and deslimed mill tailings from Jaduguda are used as backfill.

- Narwapahar mine

In the Narwapahar deposit, discrete uraninite grains occur within chlorite-quartz schist with associated magnetite. There are several ore lenses in this deposit extending over a strike length of about 2 100 m. The ore shoots are lenticular in shape, with an average north-easterly 30 to 40 degree dip. The thickness of individual ore shoots varies from 2.5 m to 20 m. The deposit is accessed by a 355 m deep vertical shaft and a 7 degree decline from the surface. Cut-and-fill stoping is also practiced in this mine and deslimed mill tailings from Jaduguda are used as backfill.

- Turamdih mine

The Turamdih deposit is located about 12 km west of Narwapahar. Discrete uraninite grains within feldspathic-chlorite schist form a number of ore lenses with a very erratic configuration. This mine, commissioned in 2003, has two levels at 70 m and 100 m depth accessed by an 8 degree decline from surface. A vertical shaft is being sunk to provide access to deeper levels.

- Bagjata mine

The Bagjata deposit, about 26 km east of Jaduguda, has been developed as an underground mine with a 7 degree decline as entry and a vertical shaft to access deeper levels. This mine was commissioned in 2008.

- Banduhurang mine

The deposit has been developed as an opencast mine, commissioned in 2009. The ore body at Banduhurang is the western extension of the Turamdih ore lenses.

- Jaduguda mill

Uranium ore produced from the Jaduguda, Bhatin, Narwapahar and Bagjata mines is being processed at the Jaduguda mill. Commissioned in 1968, the mill has an installed capacity of 2 500 t/day dry ore. Following crushing and grinding to 60% passing 200 mesh, ore is leached in pachuca tanks using sulphuric acid under controlled pH and temperature. After the filtration of the pulp, ion exchange resin is used to recover uranium. After elution, the product is precipitated using magnesia to produce magnesium di-uranate containing 70% $U_3O_8$. The treatment of mine water and recycling of tailings water has resulted in the reduction of fresh water requirements, as well as increasing purity of the final effluent. A magnetite recovery plant producing a very fine grained magnetite by-product is also in operation.

- Turamdih mill

The Turamdih mill was commissioned in 2009 to process ore from the Turamdih, and Banduhurang mines. It has an installed capacity to treat about 3 000 t/day dry ore. An expansion to increase process capacity to 4 500 tpd is underway.

## Uranium production centre technical details

(as of 1 January 2011)

| | Centre #1 | Centre #2 | Centre #3 | Centre #4 |
|---|---|---|---|---|
| Name of production centre | Jaduguda | Bhatin | Narwapahar | Bagjata |
| Production centre classification | Existing | Existing | Existing | Existing |
| Date of first production (year) | 1967 | 1986 | 1995 | 2008 |
| Source of ore: | | | | |
| Deposit name(s) | Jaduguda | Bhatin | Narwapahar | Bagjata |
| Deposit type(s) | Vein | Vein | Vein | Vein |
| Reserves | - | - | - | - |
| Grade (% U) | - | - | - | - |
| Mining operation: | | | | |
| Type (OP/UG/*in situ*) | UG | UG | UG | UG |
| Size (tonnes ore/day) | 650 | 150 | 1 500 | 500 |
| Average mining recovery (%) | 80 | 75 | 80 | 80 |
| Processing plant: | Jaduguda | | | |
| Type (IX/SX/AL) | IX/AL | | | |
| Size (tonnes ore/day) | 2 500 | | | |
| Average processing ore recovery (%) | 80 | | | |
| Nominal production capacity (tU/year) | 200 | | | |
| Plans for expansion | | | | |
| Other remarks | Ore being processed at the Jaduguda plant | | | |

| | Centre #5 | Centre #6 | Centre #7 |
|---|---|---|---|
| Name of production centre | Turamdih | Banduhurang | Mohuldih |
| Production centre classification | Existing | Existing | Committed |
| Date of first production (year) | 2003 | 2007 | 2011 |
| Source of ore | | | |
| Deposit name(s) | Turamdih | Banduhurang | Mohuldih |
| Deposit type(s) | Vein | Vein | Vein |
| Reserves | - | - | - |
| Grade (% U) | - | - | - |
| Mining operation: | | | |
| Type (OP/UG/*in situ*) | UG | OP | UG |
| Size (tonnes ore/day) | 750 | 3 500 | 500 |
| Average mining recovery (%) | 75 | 65 | 80 |
| Processing plant: | Turamdih | | |
| Type (IX/SX/AL) | IX/AL | | |
| Size (tonnes ore/day) | 3 000 | | |
| Average processing ore recovery (%) | 80 | | |
| Nominal production capacity (tU/year) | 190 | | |
| Plans for expansion | Turamdih mine (1 000 TPD) and Turamdih plant (4 500 TPD) are under expansion | | |
| Other remarks | Ore being processed in Turamdih plant | | Ore to be processed at the expanded Turamdih plant |

**Uranium production centre technical details** (*continued*)

(as of 1 January 2011)

| | Centre #8 | Centre #9 | Centre #10 | Centre #11 |
|---|---|---|---|---|
| Name of production centre | Tummalapalle | Gogi | Lambapur-Peddagattu | Kylleng-Pyndengsohiong, Mawthabah |
| Production centre classification | Committed | Committed | Planned | Planned |
| Date of first production (year) | 2012 | 2014 | 2016 | 2017 |
| Source of ore: | | | | |
| Deposit name(s) | Tummalapalle | Gogi | Lambapur-Peddagattu | KPM |
| Deposit type(s) | Stratabound | Vein | Unconformity | Sandstone |
| Reserves | - | - | - | - |
| Grade (% U) | - | - | - | - |
| Mining operation: | | | | |
| Type (OP/UG/*in situ*) | UG | UG | UG/OP | OP |
| Size (tonnes ore/day) | 3 000 | 500 | 1 250 | 2 000 (250 days/y working) |
| Average mining recovery (%) | 60 | 60 | 75 | 90 |
| Processing plant: | Tummalapalle | Gogi | Seripally | KPM |
| Type (IX/SX/AL) | AL/KPL | AL | IX/AL | IX/AL |
| Size (tonnes ore/day) | 3 000 | 500 | 1 250 | 2 000 (275 days/y working) |
| Average processing ore recovery (%) | 70 | 88 | 77 | 87 |
| Nominal production capacity (tU/year) | 220 | 130 | 130 | 340 |
| Plans for expansion | Tummalapalle mine (4 500 TPD) and Tummalapalle plant (4 500 TPD) are under expansion | | - | - |
| Other remarks | | Ore to be processed in the plant at Saidpur | Ore to be processed in the plant at Seripally | |

### *Ownership structure of the uranium industry*

The uranium industry is wholly owned by the Department of Atomic Energy (DAE), government of India.

The Atomic Minerals Directorate for Exploration and Research of the DAE is responsible for uranium exploration programmes in India. Following the discovery and deposit delineation, the economic viability is determined. The evaluation stage may also include exploratory mining. Once a deposit of sufficient tonnage and grade is established, UCIL initiates activities for commercial mining and production of uranium concentrates.

### *Employment in the uranium industry*

About 4 917 people are currently engaged in uranium mining and milling activities.

### *Future production centres*

The uranium deposit located at Mohuldih in Seraikela-Kharswan district, Jharkhand, is under development as an underground mine. This deposit is located about 2.5 km west of Banduhurang. The ore extracted from the mine is to be treated in the Turamdih plant.

Another uranium deposit in carbonate hosted rock at Tummalapalle in the YSR district (formerly called Kadapa) of Andhra Pradesh is also under development. The underground mine is to be accessed by three declines along the apparent dip of the ore body. The central decline will be equipped with a conveyor for ore transport and the other two declines are to be used as service paths. The ore will be treated in a nearly completed pressurised alkali leaching plant close to the mine. The mine is expected to be commissioned in January 2012. Expansion of the mine and plant at Tummalapalle is also planned.

The Gogi uranium deposit located in the Yadgir (formerly called Gulbarga) district, Karnataka, is planned for development as an underground mine. Exploratory mining is in progress to establish the ore body configuration. The plant at Gogi, expected to be commissioned during 2014-2015, will use alkali leaching technology.

A sandstone hosted uranium deposit at Kylleng-Pyndengsohiong, Mawthabah (formerly called Domiasiat) in the West Khasi Hills district, Meghalaya, is planned for development by open-pit mining with a processing plant near the site.

Uranium deposits located at Lambapur-Peddagattu in the Nalgonda district, Andhra Pradesh are also planned for development. One open-pit mine and three underground mines are proposed at this site. The uranium ore processing plant is proposed for construction at Seripally, 50 km away from the mine site. Pre-project activities are at an advanced stage of completion.

### Secondary sources of uranium

India provided no information on the production and use of mixed oxide fuels, re-enriched tails or reprocessed uranium.

### Environmental activities and socio-cultural issues

There is no environmental issue 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 of radiation, radon and dust at uranium production facilities. The Health Physics Group operates an Environmental Survey Laboratory at Jaduguda. It has an establishment at all operating units.

### Uranium requirements

As of 1 January 2011, total installed nuclear capacity in India was 4 780 MWe (gross) with 18 pressurised heavy water reactors (PHWRs) and 2 boiling water reactors (BWRs). Construction of four PHWRs (KAPP 3&4 – 2 x 700 MWe and RAPP 7&8 – 2 x 700 MWe), two light water reactors (LWRs) (KKNPP 1&2 – 2 x 1 000 MWe) and one prototype fast breeder (PFBR; 500 MWe) is in progress. The total nuclear power generating capacity is expected to grow to about 7 280 MWe (gross) to 6 700 MWe (net) by 2013 as projects under construction are completed.

The present plan is to increase total nuclear installed capacity to about 35 000 MWe by the year 2022, with of 11 460 MWe in PHWRs, 22 320 MWe in LWRs, 1 500 MWe in FBRs and 300 MWe in advanced heavy water reactors (AHWR).

Annual uranium requirements for 2010 amounted to 930 tU and will increase in tandem with increases in installed nuclear capacity. Identified conventional resources can support 10-15 GWe installed capacity of PHWRs operating at a lifetime capacity factor of 80% for 40 years.

With the opening of international co-operation in its peaceful nuclear programme, India's installed nuclear capacity is expected to grow significantly. More projects are envisaged to be taken up. However, the exact programme to be taken up based on technical co-operation with other countries is yet to be finalised.

### *Supply and procurement strategy*

Uranium requirements for PHWRs are met so far from indigenous and imported sources. Two operating BWRs and two LWRs under construction (VVER type) require enriched uranium and are fuelled by imported uranium. Future LWRs would 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 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 LWRs which would be inducted in future would be based on assurance of fuel supply for the lifetime of the reactor.

### *Uranium stocks*

NA.

**Uranium exploration and development expenditures and drilling effort – domestic**

(INR millions [Indian rupee])

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 0 | 0 | 0 | 0 |
| Government exploration expenditures | 1 074.50 | 1 935.40 | 2 581.40 | 2 519.40 |
| Industry* development expenditures | 0 | 0 | 0 | 0 |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 1 074.50 | 1 935.40 | 2 581.40 | 2 519.40 |
| Industry* exploration drilling (m) | 0 | 0 | 0 | 0 |
| Industry* exploration holes drilled | 0 | 0 | 0 | 0 |
| Government exploration drilling (m) | 117 747 | 156 791 | 217 548 | 287 450 |
| Government exploration holes drilled | NA | NA | NA | NA |
| 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) | 117 747 | 156 791 | 217 548 | 287 450 |
| Subtotal exploration holes | NA | NA | NA | NA |
| Subtotal development drilling (m) | 0 | 0 | 0 | 0 |
| Subtotal development holes | 0 | 0 | 0 | 0 |
| Total drilling (m) | 117 747 | 156 791 | 217 548 | 287 450 |
| Total number of holes drilled | NA | NA | NA | NA |

* Non-government.


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### Reasonably assured conventional resources by deposit type

(tonnes U)

| Deposit type | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | Cost range unassigned |
|---|---|---|---|---|
| Unconformity-related | NA | NA | NA | 15 500 |
| Sandstone | NA | NA | NA | 12 600 |
| Hematite breccia complex | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 |
| Vein | NA | NA | NA | 36 000 |
| Intrusive | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 |
| Other* | NA | NA | NA | 38 500 |
| Total | | | | 102 600 |

* Stratabound.

### Reasonably assured conventional resources by production method

(tonnes U)

| Production method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | Cost range unassigned | Recovery factor (%) |
|---|---|---|---|---|---|
| Underground mining (UG) | NA | NA | NA | 85 400 | *In situ* |
| Open-pit mining (OP) | NA | NA | NA | 17 200 | *In situ* |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | - |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | - |
| Co-product and by–product | 0 | 0 | 0 | 0 | - |
| Unspecified | 0 | 0 | 0 | 0 | - |
| Total | | | | 102 600 | *In situ* |

### Reasonably assured conventional resources by processing method

(tonnes U)

| Processing method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | Cost range unassigned | Recovery factor (%) |
|---|---|---|---|---|---|
| Conventional from UG | NA | NA | NA | 85 400 | *In situ* |
| Conventional from OP | NA | NA | NA | 17 200 | *In situ* |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | - |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | - |
| In-place leaching* | 0 | 0 | 0 | 0 | - |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | - |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | - |
| Unspecified | 0 | 0 | 0 | 0 | - |
| Total | | | | 102 600 | - |

* Also known as stope leaching or block leaching.

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

### Inferred conventional resources by deposit type

(tonnes U)

| Deposit type | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | Cost range unassigned | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | NA | NA | NA | 1 700 | *In situ* |
| Sandstone | NA | NA | NA | 3 900 | *In situ* |
| Hematite breccia complex | 0 | 0 | 0 | 0 | - |
| Quartz-pebble conglomerate | NA | NA | NA | 300 | *In situ* |
| Vein | NA | NA | NA | 17 700 | *In situ* |
| Intrusive | 0 | 0 | 0 | 0 | - |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | - |
| Metasomatite | NA | NA | NA | 700 | *In situ* |
| Other* | 0 | 0 | 0 | 12 900 | *In situ* |
| Total | NA | NA | NA | 37 200 | *In situ* |

* 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.

### Inferred conventional resources by production method

(tonnes U)

| Production method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | Cost range unassigned | Recovery factor (%) |
|---|---|---|---|---|---|
| Underground mining (UG) | NA | NA | NA | 34 100 | *In situ* |
| Open-pit mining (OP) | NA | NA | NA | 3 100 | *In situ* |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by–product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | | | | 37 200 | *In situ* |

### Inferred conventional resources by processing method

(tonnes U)

| Processing method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | Cost range unassigned | Recovery factor (%) |
|---|---|---|---|---|---|
| Conventional from UG | NA | NA | NA | 34 100 | *In situ* |
| Conventional from OP | NA | NA | NA | 3 100 | *In situ* |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | - |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | - |
| In-place leaching* | 0 | 0 | 0 | 0 | - |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | - |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | - |
| Unspecified | 0 | 0 | 0 | 0 | - |
| Total | NA | NA | NA | 37 200 | *In situ* |

* 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 concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | | | | | | |
| Sandstone | | | | | | |
| Hematite breccia complex | | | | | | |
| Quartz-pebble conglomerate | | | | | | |
| Vein | | | | | | |
| Intrusive | | | | | | |
| Volcanic and caldera-related | | | | | | |
| Metasomatite | | | | | | |
| Other* | | | | | | |
| 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.

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | | | | | | |
| Underground mining[1] | | | | | | |
| *In situ* leaching | | | | | | |
| Co-product/by-product | | | | | | |
| Total | NA | NA | NA | NA | NA | NA |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | | | | | | |
| In-place leaching* | | | | | | |
| Heap leaching** | | | | | | |
| U recovered from phosphate rocks | | | | | | |
| Other methods*** | | | | | | |
| Total | NA | NA | NA | NA | NA | 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.

*** Includes mine water treatment and environmental restoration.

### Prognosticated conventional resources

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 80/kgU | <USD 130/kgU | Cost range unassigned |
| NA | NA | 63 600 |

### Speculative conventional resources

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 80/kgU | <USD 130/kgU | Cost range unassigned |
| NA | NA | 17 000 |

### Ownership of uranium production in 2010

| Domestic | | | | Foreign | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | | |
| (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) |
| NA | 100 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 100 |

### Uranium industry employment at existing production centres

(person-years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 4 643 | 4 643 | 4 917 | 4 917 |
| Employment directly related to uranium production | NA | NA | NA | NA |

### Short-term production capability

(tonnes U/year)

| 2011 | | | | 2015 | | | | 2020 | | | | 2025 | | | | 2030 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-I | B-I | A-II | B-II | A-I | B-I | A-II | B-II | 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 | | | |

### Mixed oxide fuel production and use

(tonnes natural U equivalent)

| Mixed oxide (MOX) fuel | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Production | | | | | | |
| Use | | | | | | |
| Number of commercial reactors using MOX | 1 | | | | | |

### Net nuclear electricity generation

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh gross) | 17.016 | 23.271 |

### Installed nuclear generating capacity to 2035

(MWe gross)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 120 | 4 780 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 4 780 | 5 780 | 7 280 | 8 680 | | 24 000 | NA | 35 000 | NA | NA | NA | NA |


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

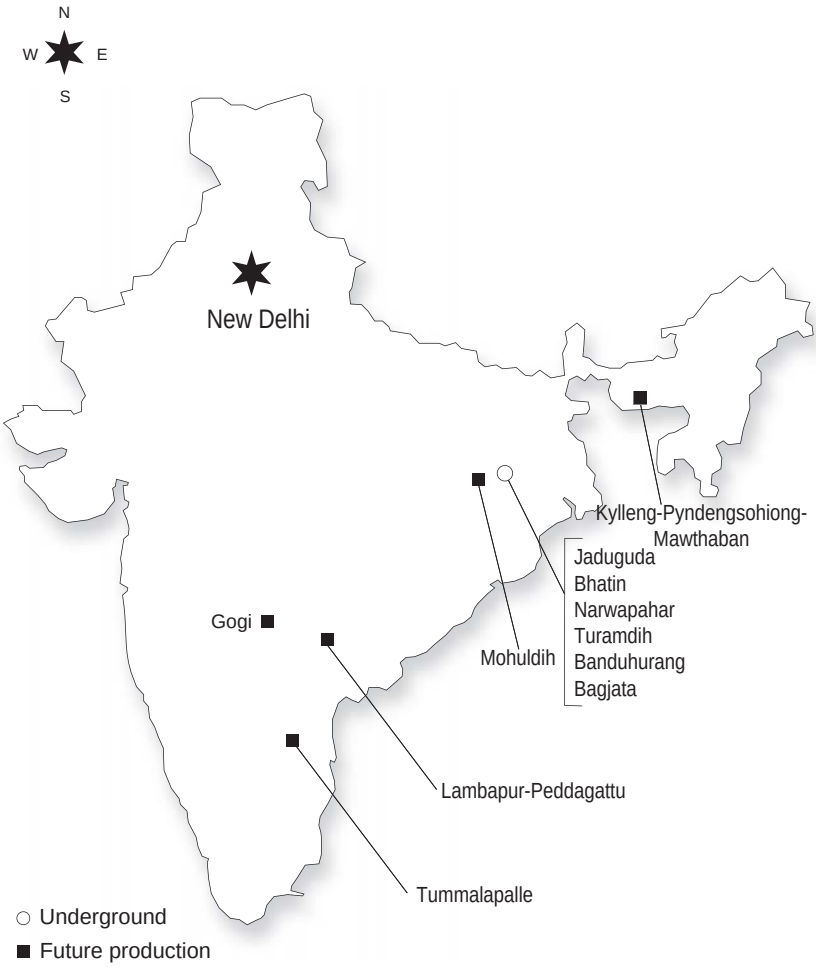
(tonnes natural U equivalent)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 930 | 1 200 | 1 600 | 1 800 | | 5 000 | | NA | | NA | | NA |

**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 | | | | | |
| Producer | | | | | |
| Utility | | | | | |
| Total | NA | NA | NA | NA | NA |



# Indonesia

## Uranium exploration and mine development

### *Historical review*

The 2009 edition of the Red Book gives a short historical review of uranium exploration.

In 2009, 452 m of exploration drilling was carried out at Sarana (Kalan sector). Systematic prospection of the Kawat area (Paluq and Nyaan sectors) was carried over an area of about 1 $km^2$ for each sector and general prospection in the Bangka Belitung province was carried over an area of 50 $km^2$.

In 2010, general prospection in the Bangka Belitung province was continued over an expanded area of about 200 $km^2$. General prospection was carried out in the Ketapang area, West Kalimantan over an area of about 150 $km^2$ and exploration drilling (84 m) was conducted in Kawat area (Kawat sector).

### *Recent and ongoing uranium exploration and mine development activities*

In 2011, continued exploration drilling (600 m expected) is planned at Sarana in the Kalan sector and general prospection will be conducted in Ketapang (200 $km^2$), Bangka Belitung province (200 $km^2$) and Papua (200 $km^2$).

No mining activity is currently under consideration.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

Following the policy of increasing identified resources, exploration drilling at Sarana in the Kalan sector resulted in a 775 tU increase in inferred resources, where mineralisation is formed in veinlets in metapelite schistose and metasilt.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

Following the policy of extending the area of exploration in order to discover new uranium deposits, investigation resulted in an increase of 23 472 tU in prognosticated resources and 293 tU in speculative resources in the Bangka Belitung province during 2009. The Bangka Belitung province has been identified as an area with significant amounts of monazite (30% monazite in heavy minerals) disperse as an alluvial deposit. Results of 2010 research continue to be analysed.

In 2011, general prospection will be carried out in the eastern part of the central mountains in Papua province. The geological setting of the selected area is considered favourable for uranium occurrences of the unconformity related type, between the Paleo-Mezoproterozoic Awitagoh and Kariem formations (820 Ma and 847 $\pm$ 21.5 Ma based on K-Ar dating) and the Mesozoic Kembelangan Group. The geological setting is similar to the Jabiluka deposit and the Ranger uranium mine in north Australia.

General prospection in the Ketapang and Bangka Belitung province also will be continued in alluvium.

Exploration drilling at Sarana in the Kalan sector will be carried out in order to obtain more information on uranium bearing rock, such as depth, grade and thickness of the ore.

### *Unconventional resources and other materials*

The result of the 2009 Bangka Belitung province general prospection provided strong indications of monazite in alluvial deposits. Occurrences of monazite along with other heavy minerals in alluvium (0.163%) include uranium (0.01%) and thorium (0.051%).

**Uranium exploration and development expenditures and drilling effort – domestic**

(IDR [Indonesian rupiah])

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | - | - | - | - |
| Government exploration expenditures | 689 770 000 | 2 750 000 000 | 2 925 000 000 | 7 863 000 000 |
| Industry* development expenditures | - | - | - | - |
| Government development expenditures | - | - | - | - |
| Total expenditures | 689 770 000 | 2 750 000 000 | 2 925 000 000 | 7 863 000 000 |
| Industry* exploration drilling (m) | - | - | - | - |
| Industry* exploration holes drilled | - | - | - | - |
| Government exploration drilling (m) | - | 452 | 84 | 600 |
| Government exploration holes drilled | - | 3 | 2 | 4 |
| Industry* development drilling (m) | - | - | - | - |
| Industry* development holes drilled | - | - | - | - |
| Government development drilling (m) | - | - | - | - |
| Government development holes drilled | - | - | - | - |
| Subtotal exploration drilling (m) | - | 452 | 84 | 600 |
| Subtotal exploration holes drilled | - | 3 | 2 | 4 |
| Subtotal development drilling (m) | - | - | - | - |
| Subtotal development holes drilled | - | - | - | - |
| Total drilling (m) | - | 452 | 84 | 600 |
| Total number of holes drilled | - | 3 | 2 | 4 |

Note: USD 1 = IDR 9 000.00/1 January 2011.

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 |
| Vein | 0 | 2 005 | 8 417 | 8 417 | 75 |
| Intrusive | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 2 005 | 8 417 | 8 417 | 75 |

* Includes surficial, collapse breccia pipe, phosphorite and other type of deposits, as well as rocks with elevated uranium content. Pegmatite, granites and black shale are not included.

### Reasonably assured 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 | 2 005 | 8 417 | 8 417 | 75 |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | 0 |
| *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 | 0 | 2 005 | 8 417 | 8 417 | 75 |

### Reasonably assured conventional resources by processing method

(tonnes U)

| Production method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Conventional from OP | 0 | 0 | 0 | 0 | 0 |
| Conventional from UG | 0 | 2 005 | 8 417 | 8 417 | 75 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | 0 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | 0 |
| Unspecified | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 2 005 | 8 417 | 8 417 | 75 |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 2 244 | 75 |
| Intrusive | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 2 244 | 75 |

* Includes surficial, collapse breccia pipe, phosphorite and other type of deposits, as well as rocks with elevated uranium content. Pegmatite, granites and black shale are not included.

### 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 | 0 | 2 244 | 75 |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | 0 |
| *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 | 0 | 0 | 0 | 2 244 | 75 |

### Inferred conventional resources by processing method

(tonnes U)

| Production method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Conventional from OP | 0 | 0 | 0 | 0 | 0 |
| Conventional from UG | 0 | 0 | 0 | 2 244 | 75 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | 0 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | 0 |
| Unspecified | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 2 244 | 75 |

* 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 |
| 0 | 0 | 23 472 |

### Speculative conventional resources

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 130/kgU | <USD 260/kgU | Unassigned |
| 0 | 0 | 22 020 |

# Iran (Islamic Republic of)

## Uranium exploration and mine development

### *Historical review*

- feasibility studies and basic engineering designs (1994-1995);
- mining preparation – designs and reports (1996);
- constructing administration and industrial buildings and arranging equipment supply (1997-1998);
- sinking No. 1 and No. 2 shafts (1999-2002);
- excavation and major tunnel development at different levels of the Saghand uranium mine (2003 to present).

### *Recent and ongoing uranium exploration and mine development activities*

*Uranium exploration activities*

Exploration has been conducted in the Kerman, Sistan-va-Baluchstan, South Khorasan and Razavi Khorasan provinces, in the south-east, east and central regions of Iran, in addition to regional structural studies covering almost the entire eastern portion of Iran.

Reconnaissance for sedimentary type uranium deposits by various procedures over the entire country has also been undertaken in order to evaluate the potential of favourable sedimentary basins for uranium mineralisation.

*Mine development activities*

During 2009 and 2010, activities at the Saghand uranium mine included excavation of development tunnels and construction of industrial buildings and mechanical equipment adjacent to the mine shafts.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

As a result of exploration activities in 2009 and 2010, a total of 360 tU has been added to RAR and inferred resources. The average uranium assay of the newly added inferred resources is about 560 ppm U.

*Saghand deposit*

Exploration activity is focused on anomalies in the Saghand area. These activities include general exploration through geological and geophysical surveys, as well as drilling boreholes and well logging. Major operations are being carried out on mineralised zones of albite-amphibole type metasomatite. These anomalies are considered to hold considerable volumes with low uranium assays.

*Gachin deposit*

Different mineral indices within this deposit area have undergone exploration in the general and detailed phases, mainly through geological and geophysical surveys, followed by shallow depth drill holes and well logging. This has led to the detection of radioactive layers in some of these indices. Mineralisation in this deposit is of the surficial type, which because of high assays has special significance.

*Narigan prospect*

Hydrothermal vein type mineralisation in the Narigan prospect has been under exploration in the past few years. In some anomalies, because of weak evidence for radioactive mineralisation, exploration has been truncated. But for other more promising anomalies, considering their radioactive zones, exploration has continued via deep borehole drilling and respective well logging in order to better define radioactive zones. Mineral resources in this deposit have been estimated within the inferred category.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

*Ravar mineral occurrence*

This area of Mesozoic red sandstone and marl sedimentary layers hosting metallic mineralisation (specifically copper) is considered promising and exploration has been carried out over the last two years. General exploration phase activities, such as geological and geophysical surveying and trenching, followed by widely spaced shallow drill holes and deep boreholes with well logging have taken place.

*Salt plugs in the Bandar-Abbas and Bandar-Lengeh exploration area*

Considering achieved exploratory results from the Gachin salt plug deposit located in this area, in addition to studies conducted on other salt plugs in the Bandar-Abbas and Bandar-Lengeh area, salt plugs in this area are to be studied based on a priority basis. General exploration of the Champeh, Bostaneh, Moghuyeh and Ghalat-Bala salt plugs has begun through geological and geophysical surveys. Depending on results, sub-surface studies may follow.

*Se-Chahun exploration area*

This area in the vicinity of Narigan deposit has been selected for general exploration via geological and geophysical surveys, trenching and shallow drill holes since it has similar geological features and hosts some favourable radioactive mineral indices.

## Uranium production

### *Historical review*

Uranium ore recovered by open-pit mining of the Gachin salt plug has been processed at Banddar-Abbas uranium plant (BUP) since 2006.

### *Status of production capability*

Iran's only operating production centre (BUP) began operating in 2006. It is capable of treating 48 tons of uranium ore per day with an annual production capacity of 21 tU. Operations began at lower production levels processing Gachin ore. A second production facility near the town of Ardakan, with a production capacity of 50 tU/yr, is under construction with production expected to begin in 2012. 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 the Islamic Republic of Iran and the operator is the Atomic Energy Organisation of Iran (AEOI).

### *Employment in the uranium industry*

In 2011, a total of 340 employees are involved in uranium mining, milling and related activities.

### *Future production centres*

In addition to the currently operating BUP production centre, a production centre in Ardakan is planned to be operational in 2012.

## Environmental activities and socio-cultural issues

### *Bandar-Abbas uranium mine and mill*

The open-pit uranium mine along with a hydrometallurgical treatment plant are located in close proximity in the south-west of Bandar-Abbas city:

- A comprehensive programme has been designed to achieve safety, health and environmental (HSE) protection. Health and safety training, including all HSE related activities, have been proposed and developed for uranium mine and mill facilities.
- Monitoring has been conducted by the HSE group to detect contamination from tailings, transportation, aerosols, dust emissions, released radionuclides and their impacts on working personnel and the environment.
- The protection against ionising radiation training course has been established and funded by the AEOI, a governmental body.
- Since the first tailings pond has been filled to capacity, a decommissioning programme was submitted and a second tailings pond has been designed, constructed and is now being used to store waste.

### *Ardakan uranium mill*

Since this uranium plant is under construction, primarily all HSE related activities have been proposed and adapted in the uranium mill.

### *Saghand underground uranium mine*

Related HSE training and personnel protective equipment (PPE) has been introduced to protect the environment and the working personnel from injuries and illness.

A ventilation system has been designed and implemented to supply the fresh air and to pump dust and radionuclides in order to reduce radon gas inhalation and related contamination from the underground mine.

### Uranium exploration and development expenditures and drilling effort – domestic

(IRR millions [Iranian rial])

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 0 | 0 | 0 | 0 |
| Government exploration expenditures | 49 500 | 97 000 | 146 156 | 450 000 |
| Industry* development expenditures | 0 | 0 | 0 | 0 |
| Government development expenditures | 24 170 | 131 529 | 186 676 | 350 000 |
| Total expenditures | 73 670 | 228 529 | 332 832 | 800 000 |
| Industry* exploration drilling (m) | 0 | 0 | 0 | 0 |
| Industry* exploration holes drilled | 0 | 0 | 0 | 0 |
| Government exploration drilling (m) | 16 645 | 24 772 | 45 230 | 70 000 |
| Government exploration holes drilled | 178 | 229 | 328 | 356 |
| 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) | 16 645 | 24 772 | 45 230 | 50 000 |
| Subtotal exploration holes drilled | 178 | 229 | 328 | 356 |
| Subtotal development drilling (m) | 0 | 0 | 0 | 0 |
| Subtotal development holes drilled | 0 | 0 | 0 | 0 |
| Total drilling (m) | 16 645 | 24 772 | 45 230 | 50 000 |
| Total number of holes drilled | 178 | 229 | 328 | 356 |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | |
| Sandstone | 0 | 0 | 0 | 0 | |
| Hematite breccia complex | 0 | 0 | 0 | 0 | |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | |
| Vein | 0 | 0 | 0 | 0 | |
| Intrusive | 0 | 0 | 0 | 0 | |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | |
| Metasomatite | 0 | 0 | 491 | 491 | 85-90 |
| Other* | 0 | 0 | 246 | 246 | 85-90 |
| Total | 0 | 0 | 737 | 737 | |

Note: Recovery factor has been considered for the above mentioned RACR tonnages.

* 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.

### 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 | 85-90 |
| Open-pit mining (OP) | 0 | 0 | 110 | 110 | 85-90 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 136 | 136 | |
| Total | 0 | 0 | 737 | 737 | |

Note: Recovery factor has been considered for the above mentioned RACR minable tonnages.

### 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 | 85-90 |
| Conventional from OP | 0 | 0 | 110 | 110 | 85-90 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 136 | 136 | 85-90 |
| Total | 0 | 0 | 737 | 737 | |

Note: Recovery factor has been considered for the above mentioned RACR tonnages.

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | |
| Sandstone | 0 | 0 | 0 | 0 | |
| Hematite breccia complex | 0 | 0 | 0 | 0 | |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | |
| Vein | 0 | 0 | 872 | 872 | 85-90 |
| Intrusive | 0 | 0 | 0 | 0 | |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | |
| Metasomatite | 0 | 0 | 876 | 876 | 85-90 |
| Other* | 0 | 0 | 32 | 32 | 85-90 |
| Total | 0 | 0 | 1 780 | 1 780 | |

Note: Recovery factor has been considered for the above mentioned ICR tonnages.

* 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.

### 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 | |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 904 | 904 | 85-90 |
| Total | 0 | 0 | 1 780 | 1 780 | |

Note: Recovery factor has been considered for the above mentioned ICR minable tonnages.

### 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 | 85-90 |
| Conventional from OP | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 904 | 904 | 85-90 |
| Total | 0 | 0 | 1 780 | 1 780 | |

Note: Recovery factor has been considered for the above mentioned ICR tonnages.

* 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 |
| 0 | 4 190 | 4 190 |

### Speculative conventional resources

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 130/kgU | <USD 260/kgU | Unassigned |
| 0 | 14 000 | 14 000 |

## Historical uranium production by deposit type

(tonnes U in concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 | 0 |
| Other* | 11.138 | 6.264 | 8.14 | 7.30 | 32.842 | 9.0 |
| Total | 11.138 | 6.264 | 8.14 | 7.30 | 32.842 | 9.0 |

* 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.

## Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 11.138 | 6.264 | 8.14 | 7.30 | 32.842 | 9.0 |
| Underground mining[1] | 0 | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching | 0 | 0 | 0 | 0 | 0 | 0 |
| Co-product/by-product | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 11.138 | 6.264 | 8.14 | 7.30 | 32.842 | 9.0 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 11.138 | 6.264 | 8.14 | 7.30 | 32.842 | 9.0 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** | 0 | 0 | 0 | 0 | 0 | 0 |
| U recovered from phosphate rocks | 0 | 0 | 0 | 0 | 0 | 0 |
| Other methods*** | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 11.138 | 6.264 | 8.14 | 7.30 | 32.842 | 9.0 |

* Also known as stope leaching or block leaching.

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

*** Includes mine water treatment and environmental restoration.

### Ownership of uranium production in 2010

| Domestic | | | | Foreign | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | | |
| (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) |
| 7.30 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 7.30 | 100 |

### Uranium industry employment at existing production centres

(person-years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 285 | 320 | 325 | 340 |
| Employment directly related to uranium production | | | | |

### Short-term production capability

(tonnes U/year)

| 2010 | | | | 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 |
| 0 | 0 | 71* | 0 | 0 | 0 | 87* | 0 | 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 |

* Not based on resources recoverable at costs of <USD 130/kgU.

### Installed nuclear generating capacity to 2035

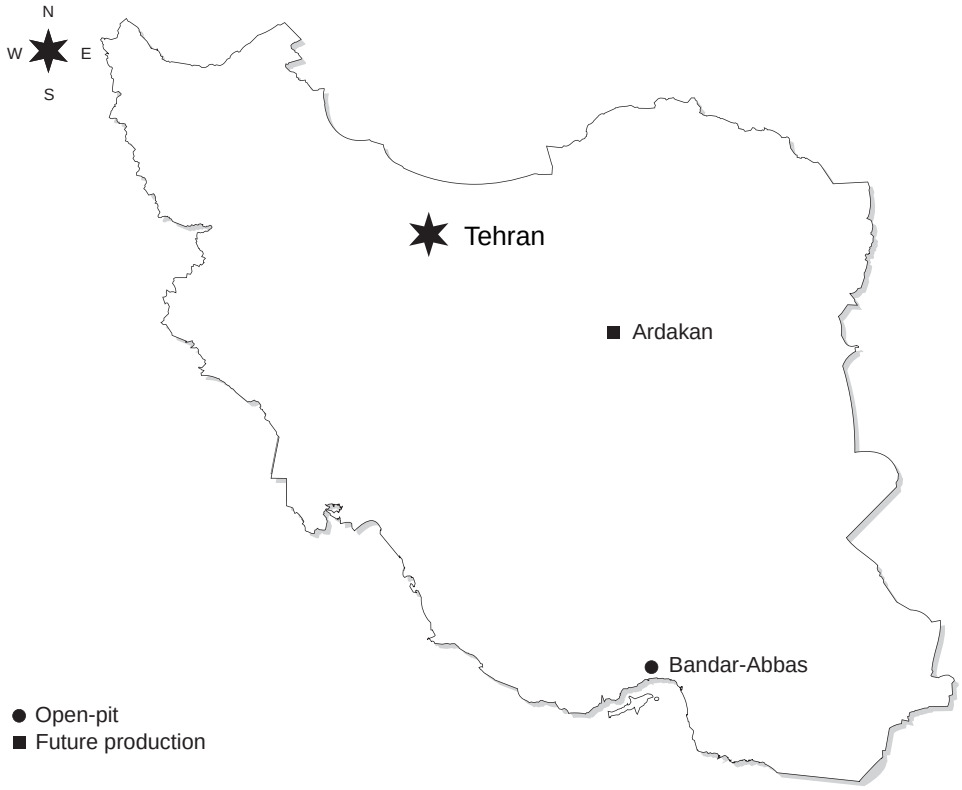
(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 915 | 915 | 915 | 915 | 3 175 | 5 075 | 6 975 | 7 925 | NA | NA | NA | NA |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 160 | 160 | 160 | 160 | 590 | 910 | 1 230 | 1 390 | NA | NA | NA | NA |




# Italy

## Uranium exploration and mine development

### *Historical review*

The first uranium deposit, the volcanogenic Permian Novazza, was discovered in the central Alps as a result of exploration from 1954 to 1962. A second deposit, Valvedello, was also discovered in the same general area as a result of exploration from 1975 to 1983. Between 1985 and 1987, very limited exploration also took place on three uranium projects over a total surface area of 25.7 km$^2$. Agip Miniere also carried out joint venture exploration projects in Australia, Canada, the United States and Zambia prior to 1990. Since then, no exploration has taken place in Italy. Efforts by an Australian company in 2006 to restart exploration on the Novazza deposit were unsuccessful due to local public resistance to the project.

Plans to construct the Valvenova uranium production (260 tU/yr) in the 1980s were never realised. No uranium exploration and/or mine development activity is currently underway either domestically or abroad.

### *Recent and ongoing uranium exploration and mine development activities*

None to report.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

There are no changes to the uranium resource figures presented in the 1991 edition of this publication. These estimates were made in 1987.

### *Unconventional resources and other materials*

None reported.

## Uranium requirements

Requirements had been estimated to comply with the national nuclear programme objective of 25% electricity generation from nuclear at 2030, corresponding to some 13 GWe net nuclear power fleet to be installed (reference case). Nevertheless, following the March 2011 nuclear accident at the Fukushima NPP in Japan, the Italian government established a one-year moratorium for the nuclear national programme. In a referendum held on 13-14 June 2011, voters strongly rejected all of the four initiatives promoted by the government, including the 2009 legislation that set up arrangements to build and operate new NPPs in the country.

### *Supply and procurement strategy*

Not yet defined.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

Italy has currently no operating NPPs, having shut all of them down by 1990 following the results of a referendum in 1987. However, in 2004 the government made the first step to reconsider the nuclear option by issuing a new energy law which opened up the possibility of making joint ventures with foreign companies in relation to NPPs abroad and importing electricity from them.

A second more decisive step was set in May 2008 when the new pro-nuclear Italian government confirmed that it would start building new NPPs within five years in order to diversify the energy mix, reduce the country's great dependence on oil, gas and imported electricity and to curb greenhouse gas emissions. At that time nuclear power was foreseen as a key component of the new energy policy which aimed to have 25% of electricity generated by nuclear by 2030, together with 50% by fossil fuels and 25% by renewable energy sources.

Comprehensive economic development legislation passed in July 2009 when the government introduced a complete package of nuclear legislation, a fundamental step in the revival of the nuclear power option. This package included measures to set up a national nuclear regulatory agency, expedite licensing of new reactors at existing NPP sites and to facilitate licensing of new reactor sites, as well as reorganising the national nuclear research and development entity.

In January 2010, provisions for public consultation were announced and the draft decree set out financial benefits for cities and regions hosting NPPs (EUR 3 000/MWe/yr during construction and 40 centimes/MWh during operation). Further legislation in February 2010 set out a framework for the siting of NPPs, involving local governments. For NPPs and fuel cycle facilities, a so-called "unique authorisation" would be required for construction, as well as an environmental permit. In November 2010, the Constitutional Court had overturned a bid by three regions (Puglia, Campania and Basilicata) to ban nuclear plants from their territory due to strong public opposition.

In January 2011, the Constitutional Court ruled that Italy could hold a referendum on the planned reintroduction of nuclear power, as proposed by an opposition party. The question posed in the referendum, held in mid-June, was whether voters wanted to cancel most of legislative and regulatory measures which had been taken by the government over the previous three years to make possible the construction and operation of new NPPs in the country. Although a strong majority voted to cancel plans for building new NPPs, the results of the referendum do not affect plans for a national waste repository, the so-called "technological park", the national nuclear research and development entity and the nuclear regulatory agency.

Immediately following the Fukushima accident, the government declared a one-year moratorium on nuclear plans and through a law decree stated the abrogation of some specific articles of the nuclear legislation package (approved by parliament at the end of May), with the intent of carrying out a reconsideration of the national energy strategy on the basis of the results from the stress test programme established by EU, and other input from competent international institutions. Nevertheless, the referendum held on 13-14 June 2011 strongly rejected all of the four initiatives promoted by the current government, including the 2009 legislation that set up arrangements to build and operate new NPPs in the country.

This situation is similar to the one following the 1987 referendum that was held in the aftermath of the Chernobyl accident. At this time it is realistic to assume the option of introducing nuclear power will be off the table in the country for at least another five years (the length of time for which a referendum result is binding in Italy).

In the meantime, the government is preparing a new National Energy Strategy (SEN) which is expected to rely mostly on fossil fuels, especially gas, as well as renewable energy sources and enhanced energy efficiency.

Nuclear power is expected to be part of the SEN chapter dealing with new technologies research and development, as it is already being done through the three year ENEA-MSE (Ministry for Economic Development) programme agreement on "new nuclear fission" R&D. The main lines of the nuclear fission "presidium" would be the system safety and innovations, emphasising lessons learnt from Fukushima, as well as Generation IV closed-cycle systems, waste repository and decommissioning technologies, non-proliferation and security, nuclear energy system assessment in view of overall sustainability of nuclear power, and international collaboration.

### *Uranium stocks*

None to report.

### *Uranium prices*

None to report.

### 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 (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | | | | | |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | 4 800 | | | 72 |
| Metasomatite | | | | | |
| Other* | | | | | |
| Total | | 4 800 | | | |

* 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.

### Inferred conventional resources by deposit type

(tonnes U)

| Deposit type | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | | | | | |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | 1 300 | | | 72 |
| Metasomatite | | | | | |
| Other* | | | | | |
| Total | | 1 300 | | | |

* 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.

### Speculative conventional resources

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 130/kgU | <USD 260/kgU | Unassigned |
| 10 000 | 10 000 | |

### Net nuclear electricity generation

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | - | - |

### Installed nuclear generating capacity to 2035

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | - | - | - | - | 1 600 | 1 600 | 6 400 | 6 400 | 13 000 | 13 000 | 13 000 | 13 000 |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | - | - | - | - | 212 | 212 | 1 908 | 1 908 | 7 844 | 7 844 | 16 324 | 16 324 |

Note: Figures are cumulated amounts at end of the reference year in the table. Estimations are based on the following assumptions:

– 13 GWe net online by 2030 and later on, whose 1.6 GWe net online by 2020 and 6.4 GWe net online by 2025.

– Fuel burn-up: 60 GWd/t $UO_2$; fuel enrichment: 4.1% U-235, tails assay: 0.3% U-235; efficiency: 34.2%; capacity factor: 0.9.

### 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 | | | | | |
| Utility* | | | | | |
| Total | | | | | |

* Spent fuel from older NPPs, sent abroad for reprocessing under the decommissioning national programme led by Sogin: 1 641 tHM (963.2 tHM sent abroad up to 1978 and 678 tHM sent abroad after 1978).

# 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 have been detected in Japan. Domestic uranium exploration activities in Japan were terminated in 1988. Overseas uranium exploration began in 1966. Exploration activities were carried out mainly in Canada and Australia, and in other countries such as the People's Republic of China, Niger, the United States and Zimbabwe.

In October 1998, PNC was reorganised into the Japan Nuclear Cycle Development Institute (JNC). Based on the decision by the Atomic Energy Commission in February 1998, uranium exploration activities, which were carried out by PNC, were terminated in 2000, and mining interests and technologies which remained in JNC 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 funding for governmental overseas uranium exploration activities and the financial support for overseas uranium exploration by Japanese companies through Japan Oil, Gas and Metals National Corporation (JOGMEC). JOGMEC is carrying out exploration activities in Australia and Canada.

## Uranium resources

### *Recent and ongoing uranium exploration and mine development activities*

Japan-Canada Uranium Co. Ltd., which took over JNC's mining interests in Canada, is carrying out exploration activities in Canada. Japanese private companies hold shares in developing and mining operations in Australia, Canada, Kazakhstan and Niger.

### *Identified conventional resources (reasonably assured and inferred resources)*

About 6 600 tU of reasonably assured resources have been identified and classified as recoverable at <USD 130/kgU.

## 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 ceased in 1982 with a total production of 84 tU. In 1978, the vat leaching test of the Ningyo-toge ore began on a small scale with a maximum capacity of 12 000 t ore/year, consisting of three 500 t ore vats. The vat leaching test was terminated at the end of 1987.

### Uranium exploration and development expenditures – non-domestic

(JPY millions [Japanese yen])

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | NA | NA | NA | NA |
| Government exploration expenditures | 400 | 455 | 270 | 244 |
| 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | | | | 6 600 | 85 |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | | | | |
| Metasomatite | | | | | |
| Other* | | | | | |
| Total | | | | 6 600 | 85 |

* 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.

### 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) | | | 6 600 | | 85 |
| Open-pit mining (OP) | | | | | |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| Co-product and by-product | | | | | |
| Unspecified | | | | | |
| Total | | | 6 600 | | |

### 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 | | | | | |
| Conventional from UG | | | 6 600 | | 85 |
| In-situ leaching acid | | | | | |
| In-situ leaching alkaline | | | | | |
| In-place leaching* | | | | | |
| Heap leaching** from OP | | | | | |
| Heap leaching** from UG | | | | | |
| Unspecified | | | | | |
| Total | | | 6 600 | | 85 |

* 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 concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | | | | | | |
| Sandstone | 84 | 0 | 0 | 0 | 84 | 0 |
| Hematite breccia complex | | | | | | |
| Quartz-pebble conglomerate | | | | | | |
| Vein | | | | | | |
| Intrusive | | | | | | |
| Volcanic and caldera-related | | | | | | |
| Metasomatite | | | | | | |
| Other* | | | | | | |
| Total | 84 | 0 | 0 | 0 | 84 | 0 |

* 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.

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 39 | 0 | 0 | 0 | 39 | 0 |
| Underground mining[1] | 45 | 0 | 0 | 0 | 45 | 0 |
| *In situ* leaching | | | | | | |
| Co-product/by-product | | | | | | |
| Total | 84 | 0 | 0 | 0 | 84 | 0 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 45 | 0 | 0 | 0 | 45 | 0 |
| In-place leaching* | | | | | | |
| Heap leaching** | 39 | 0 | 0 | 0 | 39 | 0 |
| U recovered from phosphate rocks | | | | | | |
| Other methods*** | | | | | | |
| Total | 84 | 0 | 0 | 0 | 84 | 0 |

* Also known as stope leaching or block leaching.

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

*** Includes mine water treatment and environmental restoration.

### Mixed oxide fuel production and use

(tonnes natural U equivalent)

| Mixed oxide (MOX) fuels | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Production | 605 | 4 | 36 | | | |
| Use | 531.6 | 0 | 170 | | | |
| Number of commercial reactors using MOX | | 0 | 1 | 4 | | 3 |

### Reprocessed uranium use

(tonnes natural U equivalent)

| Reprocessed uranium | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Production | 645 | 0 | 0 | 0 | 645 | 0 |
| Use | 195 | 0 | 12 | 8 | 215 | 0 |

### Net nuclear electricity generation

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 279.7 | 288.2 |

### Installed nuclear generating capacity to 2035

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 46 159 | 47 025 | 47 025 | 47 025 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 8 018 | 6 294 | NA | NA | 10 671 | 10 671 | 11 010 | 11 010 | NA | NA | NA | NA | NA | NA |



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# Jordan

## Uranium exploration and mine development

### *Historical review*

In 1980 an airborne spectrometric survey covering the entire country was completed. 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 boreholes, 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 indicate uranium contents ranging from 140 to 2 200 ppm U (0.140% to 2.2% U) 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 Sahb alabiadh) with promise for hosting uranium deposits were also covered by the reconnaissance studies.

### *Recent and ongoing uranium exploration and mine development activities*

In 2008, the Jordan Atomic Energy Commission (JAEC) was established, in accordance with the newly enacted Nuclear Energy Law (Law No. 42 of 2007) and its 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 now 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 commercial basis, JAEC created Jordan Energy Resources Inc (JERI) as its commercial arm in 2007.

In September 2008, JAEC signed an exploration agreement with Areva and created the Jordanian French Uranium Mining Company (JFMUC), a joint venture that will carry out all exploration activities leading to a feasibility study of developing resources in central Jordan. In January 2009, JAEC signed a memorandum of understanding (MoU) entitling Rio Tinto to carry out reconnaissance and prospecting in three areas (north of Al-Bahiyyah, Wadi Sahb alabiadh and Rewashid). Exploration activities by Jordanian teams in co-operation with the Chinese SinoU 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. The first phase of the exploration programme included the following activities:

- geological mapping;
- carborne radiometric survey;
- drilling and trenching programme;
- sampling;
- chemical analysis;
- environmental impact assessment;
- hydrogeological study;
- building a database inventory.

JFUMC expected to complete the first phase of the exploration programme in 2011.

In 2012, JFUMC will start the second phase of the exploration programme covering the southern part of the licence area. Resources will be evaluated and this may be the preliminary feasibility study of the project.

During 2009-2010 period, Rio-Tinto carried out very limited prospecting programme, in the very large MoU area (20 000 $km^2$). The prospecting programme included the following activities:

- airborne radiometric data processing;
- remote sensing studies;
- limited carborne radiometric survey in some areas;
- drilling of 32 boreholes down to 30 m depth;
- chemical analyses of collected borehole samples;
- gamma logging;
- limited metallurgical studies on some bulk samples.

The prospecting programme carried out was minimal and did not cover the entire MoU area. The MoU expired in July 2011.

During 2009-2010, JERI carried out a prospecting programme in Wadi Bahiya and Hasa areas (about 150 km south of the capital city, Amman). The available airborne radiometric data and the geological maps were used to delineate the potential areas for surficial uranium prospecting. The prospecting programme included the following activities:

- geological studies;
- intensive carborne radiometric surveys;
- radon survey;
- trenching programme (174 trenches);
- sampling programme (about 600 samples);
- chemical analysis (XRF, ICP, Gamma Spectrometry);
- mineralogical studies;

- delineation of mineralised zones;
- preliminary resource estimation.

Three areas were delineated as mineralised areas containing surficial uranium and a preliminary estimate of the 15 000 t $U_3O_8$ (12 720 tU) was developed. During 2011, JERI will continue the same prospecting programme in the other areas having similar geological situation, located to the north of the discovered three areas.

## Uranium production

### *Historical review*

Jordan does not currently produce uranium. In 1982, a feasibility study for uranium extraction from phosphoric acid was presented by the engineering company LURGI A.G., Frankfurt, Germany, on behalf of the Jordan Fertiliser Industry Company. This company was later purchased by the Jordan Phosphate Mines Company (JPMC). One of the extraction processes evaluated was originally found to be economically feasible, but as uranium prices dropped down in the nineties, the process became in that time uneconomic and extraction plant construction was deferred.

Feasibility studies were resumed in 1989 through the use of a micro pilot plant. These tests, which were terminated in 1990, served as the basis for preparation of a project document for a uranium extraction pilot plant from phosphoric acid.

In 2007, a total of approximately 59 360 tU was estimated to be contained in phosphate rocks in Jordan. The majority were thought to occur in the Eshidia deposits at 20 to 40 ppm, with the remainder in the smaller Al-Hassa and Al-Abiad deposits at 50 to 70 ppm.

### *Status of production capability*

Although Jordan has expressed an interest in hosting uranium mining, no firm plans are in place to develop production centres and produce uranium at this time.

## Environmental activities and socio-cultural issues

None reported.

## Uranium requirements

In 2010, Jordan announced plans to pursue the development of civil nuclear power, stating its intention to have 4 units in operation in 30 years time. A number of nuclear co-operation agreements were then signed with a number of countries including: Canada, China, France, Japan, South Korea, the Russian Federation and the United Kingdom. In 2011, Jordan reported that they would be receiving bids from NPP vendors and that the technology for the country's first nuclear reactor would be chosen by the end of the year. Currently, the Kingdom imports over 95% of its energy needs.

Following the accident at the Fukushima NPP, the plan to develop nuclear energy encountered resistance from local residents in the vicinity of the location chosen for the construction of the first plant. It was reported that the leading site for the first reactor is Balaama, near Mafraq, about 40 km north-east of Amman. An important issue in site selection is water availability, and the advantage of the Balaama site is the availability of greywater from the nearby Khirbet Al Samra wastewater treatment plant.

## National policies related to uranium

With Jordan's intention to develop a peaceful atomic energy programme for generating electricity and water desalination, the JERI is carrying out a prospecting programme in the country with the goal of achieving a degree of energy self sufficiency.

### Uranium exploration and development expenditures and drilling effort – domestic

(JOD [Jordanian dinar])

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 0 | 6 820 000 | 7 435 000 | 7 080 000 |
| Government exploration expenditures | 297 000 | 477 000 | 660 000 | 505 000 |
| Industry* development expenditures | 0 | 0 | 0 | 0 |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 297 000 | 7 297 000 | 8 095 000 | 7 585 000 |
| Industry* exploration drilling (m) | 0 | 32 231 | 29 058 | 200 000 |
| Industry* exploration holes drilled | | 1 181 | 2 422 | 1 600 |
| Government exploration drilling (m) | 0 | 0 | NA | NA |
| Government exploration holes drilled | 0 | 0 | NA | NA |
| Industry* development drilling (m) | 0 | 0 | NA | NA |
| Industry* development holes drilled | 0 | 0 | NA | NA |
| Government development drilling (m) | 0 | 0 | NA | NA |
| Government development holes drilled | 0 | 0 | NA | NA |
| Subtotal exploration drilling (m) | 0 | 32 231 | 29 058 | 200 000 |
| Subtotal exploration holes drilled | 0 | 1 181 | 2 422 | 1 600 |
| Subtotal development drilling (m) | 0 | 0 | NA | NA |
| Subtotal development holes drilled | 0 | 0 | NA | NA |
| Total drilling (m) | 0 | 32 231 | 29 058 | 200 000 |
| Total holes drilled | 0 | 1 181 | 2 422 | 1 600 |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | | | | | |
| Haematite-breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | | | | |
| Metasomatite | | | | | |
| Other* | | | 45 000 | 45 000 | *In situ* |
| Total | | | 45 000 | 45 000 | |

* 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.

### 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) | | | | | |
| Open-pit mining (OP) | | | 45 000 | 45 000 | *In situ* |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| Co-product and by-product | | | | | |
| Unspecified | | | | | |
| Total | | | 45 000 | 45 000 | |

### Reasonably assured conventional resources by processing method

(tonnes U)

| Processing method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Conventional from UG | | | | | |
| Conventional from OP | | | | | |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| In-place leaching* | | | | | |
| Heap leaching** from UG | | | | | |
| Heap leaching** from OP | | | | | |
| Unspecified | | | 45 000 | 45 000 | *In situ* |
| Total | | | 45 000 | 45 000 | |

* 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 |
| 0 | 15 000 | 15 000 |

### Speculative conventional resources

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 130/kgU | <USD 260/kgU | Unassigned |
| 0 | 50 000 | NR |

NR = Not reported.

# Kazakhstan

## Uranium exploration and mine development

### *Historical review*

In 1944, the USSR State Defense Committee ordered the Committee for Geological Affairs to conduct exploration of uranium deposits using all "geology" organisations. This regulation is the reference point of so called "mass" uranium exploration in the USSR. In 1948, the "Volkovskaya Expedition" (now Volkovgeology JSC) was established and in 1951 the Kurdai deposit was discovered, the first in Kazakhstan.

By early 1960, due to the efforts of the geological associations "Volkovgeology", "Krasnoholmskgeology", "Steppegeology" and "Koltzovskgeology", the first stage of the establishment of a uranium mineral and raw materials resource base was completed in order to provide stable operation of the Tselinnyi (later TsMCC), Prikaspian ("Kaskor") and Kara-Balty ("KMPP") refineries in Kazakhstan.

By late 1970, 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 2009 and 2010, exploration of sandstone-type deposits was performed at Kanzhugan, Moinkum, Inkai, Mynkuduk and Budenovskoye in the Shu-Sarysu uranium province and at Northern Kharassan in the Syrdaria uranium province. Re-estimation of uranium resources in vein-type deposits was also undertaken in the Northern Kazakhstan uranium province, based on geological evidence and current recovery costs.

In 2009, the Taukent Mining Chemical Plant LLP completed exploration of the Kanzhugan deposit (Kaynarskiy site) and the Betpak Dala LLP completed first stage exploration at site No. 4 of the Inkai deposit, including ISL pilot production.

In 2010, the Appak LLP completed exploration and ISL pilot production at the western site of the Mynkuduk deposit.

JV Katco continues exploration at site No. 3 (central) and detailed exploration at site No. 2 (Tortkuduk) of the Moinkum deposit and JV Inkai continues exploration at site No. 3 of the Inkai deposit. The Kyzylkum LLP and the Baiken-U LLP are performing exploration at the Northern Kharassan deposit.

In 2009, the Akbastau JSC started exploration at site No. 1 of the Budenovskoye deposit and since 2010 exploration is being performed at sites No. 3 and No. 4. ISL pilot production is ongoing at sites No. 1 and No. 3. The Zarechnoye JSC also started exploration at the South Zarechnoye deposit.

In 2011, NAC Kazatomprom JSC finished exploration at the central site of the Mynkuduk deposit and the Karatau LLP finished second stage exploration at site No. 2 of the Budenovskoe deposit. The GRK LLP also began exploration and ISL pilot production at the new Zhalpak and Moinkum site No. 3 (central) deposits.

The exploration in 2009-2010 resulted in an increase of identified resources by 19 270 tU, including an increase of reasonably assured resources by 20 942 tU and a

decrease of inferred resources by 1 672 tU. These resource increases have occurred at the Kanzhugan, Budenovskoe (sites 1, 2), Inkai (site 4), Mynkuduk (western site), Vostok and Zvezdnoe deposits.

During 2011, the Volkovgeology JSC plans to renew geological exploration of sandstone-type deposits amenable for ISL mining in new perspective areas of the Shu-Sarysu and Syrdaria uranium provinces, with funding from the state budget.

No new deposits were discovered during the reporting period.

No uranium exploration and development was performed by Kazakh enterprises outside of the Republic of Kazakhstan.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

As of 1 January 2011, identified *in situ* uranium resources recoverable at <USD 260/kgU amounted to a total of 933 655 tU, including 621 750 tU of resources amenable for ISL recovery.

In 2009-2010, a total of 31 823 tU were mined. Considering losses during mining (3 848 tU or 10.8%), 35 671 tU of resources were depleted. Whereas 31 124 tU (97.8%) were produced by ISL, 699 tU were produced by underground mining at the Vostok and Zvezdnoye deposits (depleting resources by 746 tU).

Reasonably assured resources increased by 20 942 tU as a result of geological exploration, including 91 tU at the Vostok and Zvezdnoye deposits (amenable for UG mining), 20 851 tU at Kanzhugan, Inkai (site 4), Mynkuduk (western site) and Budenovskoye (sites 1, 2) deposits, amenable for ISL. A total of 19 270 tU in sandstone deposits were transferred from prognosticated resources to reasonably assured resources and 1 672 tU were transferred from inferred resources to reasonably assured resources.

Although there were not significant changes in cost categories, a decrease in production cost of sandstone resources occurred.

All of Kazakhstan's RAR plus IR recoverable at <USD 40/kgU are associated with existing and committed production centres, whereas 93% recoverable at <USD 80/kgU are in existing and committed production centres, 81% recoverable at <USD 130/kgU are in existing and committed production centres and 62% 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 has not resulted to a significant change in the reporting period. The majority (498 000 tU) of the total of 500 000 tU of prognosticated resources are related to sandstone deposits, while the remaining 2 000 tU are vein deposits. Of the 300 000 tU of speculative resources, 90% are related to sandstone deposits and 10% to unconformity-related or vein deposits.

### *Unconventional resources and other materials*

Estimates are not made of Kazakhstan's unconventional uranium resources and other materials.

## Uranium production

### *Historical review*

Uranium mining began in 1957 with open-pit mining of the Kurdai deposit in southern Kazakhstan. Until 1978, four companies belonging to the USSR Ministry of

Middle Machine Construction (Kyrgyzski Mining Combine, Leninabadski Mining and Chemical Combine in the south, Tselinny Mining and Chemical in the north and Prikaspiiski Mining and Chemical Combine in the west) mined some 15 deposits by underground and open-pit methods, extracting a total of about 5 000 tU.

ISL production from sandstone deposits was initiated in 1978. By the early 1990s, production amounted to about 2 800 tU/yr, but declined until 2002. From 2002 on, uranium production in Kazakhstan (principally by ISL) has been increased dramatically, passing 5 000 tU/yr in 2006. In 2009, production amounted to over 14 000 tU and the Republic of Kazakhstan became the world's leading producer of uranium, a position it maintains today.

***Production capability and recent and ongoing activities***

In 2009-2010 uranium was mined at the Kanzhugan, Moinkum, Akdala, Uvanas, Mynkuduk, Inkai, Budenovskoye, North Karamurun, South Karamurun, Irkol, Zarechnoye, Semizbay, North Charasan, Vostok and Zvezdnoye deposits. All except Vostok and Zvezdnoye, where underground mining is being practiced, extract uranium by ISL.

The Uvanas, Mynkuduk (eastern site), Kanzhugan, Moinkum (southern part of site No. 1), North Karamurun, South Karamurun deposits are operated by the Mining Company LLP. The Akdala and Inkai (site No. 4) deposits are operated by JV Betpak Dala LLP. JV Katco LLP takes part in the operation of the Moinkum deposit (northern part of site No. 1 and site No. 2). The Inkai deposit (sites No. 1 and 2) is operated by JV Inkai LLP; the Budenovskoye deposit (site No. 2) by Karatau LLP; the Zarechnoye deposit by JV Zarechnoye JSC; the central site of the Mynkuduk deposit by NAC Kazatomprom JSC and the western site of the Mynkuduk deposit by Appak LLP. The Vostok and Zvezdnoye deposits are operated by Stepnogorskiy Mining and Chemical Complex LLP using underground mining and heap leaching methods.

The Semyzbay-U LLP operates Irkol deposit and since 2009 has been mining the Semyzbay deposit in the North Kazakhstan uranium province. Planned project output is 500 tU/yr in 2012.

In Syrdaria uranium province, the Kyzylkum LLP has undertaken ISL pilot production of the North Kharasan deposit (Kharasan-1), working towards commercial production of 1 000 tU/yr starting from 2015, with a further expansion to 3 000 tU/yr in 2021. The Baiken-U LLP started ISL pilot production at the North Kharasan deposit (Kharasan-2) in 2009, working towards a design capacity of 2 000 tU/yr by 2017.

In 2009, JV Akbastau JSC started pilot production by ISL at the Budenovskoye deposit (site No. 1). Design capacity of the plant is 1 000 tU/yr and since 2010 pilot ISL production is underway at site No. 3 of the Budenovskoe deposit.

In 2010, NAC Kazatomprom JSC received licences for uranium exploration and mining at the Moinkum deposit, site No. 3 (central), and for uranium exploration and pilot production at the Zhalpak deposit.

JV Inkai LLP began commercial mine production in 2008, using *in situ* leaching technology at Inkai deposits 1 and 2. This was followed by the commissioning of the main processing plant in 2010 which has a design capacity of 2 000 tU/yr.

Over the course of 2009 and 2010, uranium production in Kazakhstan amounted to a total 31 823 tU, of which 699 tU were produced be traditional underground mining methods (including 32 tU by heap leaching), and 31 124 tU by ISL (97.8% of total production).

As of 1 January 2011, the total capacity of uranium production centres in Kazakhstan is 22 000 tU/yr and current plans call for the expansion of production capacity to 25 000 tU/yr by 2015.

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, Kratau LLP, JV Betpak-Dala LLP, Inkai LLP) obtain natural uranium concentrate by sedimentation of uranium using hydrogen peroxide and further calcination without an extraction stage.

Production of natural uranium concentrates from the Vostok and Zvezdnoye deposits uses autoclave soda leaching at the hydrometallurgical plant.

### *Ownership structure of the uranium industry*

In 2010, the state share of uranium production in Kazakhstan was 55.9%, including 31.4% from NAC Kazatomprom owing to its partnership in joint-ventures and 24.5% from the Mining Company LLP, which is wholly owned by NAC Kazatomprom, a 100% state-owned company, through the Samruk-Kazyna JSC national wealth fund.

As of 10 March 2010, ownership of the Mynkuduk deposit (central site) was transferred to NAC Kazatomprom.

The Mining Company LLP includes the following production centres: Taukent Mining and Chemical Plant LLP, Stepnoye Mining Group LLP, Mining Group-6 LLP, all of which produce uranium by ISL.

As of 1 January 2011, NAC Kazatomprom had shares in nine joint ventures with private companies from Canada, Japan and Kyrgyzstan (JV Betpak Dala LLP, JV Inkai LLP, JV Katco LLP, Appak LLP, Kyzylkum LLP and Baiken-U LLP), and with foreign state companies of the Russian Federation, China and France (JV Zarechnoye JSC, JV Akbastau JSC, Karatau LLP, Semizbai-U LLP and JV Katko LLP).

All of the shares of the Stepnogorsk Mining-Chemical Complex LLP (SMCC LLP) belong to a foreign private company. The Mining-Chemical Complex mines deposits by the underground method.

In 2011, all shares of the Russian state company in JV Zarechnoye JSC, JV Akbastau JSC and Karatau LLP were transferred to a Canadian private company.

In 2010, the production share of private foreign companies of Canada, Japan and Kyrgyzstan in Kazakhstan amounted to 22.8%, while the share of state foreign companies of the Russian Federation, France and China in Kazakhstan amounted to 21.3% of total production.

### *Employment in the uranium industry*

Owing to the expansion of uranium production in 2009 and 2010, Kazakhstan experienced a shortage of qualified staff. As a result, training was conducted in two educational centres to prepare qualified personnel, drawing on local residents of the Kyzylorda region (Shieli) and the southern Kazakhstan region (Taukent), near the location of the production centres. The Kazakhstan Nuclear University, founded by NAC Kazatomprom JSC, and the Regional Geotechnology Training Center were involved in retraining and raising skill levels of new personnel. New uranium production centres also create opportunities for students of higher and secondary technical institutes in Kazakhstan.

According to the subsoil use contracts, annual obligatory training expenses amount to about 1% of annual exploration expenses and 1% of annual expenses for uranium production in the production period.

## Uranium production centre technical details

(as of January 2011)

| | Centre #1 | Centre #2 | Centre #3 | Centre #4 | Centre #5 | Centre #6 | Centre #7 | Centre #8 |
|---|---|---|---|---|---|---|---|---|
| Name of production centre | Taukent Mining Chemical Plant LLP | Stepnoye Mining Group LLP | Mining group-6 LLP | Betpak-Dala JV LLP | Katko JV LLP | Inkai JV LLP | Stepnogorsk Mining Chemical Complex LLP | Zarechnoe JV JSC |
| Production centre classification | Existing | Existing | Existing | Existing | Existing | Existing | Existing | Existing |
| Start-up date | 1982 | 1978 | 1985 | 2001 | 2004 | 2004 | 1958 | 2007 |
| Source of ore: | | | | | | | | |
| Deposit name(s) | Kanzhugan, Mpinkum (sites 1, 3) | Mynkuduk (eastern site), Uvanas | North & South Karamurun | Akdala, Inkai (site 4) | Moinkum (sites 1, 2, 3) | Inkai (sites 1, 2, 3) | Vostok, Zvezdnoe | Zarechnoye, South Zarechnoye |
| Deposit type(s) | Sandstone | Sandstone | Sandstone | Sandstone | Sandstone | Sandstone | Vein-stockwork | Sandstone |
| Recoverable resources (tU) | 35 621 | 18 622 | 26 197 | 39 524 | 44 955 | 156 594 | 9 718 | 17 270 |
| Grade (% U) | 0.046 | 0.032 | 0.081 | 0.048 | 0.074 | 0.047 | 0.167 | 0.050 |
| Mining operation: | | | | | | | | |
| Type (OP/UG/ISL) | ISL | ISL | ISL | ISL | ISL | ISL | UG | ISL |
| Size (tonnes ore/day) | | | | | | | 1 000 | |
| Average mining recovery (%) | 87 | 90 | 91 | 90 | 85 | 80 | 90 | 94 |
| Processing plant: | | | | | | | | |
| Acid/alkaline | Acid | Acid | Acid | Acid | Acid | Acid | Acid | Acid |
| Type (IX/SX) | IX, SX | IX | IX | IX | IX | IX | SX, AL | IX |
| Size (tonnes ore/day) | 50 000 | 45 000 | 40 000 | 80 000 | 100 000 | 60 000 | 1 000 | 60 000 |
| Average process recovery (%) | 98.9 | 98.7 | 98.7 | 98.9 | 98.9 | 98.5 | 92.5 | 98.5 |
| Nominal production capacity (tU/year) | 1 200 | 1 300 | 1 000 | 3 000 | 4 000 | 1 500 | 500 | 1 000 |
| Plans for expansion | Yes | No | No | No | No | Yes | No | Yes |
| Other remarks | | | | | | | | |

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**Uranium production centre technical details** (*continued*)

(as of January 2011)

| | Centre #9 | Centre #10 | Centre #11 | Centre #12 | Centre #13 | Centre #14 | Centre #15 | Centre #16 |
|---|---|---|---|---|---|---|---|---|
| Name of production centre | Karatau LLP | NAC Kazatomprom JSC | Appak LLP | Kyzylkum LLP | Bayken-U LLP | Akbastau JV JSC | Semyzbai-U LLP | NAC Kazatomprom JS |
| Production centre classification | Existing | Existing | Existing | Existing | Existing | Existing | Existing | Committed |
| Start-up date | 2007 | 2007 | 2008 | 2008 | 2009 | 2009 | 2007 | 2012 |
| Source of ore: | | | | | | | | |
| Deposit name(s) | Budenovskoe (site 2) | Mynkuduk (central site) | Mynkuduk (western site) | North Kharasan (site 1) | North Kharasan (site 2) | Budenovskoe (sites 1, 3, 4) | Semyzbai, Irkol | Zhalpak |
| Deposit type(s) | Sandstone | Sandstone | Sandstone | Sandstone | Sandstone | Sandstone | Sandstone | Sandstone |
| Recoverable resources (tU) | 20 342 | 47 053 | 25 308 | 33 937 | 24 447 | 23 075 | 44 575 | 14 525 |
| Grade (% U) | 0.094 | 0.032 | 0.032 | 0.108 | 0.108 | 0.094 | 0.050 | 0.035 |
| Mining operation: | | | | | | | | |
| Type (OP/UG/ISL) | ISL | ISL | ISL | ISL | ISL | ISL | ISL | ISL |
| Size (tonnes ore/day) | | | | | | | | |
| Average mining recovery (%) | 85 | 90 | 90 | 90 | 90 | 85 | 87 | 90 |
| Processing plant: | | | | | | | | |
| Acid/alkaline | Acid | Acid | Acid | Acid | Acid | Acid | Acid | Acid |
| Type (IX/SX) | IX | IX | IX | IX | IX | NA | IX | IX |
| Size (tonnes ore/day) | 80 000 | 60 000 | 40 000 | 40 000 | 0 | 0 | 50 000 | 0 |
| Average process recovery (%) | 98.9 | 98.5 | 98.9 | 98.5 | 98.5 | 98.9 | 98.5 | NA |
| Nominal production capacity (tU/year) | 3 000 | 1 400 | 1 000 | 1 000 | 2 000 | 3 000 | 1 100 | 0 |
| Plans for expansion | No | Yes | No | Yes | Yes | Yes | Yes | Yes |
| Other remarks | | | | | | | | |

### *Future production centres*

In 2009-2010, no new centres for uranium exploration and production were established.

In 2010, NAC Kazatomprom JSC received two licences for uranium exploration and production of two sandstone deposits – Zhalpak and Moinkum (site No. 3).

ISL pilot production at the Zhalpak deposit is scheduled to begin by 2013 (identified resources 14 525 tU with an average grade of 0.035% U), with realisation of total mine design capacity of 750 tU/yr planned by 2016. Mining Company LLP began development of this deposit in 2011.

ISL pilot production at the Moinkum deposit, northern part of site No. 3 (central), where IR total 10 091 tU with an average grade of 0.052% U, is scheduled to begin in 2012 with realisation of design capacity of 500 tU/year targeted by 2018. Exploration and ISL uranium production will be carried out by the Taukent Mining Chemical Plant LLP.

Once exploration 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 socio-cultural issues

### *Environmental activities*

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.

Environmental protection activities of enterprises and organisations within the Holding corporate management are being fulfilled in accordance with legislation, other by-laws and regulatory documents. Statutory acts regulating negative impacts on the environment were developed, including requirements for documenting emission and pollutant discharges.

In the reporting period a significant reduction in emissions and pollutant discharges were achieved at major enterprises due to the implementation of environmental activities. Production of waste volumes and consumption of material inputs are being minimised.

A new organisation for remediation of land after ISL mining has been created (part of Kazatomprom-Mining-Company LLP) and a long-term, “step-by-step” programme for disposition of mined-out blocks at ISL sites was developed.

The first stage (2007-2010) involved remediation of mined-out blocks of the Uvanas deposit, exploited since 1978, with a total area of 284 ha reclaimed. A total of 4 015 wells were removed and 16 ponds reclaimed at a total cost of KZT 301.6 million (Kazakhstani tenge). In 2011, remediation works were scheduled to start on the Kanzhugan deposit.

Uranlikvidrudnik RSE finished reclamation of areas of closed uranium mines (2001-2010), as well as liquidation and shutdown of pits in accordance with the Governmental Decree #1006 (25 July 2001). By Governmental Decree #602 (30 May 2011) Uranlikvidrudnik RSE was closed out.

As a result of the planned remediation works, the following was achieved:

- Reduction of contamination levels to regulatory requirements at all 12 sites undergoing remediation over a territory containing 15 historical geological survey sites and also 2 fields of the Koshkar-Ata tailing pond.
- Termination of dust production at radioactive dumps and minimisation of radon emissions to the environment.
- Prevention of unauthorised use of materials from radioactive dumps.
- Prevention of radioactive contamination of national park "Kokshetau", rivers Ishim, Iman-Burluk.
- Burial of 206 sealed orphan sources.
- Receipt of monitoring data following remediation works during 2005-2010.
- Examination of eight geological survey sites in the Karaganda, Akmola, north and east regions of Kazakhstan.

Between 2001-2010 a total of KZT 4 217.082 million was spent to realise the abovementioned achievements.

### *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).

Demeu-Kazatomprom LLP, established at the end of 2004, is responsible for social and cultural issues related to uranium production in Kazakhstan.

**Expenditures on environmental activities and socio-cultural issues in 2009-2010**

(KZT million)

| | 2009 | 2010 | Total |
|---|---|---|---|
| Environmental impact assessments | 180 | 153 | 333 |
| Monitoring | 197 | 187 | 384 |
| Tailings impoundment | 258 | 258 | 516 |
| Waste rock management | 180 | 226 | 406 |
| Effluent management | 100 | 132 | 232 |
| Site rehabilitation | 245 | 5 | 250 |
| Regulatory activities | 9 | 5 | 14 |
| Social and/or cultural issues | 3 903 | 2 513 | 6 416 |

## Uranium requirements

Internal demand for natural and enriched uranium is not expected in Kazakhstan until 2020. Construction of a NPP (VBER-300 reactor) is under consideration. The NPP could be constructed in the Mangistau region, where the fast-breeder reactor BN-350 had operated between 1973 and 1998. The reactor has been shut down and the fuel packaged and placed in long-term storage.

### *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*

National policy in the area of atomic energy use targeted:

- creation of a basis for the development of nuclear power;
- further development of uranium production and processing enterprises, development of related industry sectors;
- development of nuclear science to assist development of nuclear energy and uranium production;
- protecting the health of the population, environment, and the remediation of radioactive contaminated territories;
- improvement of education and build-up of qualified personnel in the nuclear industry;
- improving regulations in nuclear area;
- assurance of radiation, nuclear and industrial safety and the security of nuclear sites;
- assurance of non-proliferation of nuclear weapons;
- development of international co-operation in field of atomic energy use.

In 2010 a new programme for the development of the nuclear industry was launched in the Republic of Kazakhstan for the period 2011-2014 with a view to developments to 2020. The objective is the priority development of the nuclear industry and the creation of a civil nuclear programme as a platform for accelerating industrial innovation and country development.

Implementation of this programme will allow the optimal use of available resources, increase the country's export capacity, assure environmental protection and the safety of energy technologies, development nuclear technologies, as well as social and economic development of regions in Kazakhstan and developments in other areas.

Programme planning includes:

- creation of conversion facilities by 2016 with a capacity 12 000 $tUF_6$/yr, with a Kazatomprom share of 6 000 $tUF_6$/yr;
- creation of a 400 t/yr fuel assembly facility at the Ulba metallurgical plant;

- creating a partnership with the Russian Federation for assured supply of 2.5 million SWU/yr of enrichment;
- building a new NPP by 2020, pending positive government decisions.

The estimated total cost of this 2011-2020 programme is KZT 1 161 428.0 million of which:

- KZT 1 134 092.0 million will be off budget, and;
- KZT 27 336.0 million will be from the budget.

Kazakhstan has also offered to host an IAEA bank of low enrichment uranium in the country.

### *Uranium stocks*

There are no stocks of enriched uranium or nuclear fuel in Kazakhstan.

**Uranium exploration and development expenditures and drilling effort – domestic**

(KZT millions)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 5 051 | 8 528 | 7 324 | 9 168 |
| Government exploration expenditures | 0 | 0 | 0 | 654 |
| Industry* development expenditures | 4 351 | 433 | 1 112 | 1 001 |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 9 402 | 8 961 | 8 436 | 10 823 |
| Industry* exploration drilling (m) | 716 766 | 827 602 | 1 231 684 | 1 007 941 |
| Industry* exploration holes drilled | 1 368 | 1 756 | 2 670 | 2 055 |
| Government exploration drilling (m) | 0 | 0 | 0 | 20 000 |
| Government exploration holes drilled | 0 | 0 | 0 | 95 |
| Industry* development drilling (m) | 137 096 | 419 352 | 505 758 | 610 825 |
| Industry* development holes drilled | 325 | 1 068 | 1 451 | 1 593 |
| Government development drilling (m) | 0 | 0 | 0 | 0 |
| Government development holes drilled | 0 | 0 | 0 | 0 |
| Subtotal exploration drilling (m) | 716 766 | 827 602 | 1 231 684 | 1 027 941 |
| Subtotal exploration holes drilled | 1 368 | 1 756 | 2 670 | 2 150 |
| Subtotal development drilling (m) | 137 096 | 419 352 | 505 758 | 610 825 |
| Subtotal development holes drilled | 325 | 1 068 | 1 451 | 1 593 |
| Total drilling (m) | 853 862 | 1 246 954 | 1 737 442 | 1 638 766 |
| Total number of holes drilled | 1 693 | 2 824 | 4 121 | 3 743 |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | |
| Sandstone | 19 777 | 278 875 | 314 133 | 314 133 | NA |
| Hematite breccia complex | 0 | 0 | 0 | 0 | |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | |
| Vein | 0 | | 21 078 | 97 026 | NA |
| Intrusive | 0 | 0 | 0 | 0 | |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | |
| Metasomatite | 0 | 0 | 0 | 0 | |
| Other** | 0 | 0 | 29 184 | 47 193 | NA |
| Total | 19 777 | 278 875 | 364 395 | 458 352 | 87.8 |

* *In situ* resources reported with recovery factors provided.

****** Phosphorite and uranium-coal deposit type.

### 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 | 16 375 | 110 332 | 83 |
| Open-pit mining (OP) | 0 | 0 | 47 237 | 47 237 | 91 |
| *In situ* leaching acid | 19 777 | 278 875 | 300 783 | 300 783 | 89 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | NA | NA | NA | NA | |
| Unspecified | NA | NA | NA | NA | |
| Total | 19 777 | 278 875 | 364 395 | 458 352 | 87.8 |

* *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 | 0 | 16 375 | 110 332 | 83 |
| Conventional from OP | 0 | 0 | 47 237 | 47 237 | 91 |
| *In situ* leaching acid | 19 777 | 278 875 | 300 783 | 300 783 | 89 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching** | NA | NA | NA | NA | |
| Heap leaching*** from UG | NA | NA | NA | NA | |
| Heap leaching*** from OP | NA | NA | NA | NA | |
| Unspecified | NA | NA | NA | NA | |
| Total | 19 777 | 278 875 | 364 395 | 458 352 | 87.8 |

* *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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | | |
| Sandstone | 34 116 | 274 320 | 333 558 | 333 558 | NA |
| Hematite breccia complex | 0 | 0 | 0 | | |
| Quartz-pebble conglomerate | 0 | 0 | 0 | | |
| Vein | 0 | | 18 566 | 139 461 | NA |
| Intrusive | 0 | 0 | 0 | | |
| Volcanic and caldera-related | 0 | 0 | 0 | | |
| Metasomatite | | | | | |
| Other** | 0 | | 0 | 2 284 | NA |
| Total | 34 116 | 274 320 | 352 124 | 475 303 | 87.8 |

* *In situ* resources.

****** Phosphorite and uranium-coal deposit type.

### 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 | 12 686 | 135 865 | 83 |
| Open-pit mining (OP) | 0 | 0 | 18 471 | 18 471 | 91 |
| *In situ* leaching acid | 34 116 | 274 320 | 320 967 | 320 967 | 89 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | NA | NA | NA | NA | |
| Unspecified | NA | NA | NA | NA | |
| Total | 34 116 | 274 320 | 352 124 | 475 303 | 87.8 |

* *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 | 0 | 12 686 | 135 865 | 83 |
| Conventional from OP | 0 | 0 | 18 471 | 18 471 | 91 |
| *In situ* leaching acid | 34 116 | 274 320 | 320 967 | 320 967 | 89 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching** | NA | NA | NA | NA | |
| Heap leaching*** from UG | NA | NA | NA | NA | |
| Heap leaching*** from OP | NA | NA | NA | NA | |
| Unspecified | NA | NA | NA | NA | |
| Total | 34 116 | 274 320 | 352 124 | 475 303 | 87.8 |

* *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.

### Prognosticated conventional resources

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 80/kgU | <USD 130/kgU | <USD 260/kgU |
| 335 000 | 498 000 | 500 000 |

### Speculative conventional resources

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 130/kgU | <USD 260/kgU | Unassigned |
| 227 000 | 300 000 | NA |

### Historical uranium production by deposit type

(tonnes U in concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 56 065 | 8 037 | 13 673 | 17 451 | 95 226 | 19 568 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 | 0 |
| Vein | 40 705 | 475 | 347 | 352 | 41 879 | 400 |
| Intrusive | 0 | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 | 0 |
| Other* | 21 618 | 0 | 0 | 0 | 21 618 | 0 |
| Total | 118 388 | 8 512 | 14 020 | 17 803 | 158 723 | 19 968 |

* 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.

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 21 618 | 0 | 0 | 0 | 21 618 | 0 |
| Underground mining[1] | 40 705 | 475 | 347 | 352 | 41 879 | 400 |
| *In situ* leaching | 56 065 | 8 037 | 13 673 | 17 451 | 95 226 | 19 568 |
| Co-product/by-product | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 118 388 | 8 512 | 14 020 | 17 803 | 158 723 | 19 968 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 118 388 | 8 512 | 14 020 | 17 803 | 158 723 | 19 968 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** | 250 | 54 | 22 | 10 | 336 | 10 |
| U recovered from phosphate rocks | 0 | 0 | 0 | 0 | 0 | 0 |
| Other methods*** | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 118 388 | 8 512 | 14 020 | 17 803 | 158 723 | 19 968 |

* 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 2010

| Domestic | | | | Foreign | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | | |
| (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) |
| 9 959 | 56 | - | - | 3 785 | 21 | 4 059 | 23 | 17 803 | 100 |

## Uranium industry employment at existing production centres

(person-years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 7 940 | 9 261 | 8 828 | 8 550 |
| Employment directly related to uranium production | 6 598 | 7 456 | 6 718 | 7 792 |

## Short-term production capability

(tonnes U/year)

| 2011 | | | | 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 |
| 18 000 | 18 000 | 22 000 | 22 000 | 19 000 | 20 000 | 24 000 | 25 000 | 20 000 | 21 000 | 24 000 | 25 000 |

| 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 |
| 12 000 | 13 000 | 14 000 | 15 000 | 10 000 | 11 000 | 12 000 | 13 000 | 4 000 | 5 000 | 5 000 | 6 000 |

### Installed nuclear generating capacity to 2035

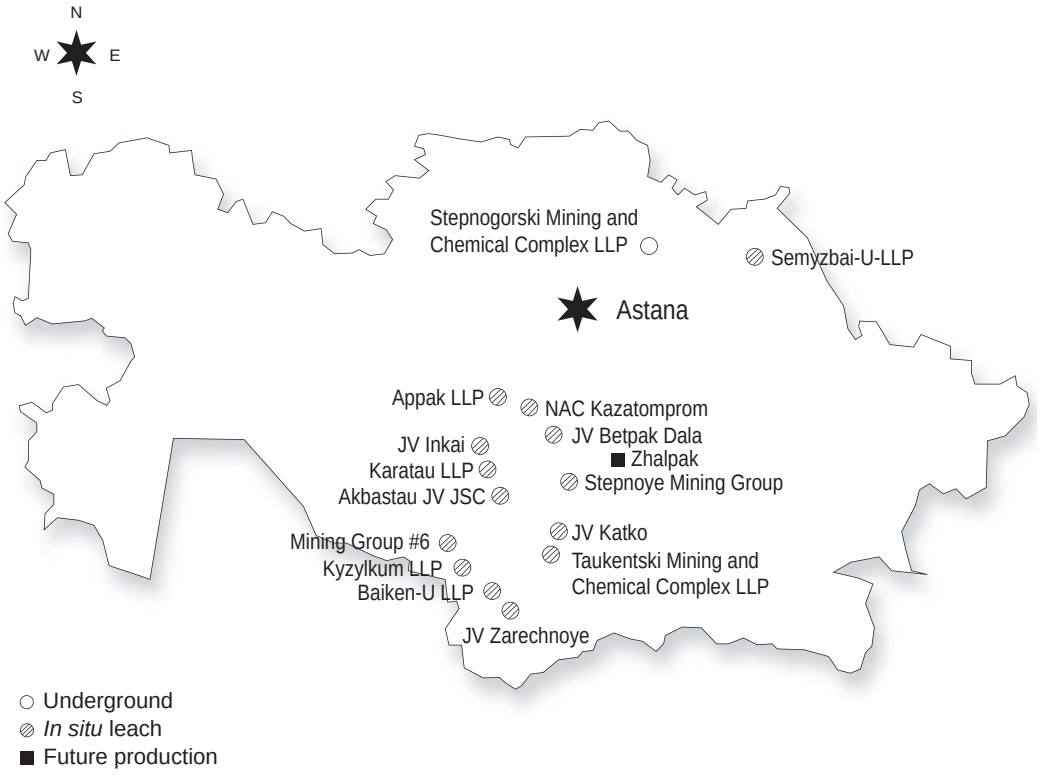
(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 0 | 0 | 0 | 0 | 0 | 0 | NA | 600 | NA | NA | NA | NA | NA | NA |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 0 | 0 | 0 | 0 | 0 | 0 | NA | NA | NA | NA | NA | NA | NA | NA |





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# Malawi*

## Uranium exploration and mine development

### *Historical review*

In the early 1980s, the Central Electricity Generating Board of Great Britain (CEGB) discovered mineralisation in the sandstones of Kayelekera. Extensive drilling from 1982 to 1988 defined an initial inferred resource of 9 800 tU at an average grade of 0.13% U. From 1989 to 1992, geotechnical, metallurgical, hydrological and environmental works were conducted, as well as a feasibility study to assess the viability of a conventional open-pit mining operation. This work was completed in 1991 at a total cost of USD 9 million. The CEGB study concluded that the project was uneconomic using the mining model adopted and the low uranium prices of that time and the project was abandoned in 1992.

In 1998, Paladin Resources Ltd (Paladin Energy Ltd as of 1 February 2000) acquired an interest in the Kayelekera project through a joint venture with Balmain Resources Ltd which then held exploration rights over the project area. Engineering and financial evaluation work indicated a positive outcome for the project. In 2004, additional drilling was completed to improve confidence in resource estimates, and the pre-feasibility study was updated. Resource drilling and bulk sample drilling for metallurgical test-works were completed in 2005 and a bankable feasibility study was then undertaken. Paladin purchased Balmain's remaining stake in the project in 2005 and became the sole owner.

The Kayelekera uranium deposit is a sandstone-hosted uranium deposit, located close to the north tip of the North Rukuru Basin. This basin contains a thick (at least 1 500 m) sequence of Permian Karoo sandstones preserved in a semi-graben about 35 km to the west of and broadly parallel to the Lake Malawi section of the East African Rift System.

The Kayelekera mineralisation lies within the uppermost 150 m of the Muswanga Member, which is the upper part of the Karoo formation. The Muswanga Member consists of a total of eight separate arkose units with intervening silty mudstones in an approximate 1:1 ratio. Such a succession is indicative of cyclic sedimentation within a broad, shallow, intermittently subsiding basin.

The arkose units contain most of the uranium mineralisation. They are on average about 8 m thick, are generally coarse grained and poorly sorted, and contain a high percentage of fresh, pink feldspar clasts. The basal layer of arkose units is usually a quartz-feldspar pebble conglomerate.

Coffinite has been identified as the principal uranium bearing species and it occurs together with minor uraninite. Near surface weathering of primary ore has produced a zone of oxide ore characterised by yellow and green secondary uranium minerals

* Report prepared by Secretariat, and based on information from the *Environmental Impact Study* (Knight Piesold, 2007), the Paladin Energy internet site (www.paladinenergy.com.au/index.aspx) and the Resource Star internet site (www.resourcestar.com.au).

(meta-autunite and boltwoodite). Approximately 40% of the total ore is reduced arkose, 30% oxydised arkose, 10% mixed arkose and 20% of the mudstone type.

Historical studies indicate that economically recoverable resources of uranium and coal only occur within the Kayelekera area. Coal is present in the project tenement area in two deposits: the Nkhachira deposit (850 000 tonnes, recoverable by open-pit and underground mining) and in association with the Kayelekera deposit. Coal in the Kayelekera deposit is contained within the uranium resources and is therefore unavailable for commercial extraction. Moreover, this coal is of very low quality.

### *Recent and ongoing uranium exploration and mine development activities*

The Livingstonia uranium project is a joint venture between Resource Star and Globe Metals and Mining. Global Metals are holders of the prospecting licence, and Resource Star manages the work and earns equity in the project. The geologic setting is very similar to that at Kayelekera with Karoo sandstones being preserved in a large down-faulted block. The uranium mineralisation is contained in several layers in a relatively permeable sandstone package between a basal coal measure and a mudstone cap.

In 2006, Globe drilled 94 holes totalling 11 533 m. Resource Star did an additional 1 502 m of drilling in 13 holes to prove up a JORC compliant inferred resource of 7.7 million tonnes at 229 ppm U in July 2010. Given the high potential for additional resources, follow-up drilling was expected to continue through 2011.

Globe Metals and Mining has its Kanyika Niobium project in central Malawi that they started work on in 2006. Uranium is an important by-product in the complex polymetallic ore. A scoping study was completed in June 2008 with positive results and investigations continued. A pre-feasibility study commenced in 2008 which resulted in the initiation of a bankable feasibility study (BFS) in mid-2009. Completion of this BFS is scheduled for mid-2012. Initial plans indicate mine construction will commence in 2013 with production commencing in 2014. An initial mining rate of 1.5 Mt ore/yr is planned which would result in the production of about 100 tU/yr as a by-product. An environmental impact and social assessment study is underway as are negotiations with the Malawian government to finalise a Development Agreement.

The feasibility study and the environmental impact study of the Kayelekera project were finalised in early 2007 and a mining licence was obtained in April 2007. Construction of the project started later that year at a budgeted cost of USD 200 million. Major infrastructure upgrades to local roads were required. The construction project workforce peaked at around 2 000 (more than 75% Malawian nationals). Open-pit mining began in June 2008, commissioning of the production facility took place in January 2009, and the Kayelekera mine was officially opened in April 2009.

In 2010, Paladin Energy conducted an infill and extension drilling programme of the Kayelekera mine totalling 67 holes and 7 061 m. A further 3 084 m of drilling in 25 holes were completed in exploration areas to the north-west and south of the mine area. Ongoing exploration work is aimed at extending the existing orebody as well as identifying and evaluating new ore bodies.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

Malawi's *in situ* identified resources recoverable at costs <USD 260 have increased from 15 100 tU to 21 500 tU. This is largely the result of Resource Star's maiden declaration of resources for its Livingstonia project and by Global Metals for its Kanyika project. A small proportion of the increase results from the infill and extension drilling carried out at Kayelekera.

Resource Star has made no plans to commence production but exploration work is being continued to extend the resource base.

The majority of the resources are found in sandstone hosted deposits in the northern part of Malawi. A small contribution is from uranium as a by-product to intrusive hosted complex polymetallic REE mineralisation.

## Uranium production

### *Historical review*

The Kayelekera mine is located in the Karonga district of the northern region of Malawi, about 600 km by road from the capital city of Lilongwe. Transport of the first product to Walvis Bay, Namibia, via Zambia, took place on 17 August 2009. Uranium production by open-pit mining with an annual production of 1 270 tU was planned with a mine life of nine years. Nameplate capacity was expected to be achieved in mid-2012.

Kayalekera is the first mine to have produced uranium in Malawi and is currently the only producer. However Globe Metals and Mining's Kanyika Niobium project is planned to come on stream in 2014 and will produce a small but significant amount of uranium as a by-products.

### *Status of production capability and recent and ongoing developments*

In 2010, Paladin Energy announced that expansion to a capacity of 1 460 tU/yr would be undertaken with a completion date of mid-2013. Mine life was also increased to 11 years as processing of marginal ores at the end of mining operations is expected to add additional years to the mine life of the facility. The final open-pit dimensions are expected to be in the order of 300 m wide, by 600 m long and 130 m deep. The stripping ratio (waste to ore) is expected to be on average 2.4:1.

Uranium is recovered using a solvent extraction process, with sulphuric acid as the lixiviant and sulphur dioxide/air mixture as the oxidant. The plant utilises a resin-in-pulp (RIP) process which is a first in the Western world for uranium production. Expected uranium mill recovery is 90%. Production was hampered in 2009 and 2010 by technical problems with the RIP process. In addition, land slip problems in 2010 have resulted in remediation work being implemented and made necessary relocation of certain parts of the plant and machinery.

### *Ownership structure of the uranium industry*

Two companies are active in Malawi in the primary uranium sector. Paladin Energy Ltd, an Australian listed public company, holds an 85% interest in the Kayelekera project through its subsidiary company Paladin (Africa) Limited. The remaining 15% is held by the Republic of Malawi according to terms of the Development Agreement signed in 2007. Paladin supplements ongoing mining with extensive exploration activities aimed at growing its resource base in Malawi. Resource Star Ltd, an Australian based junior company is involved in uranium exploration to the south of Kayelekera as well as rare earth exploration activities elsewhere in Malawi. Global Metals is also involved in rare earth exploration but with significant uranium by-product potential.

## Environmental activities and socio-cultural activities

The commencement of mining at Kayelekera met with considerable resistance from religious groups, civil rights groups and NGOs but these have largely been resolved. Environmental legislation requires that a comprehensive environmental impact and social assessment report be submitted to government before mining can commence, to ensure the protection of local communities and society in general.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

All mining activities are under the control of the Department of Mines of the Ministry of Natural Resources with environmental matters falling under the Department of Environmental Affairs in the same ministry. However, in common with many developing countries, Malawi has no specific legislation or a regulation relating to uranium, but it is working in co-operation with the IAEA to develop appropriate legislation. In 2011 the National Assembly passed an atomic energy bill which is the first step of the introduction of comprehensive legislation to provide for adequate protection of people as well as the environment against harmful effects of radiation, nuclear material and radioactive materials.

Government is committed to putting in place policies that will attract private sector participation in the exploration, exploitation, processing and utilisation of Malawi's mineral resources. It is at all times mindful of the principles of sustainable development and utilisation as well as the protection of the environment and society in general.

**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 (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 9 990 | 9 990 | 80 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 1 349 | 80 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 9 990 | 11 339 | 80 |

*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.

**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 | 0 | 0 | |
| Open-pit mining (OP) | 0 | 0 | 9 990 | 11 339 | 80 |
| *In situ* leaching | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 0 | 9 990 | 11 339 | |

### 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 | 0 | | 9 990 | 11 339 | 80 |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** | 0 | 0 | 0 | 0 | |
| Total | 0 | | 9 990 | 11 339 | 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 2 331 | 3 740 | 80 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 2 007 | 80 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 2 331 | 5 747 | 80 |

* 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.

### 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 | 0 | 0 | 0 |
| Open-pit mining (OP) | 0 | 0 | 2 331 | 3 740 | 80 |
| *In situ* leaching | 0 | 0 | 0 | 0 | 0 |
| Co-product and by-product | 0 | 0 | 0 | 2 007 | 80 |
| Unspecified | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 2 331 | 5 747 | 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 | 0 | 0 | 2 331 | 5 747 | 80 |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** | 0 | 0 | 0 | 0 | |
| Total | 0 | 0 | 2 331 | 5 747 | |

* 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 concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 90 | 681 | 771 | 1 000 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 90 | 681 | 771 | 850 |

* 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.

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 0 | 0 | 90 | 681 | 771 | 850 |
| Underground mining[1] | 0 | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching | 0 | 0 | 0 | 0 | 0 | 0 |
| Co-product/by-product | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 90 | 681 | 771 | 850 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 0 | 0 | 90 | 681 | 771 | 850 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** | 0 | 0 | 0 | 0 | 0 | 0 |
| U recovered from phosphate rocks | 0 | 0 | 0 | 0 | 0 | 0 |
| Other methods*** | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 90 | 681 | 771 | 850 |

* 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.



# Mexico

## Uranium exploration and mine development

### *Historical review*

Uranium exploration began in 1957 with both ground and aerial prospecting with geological and radiometric methods. National exploration efforts were initially hampered by limited technical and financial resources, but these problems were alleviated with 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, Querétaro 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*

Renewed interest in nuclear power has resulted in renewed exploration activities in Mexico. This initially involves the selection of prospective areas for uranium through analyses of the available technical information and field visits to the most favourable areas (Chihuahua, Nuevo León, Sonora, Oaxaca y Puebla).

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

| Projects | Tonnes | % uranium |
|---|---|---|
| Los Amoles, Sonora State | 293 410 | 0.172 |
| La Coma, Nuevo Leon State | 1 132 000 | 0.158 |
| Peña Blanca, Chihuahua State Margaritas | 660 000 | 0.0992 |
| Puerto III | 442 000 | 0.1107 |
| Nopal I | 284 000 | 0.117 |

Past evaluation of these projects by URAMEX do not fulfil the international standards of evaluation. Potential was demonstrated however, and the Mexican Geological Survey has begun a programme to evaluate resources following international standards. The first results of this programme are presented here.

### *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. The deposit contains a total of about 80 million tonnes with a uranium content of about 0.004% $U_3O_8$ (0.003% U). Re-evaluation indicates a total of 3 200 tU is available at a cost of <USD 40/kgU.

## Uranium production

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 2011, two boiling water reactors with a total installed capacity of 1.35 GW net were in operation at the Laguna Verde NPP. These two units have been in operation since 1990 and 1995. The Federal Electricity Commission (CFE) completed an extended power upgrade programme in 2011 on the two reactors, resulting in about a 20% increase in capacity. The project also extended the operating life of the 2 reactors to 40 years, pending regulatory approval. The two units supply about 4-5% of the country's electricity. The Mexican government is reportedly considering building new reactors to meet rising demand and to limit greenhouse gas emissions.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

The 1984 Act on Nuclear Activities, adopted pursuant to Article 27 of the Constitution entered into force on 5 February 1985. It specifies that the exploration, exploitation and 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*

After URAMEX was dissolved in 1985, activities for the exploration, exploitation and benefit of uranium were suspended. In 2008, the Mexican Geological Survey restarted activities on uranium exploration with the analysis, reinterpretation and re-evaluation of existing data, with the aim of developing a database meeting international reporting standards, and additional field work.

### Uranium exploration and development expenditures and drilling effort – domestic

(USD)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 50 000 | 100 000 | 150 000 | 500 000 |
| Government exploration expenditures | | | | |
| Industry* development expenditures | | | | |
| Government development expenditures | | | | |
| Total expenditures | 50 000 | 100 000 | 150 000 | 500 000 |
| Industry* exploration drilling (m) | | | | |
| Industry* exploration holes drilled | | | | |
| Government exploration drilling (m) | | | | |
| Government exploration holes drilled | | | | |
| Industry* development drilling (m) | | | | |
| Industry* development holes drilled | | | | |
| Government development drilling (m) | | | | |
| Government development holes drilled | | | | |
| Subtotal exploration drilling (m) | | | | |
| Subtotal exploration holes drilled | | | | |
| Subtotal development drilling (m) | | | | |
| Subtotal development holes drilled | | | | |
| Total drilling (m) | | | | |
| Total number of holes drilled | | | | |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | | 1 783 | 1 783 | 1 783 | *In situ* |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | 1 975 | 1 975 | 1 975 | *In situ* |
| Metasomatite | | | | | |
| Other* | | | | | |
| Total | | 3 758 | 3 758 | 3 758 | |

* 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.

### 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) | | | | | |
| Open-pit mining (OP) | | 1 975 | 1 975 | 1 975 | *In situ* |
| *In situ* leaching acid | | 1 783 | 1 783 | 1 783 | *In situ* |
| *In situ* leaching alkaline | | | | | |
| Co-product and by-product | | | | | |
| Unspecified | | | | | |
| Total | | 3 758 | 3 758 | 3 758 | |

### Net nuclear electricity generation

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 10.1 | 5.6 |

### Installed nuclear generating capacity to 2035

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 1 350 | 1 350 | | | | | 1 634 | | | | | | | |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 229 | 229 | | | | | 365 | | | | | | | |

# 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 deposits of brown coal in eastern Mongolia.

Between 1970 and 1990, under a bilateral agreement between the People's Republic of Mongolia and the 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 1:25 000 and 1:50 000 were conducted over 420 000 $km^2$, some 27% of Mongolian territory; at a scale 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 were conducted. The territory along the border with 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, hosts different deposit types, mineral associations and ages of mineralisation vary. Within these provinces, 9 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 70-250 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, Mardain gol, 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 terriginous sediments related to stratum oxidation and restoration. The district units include a perspective uranium deposit in the south, near the Dulaan uul and Nars deposits and numerous occurrences, as well as perspective uranium-bearing basins, such as Tamsag, Sainshand, Zuunbayan 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 of 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-rare earth elements related to alkaline mineralisation, uranium-thorium in metasomatites, pegmatite, magmatic and the silicon schist uranium host rock.

***Recent and ongoing uranium exploration and mine development activities***

Uranium exploration expenditures decreased from MNT 33 908 million (Mongolian tugrik) in 2008 to MNT 16 182 million in 2009, then increased to MNT 25 122 million in 2010.

The main areas where uranium exploration was carried out during 2008 and 2009 were:

- Dornod district (north-east Mongolia) – exploration for volcanic and caldera-related uranium bearing rocks.
- Tamsag province, Ulziit basin (south-east Mongolia) – exploration for sandstone hosted uranium deposits.
- Sainshand, Airag, central Gobi provinces (south Mongolia) – exploration for sandstone type uranium deposits.

Recent exploration activity has led to uranium discoveries in the Matad province, the Engershand, Ugtam, Ulziit uul, Dund-Gobi districts and the Ulziit, Nylga, Choir, Gurvansaikhan, Zuun bayan and Sainshand basins.

In 2009 and 2010, 18 foreign companies carried out exploration activities in the country.

"Gurvansaikhan LLC", a subsidiary of Denison Mines Co Ltd, conducted exploration, evaluation and research activities in the Choir, Hairkhan, Undurshil, Ulziit and Gurvansaikhan Cretaceous basins. The company is planning to start an ISL operation at the Kharaat and Khairkhan deposits in 2013.

"Coge-Gobi LLC", a subsidiary of AREVA Group, carried out exploration, evaluation and research activities in the Sainshand, Oshiin Nuur, Nyalga and Tamsag basins. The company is planning to start ISL operation at the Dulaan uul deposit in 2013.

"Emeelt mines LLC", a subsidiary of the Central Asian Uranium Company Ltd carried out exploration and research activities in the North Choibalsan district. The company is planning to start underground mining of the Gurvanbulag deposit in 2014.

"Cameco Mongolia LLC", a subsidiary of Cameco Corporation, carried out exploration and research activities in the Nyalga and Tamsag basins.

"East Asia Minerals LLC", a Canadian company, carried out exploration and research activities in the Choir and Sainshand basins in the North Choibalsan district.

"MUC resources LLC", a Dutch company, carried out exploration and research activities in the North Choibalsan district in the Sainshand, Matad, Choir and Tamsag basins.

## Uranium resources

Mongolia potentially hosts substantial uranium resources. According to mathematic studies conducted by a science organisation and exploration data, it is estimated that resources in the country could amount to a total of 1.47 million tU.

As a result of specialised uranium geological surveys and exploration between 1970 and 2009, 9 uranium deposits with about 100 occurrences and over 1 000 mineralised occurrences and radioactive anomalies have been revealed on Mongolian territory.

The following is a summary of uranium resources calculated by mathematical/statistical methods, based on the size of mineralised regions, radio-geochemical data and tectonic maps of fields.

### *Identified conventional resources (reasonably assured and inferred resources)*

The principal identified conventional resources of Mongolia occur into two deposit types: volcanic type deposits such as Dornod, Gurvanbulag, Mardaingol, Nemer and Ulaan, and sandstone-type deposits such as Kharaat, Khairkhan and Dulaan uul.

As of 1 January 2011, identified conventional resources increased significantly since 2009, amounting to a total of 74 266 tU, as *in situ* resources recoverable at costs of <USD 130/kgU. Of this total, 40 852 tU are classified as reasonably assured resources (C1 in Mongolian classification), recoverable at costs of <USD 130/kg/U.

Inferred resources (corresponding to C2 in Mongolian classification system) amount to a total of 33 414 tU recoverable at costs of <USD 80/kgU.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

Prognosticated resources (P1 in Mongolian classification system) refer to uranium that is expected to occur in deposits for which the evidence is mainly indirect and which are believed to exist in well-defined areas (e.g. 3 000 tU in the Nars deposit).

Speculative resources, comprising 95% of the country's potential resource base, amount to a total of 1 390 000 tU. In the Mongolian classification system, they are divided into two groups. P2 resources include uranium that is thought to exist on the basis of general geological knowledge with limited exploration, whereas P3 resources refer to uranium evaluated on the basis of indirect geological evidence and sometimes by analogy to adjacent areas.

### *Unconventional resources and other materials*

No unconventional resources have been identified.

## Uranium production

### *Historical review*

The "Erdes" uranium mining enterprise, established under the bilateral Mongolian-Soviet intergovernmental agreement, encompassed underground and open-pit mining in the late 1980s at Dornod (the Dornod, Gurvandulag and Mardain gol deposits). Uranium production began at the Dornod open-pit mine in the Mardai gol district in 1989, based on the known uranium resources on the Dornod and Gurvanbulag deposits. This operation had a design of 2 million t ore/year. Assuming an ore grade of 0.12%, this equals a mining production capability of 2 400 tU/year. Since Mongolia had no processing facilities, ore mined in the Mardai gol district was transported by rail 484 km to the Priargunsky mining and processing combine in Krasnokamensk in the Russian Federation. The mines were operated by the Erdes mining enterprise and marketing was done by Techsnabexport.

Due to the political and economical changes both in Mongolia and neighbouring areas of Russia, uranium production of Erdes was terminated in 1995.

**Uranium production centre technical details**

(as of 1 January 2011)

| | Centre #1 | Centre #2 | Centre #3 |
|---|---|---|---|
| Name of production centre | Emeelt | Gurvansaikhan | Coge-Gobi |
| Production centre classification | Planned | Planned | Planned |
| Date of first production (year) | 2014 | 2013 | 2013 |
| Source of ore: | | | |
| Deposit name(s) | Gurvanbulag | Kharaat, Khairkhan | Dulaan uul |
| Deposit type(s) | | | |
| Recoverable resources (tU) | | | |
| Grade (% U) | | | |
| Mining operation: | | | |
| Type (OP/UG/ISL) | UG | ISL | ISL |
| Size (tonnes ore/day) | | | |
| Average mining recovery (%) | | | |
| Processing plant: | | | |
| Acid/alkaline | | | |
| Type (IX/SX) | | | |
| Size (tonnes ore/day) | | | |
| Average process recovery (%) | 0 | 0 | 0 |
| Nominal production capacity (tU/year) | 0 | 0 | 0 |
| Plans for expansion (yes/no) | 0 | 0 | 0 |
| Other remarks | 0 | 0 | 0 |

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

Currently, there are no operating mines in Mongolia.

### *Future production centres*

As indicated in the table above, the Emeelt Mines Company is planning to start production from the Gurvanbulag deposit in 2014, the Gurvansaikhan Company is planning to start production from the Kharaat, Khairkhan deposit in 2013 and the Coge-Gobi Company is planning to start production from the Dulaan uul deposit in 2013.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

The Nuclear Energy Law has enacted on 16 July 2009. A draft code of practice on waste management and regulation is now under review.

The Mongolian Nuclear Energy Agency is responsible for development of policy for the activities relating to development of nuclear research and technology, radiation protection and safety, use of radiation sources and co-ordination of uranium mining activity with other relevant organisations.

The Mongolian Nuclear Energy Agency, attached to the Prime Minister's office, is the national focal point for dealing with the International Atomic Energy Agency (IAEA). Its main functions include co-ordination of nuclear research activities in the country and implementing nuclear regulatory activities.

Mon-Atom LLC, a recently established state-owned company under the auspices of the Mongolian Nuclear Energy Agency is responsible for geological survey and uranium production.

The Mongolian government is attaching great significance to mining of uranium deposits which would positively influence and improve the national economy. It has developed a special programme on uranium and is committed to implement 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 direction here is to reduce Mongolian government investment and to encourage foreign investment.
- Conducting surveys on the potential hazards of uranium exploration and mining and to protect the environment, people, fauna and flora.
- 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.
- Starting uranium geological surveys of sandstone type deposits or occurrences on the territory of Mongolia.
- 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.

The programme defines actions and activities necessary for training national personnel in uranium prospecting and production, introducing advanced and efficient technologies and supplying high capacity equipment, instruments and tools. The programme also lists achievements in this field and highly appreciates the impact of IAEA projects.

### Uranium exploration and development expenditures and drilling effort – domestic

(MNT millions)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 33 909 | 16 182 | 25 022 | NA |
| Government exploration expenditures | 0 | 0 | 0 | 0 |
| Industry* development expenditures | 0 | 0 | 0 | 0 |
| Government development expenditures | 0 | 0 | 100 | 0 |
| Total expenditures | 33 909 | 16 182 | 25 122 | 0 |
| Industry* exploration drilling (m) | 172 669.2 | 11 350.75 | 82 925.2 | 0 |
| Industry* exploration holes drilled | 814 | 453 | 670 | 0 |
| Government exploration drilling (m) | 0 | 0 | 0 | 0 |
| Government exploration holes drilled | 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) | 172 662.2 | 11 350.75 | 82 925.2 | 0 |
| Subtotal exploration holes drilled | 814 | 453 | 670 | 0 |
| Subtotal development drilling (m) | 0 | 0 | 0 | 0 |
| Subtotal development holes drilled | 0 | 0 | 0 | 0 |
| Total drilling (m) | 172 662.2 | 11 350.75 | 82 925.2 | 0 |
| Total number of holes drilled | 814 | 453 | 670 | 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | |
| Sandstone | 0 | 25 582 | 25 582 | 25 582 | |
| Hematite breccia complex | 0 | 0 | 0 | 0 | |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | |
| Vein | 0 | 0 | 0 | 0 | |
| Intrusive | 0 | 0 | 0 | 0 | |
| Volcanic and caldera-related | 0 | 15 270 | 15 270 | 15 270 | |
| Metasomatite | 0 | 0 | 0 | 0 | |
| Other* | 0 | 0 | 0 | 0 | |
| Total | 0 | 40 852 | 40 852 | 40 852 | |

* 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.

### 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 | 15 270 | 15 270 | 15 270 | NA |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 0 | 25 582 | 25 582 | 25 582 | NA |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 40 852 | 40 852 | 40 852 | |

### 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 | 0 | 0 | |
| Conventional from OP | 0 | 25 582 | 40 852 | 40 852 | NA |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 25 582 | 40 852 | 40 852 | |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 33 414 | 33 414 | 33 414 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 33 414 | 33 414 | 33 414 | 0 |

* 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.

### 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 | 33 414 | 33 414 | 33 414 | |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 33 414 | 33 414 | 33 414 | |

### 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 | 0 | 0 | |
| Conventional from OP | 0 | 33 414 | 33 414 | 33 414 | |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 33 414 | 33 414 | 33 414 | |

* 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 |
| 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 | |

## Historical uranium production by deposit type

(tonnes U in concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 535 | 0 | 0 | 0 | 535 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 535 | 0 | 0 | 0 | 535 | 0 |

* 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.

## Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 535 | 0 | 0 | 0 | 535 | 0 |
| Underground mining[1] | 0 | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching | 0 | 0 | 0 | 0 | 0 | 0 |
| Co-product/by-product | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 535 | 0 | 0 | 0 | 535 | 0 |

1. Pre-2008 totals may include uranium recovered by heap and in-place leaching.

## Short-term production capability

(tonnes U/year)

| 2011 | | | | 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 |
| 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 |

## 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 | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 0 | 0 |

# Namibia*

## Uranium exploration and mine development

### *Historical review*

The new millennium upward trend in uranium prices stimulated extensive exploration activity, mainly in the Namib Desert. 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. Exploration activities continue but the declining uranium price since 2007, partly as a result of the Fukushima accident, has slowed activities to a certain extent.

Despite this slowdown, substantial growth in uranium exploration has taken place in the Erongo area of west-central Namibia, focusing mainly on previously known deposits with considerable historical data. Over 60 exploration licences had been issued up until early 2007, when a moratorium on new licences was imposed by the Namibian government.

Refer to the 2007 Red Book for additional details.

A comprehensive review of Namibia's uranium geology and exploration can be found in: *Mineral Resources of Namibia, Nuclear and Fossil Fuels – Uranium*, by H. Roesener and C.P. Schreuder, Section 7, pp. 1-62.

### *Recent and ongoing uranium exploration and mine development activities*

The state-owned Epangelo Mining Company, created by the Namibian government in 2008, was given exclusive rights to all future uranium exploration and mining licences in April 2011. This caused great concern among companies currently actively exploring for uranium in Namibia. The government however did state that existing licences held by private companies would be honoured.

In 2010 the Namibian and Russian governments signed a memorandum on co-operation for the exploration and development of Namibian uranium deposits. The head of the Russian State Atomic Energy Corporation reportedly stated that the Russian Federation would be prepared to invest up to USD 1 billion in joint ventures on Namibian uranium deposits.

*Rössing*

In August 1966, Rio Tinto Zinc (RTZ) acquired the exploration rights for the Rössing deposit and Rössing Uranium Limited was formed in 1970 to develop the deposit. Rio Tinto was the leading shareholder with 51.3% of the equity (at the time of the formation of the company; ownership share now 69%). Mine development began in 1974 and first production was achieved in July 1976. Full design capacity of 5 000 short tons of $U_3O_8$/year (3 845 tU/year) was not achieved until 1979 due to the highly abrasive nature of the ore.

* Prepared by Secretariat based on open source information and company reports.

In 2009, a new life of mine plan to extend operations to 2023 was released. This calls for the development of two open-pit mines and associated support facilities. Exploration at Rössing during 2009 and 2010 focused on the SJ and SK pit areas, the former to better understand the geology of the current open pit to facilitate exploitation and the latter to define the ore body and plan future mining. Additional areas of interest in the southern parts of the lease area also received attention.

Excavation of the SK pit began in 2009. Mining is expected to produce 1 million t of rock in the first year of operations, climbing to 9 million t in 2011 when mining this pit is expected to be completed. Development of this new pit is to make up for the lost production from the SJ pit when ore at the bottom of the pit was depleted at the end of 2010. Waste stripping in the SJ pit will continue until 2013, when new areas of ore are exposed for mining. These activities involve extensive waste stripping operations to the north-west and south of the existing pit.

Two projects were launched with the aim of increasing process extraction efficiency. The tank leach improvement project is investigating options for improving the current process. The heap leach project successfully commissioned a pilot plant in 2010 with the pre-feasibility study expected to be completed in 2011. In addition, a third acid storage tank has been constructed to ensure security of supply and to mitigate one of the key risk areas in the operation.

*Langer Heinrich*

The Langer Heinrich uranium project, currently the second operating uranium mine in Namibia, is located in the western portion of central Namibia about 80 km east of the major deepwater seaport at Walvis Bay and the coastal town of Swakopmund. An eight-year evaluation period followed the discovery of calcrete hosted uranium mineralisation in the early 1970s. In 1980, Gencor, now part of BHP Billiton, completed an USD 8.5 million evaluation study but the project was subsequently placed on care and maintenance due to depressed uranium prices.

In 1998, the project was sold to the Australian listed public company Acclaim Uranium NL who completed a pre-feasibility study but low uranium prices again curtailed further development. In 2002, Acclaim sold its holdings in the Langer Heinrich Uranium (Pty) Ltd to Paladin Resources, who in 2005 initiated exploration activities to increase confidence in resource modeling and to delineate extensions to known uranium occurrences in the paleo-channel hosting the mineralisation.

The Ministry of Mines and Energy (MME) granted an exclusive exploration licence (EPL) to Langer Heinrich Uranium (Pty) Ltd in October 2006. The EPL covers 30 $km^2$ to the west of and adjoining the Langer Heinrich mining licence (ML140). Exploration in 2007 and 2008 included 3 000 m of reverse circulation drilling, delineation of the additional 5 km palaeo-channel extension on the new tenement to complement the increased production requirements associated with the Stage III Langer Heinrich expansion.

The initial production level of 2.6 Mlb/yr $U_3O_8$ (1 040 tU) was achieved in 2008/2009. This was followed by the Stage 2 expansion to 3.7 Mlb/yr $U_3O_8$ (1 348 tU) in 2010. Stage 3 expansion is in progress and is expected to reach 5.2 Mlb/yr $U_3O_8$ (2 030 tU) in 2012. Stage 4 expansion feasibility study and environmental impact assessment (EIA) were submitted to government and public meetings are expected to be held in 2012. The expansion plan is aimed at achieving a production level of 10 Mlb/yr $U_3O_8$ (3 852 tU).

Drilling for the Stage 4 mineral resource update was completed in 2010 and a new resource estimate was announced in 2011. The current mine model indicates a life of mine in excess of 18 years.

### *Proposed developments*

*Trekkopje*

Trekkopje is comprised of the Klein Trekkopje and Trekkopje ore bodies (located approximately 7 km apart over a total area of 16 by 4 km) in basal channel surficial calcrete deposits (a geological setting similar to that of Langer Heinrich). The calcrete host rocks are calcium carbonate-cemented fluvial sediments deposited in ancient drainage valleys. The basal channels in the Trekkopje area follow the northeast-trending structural grain of the underlying basement rocks. In December 1999, UraMin Inc, the parent company of UraMin Namibia, acquired control of the combined deposits. In 2006, UraMin initiated a programme of exploration drilling and in November that year developed a resource estimate. Uramin Inc. was then taken over by AREVA to become AREVA Resources Southern Africa, with subsidiary AREVA Resources Namibia now developing the mine. China Guangdong Nuclear Power Company (CGNPC) subsequently acquired 49% of the company, reportedly with take-off rights of 35% of mine production.

AREVA's heap leach project at Trekkopje is located about 80 km north-east of Swakopmund and 35 km north of Rössing. In total, resources have been defined over an area of about 16 by 1 to 3 km. Some 80% of the ore is found at shallow depth, less than 15 m below the surface, but it is low-grade. The most recent resource update available at the time of writing was provided by AREVA in its 2010 Reference Document submitted to the Autorité des marchés financiers (AMF) of France.

The USD 900 million project is a shallow open-pit mine with a sodium carbonate/bicarbonate heap leach process – the first of this kind in the world. In 2009, a geotechnical site investigation and the engineering design were completed for a new 30 million t, on-off uranium heap leach pad covering 2.5 $km^2$.

The extraction process was developed and tested on a small heap leach pad processing 250 000 t of crushed ore. This was followed by development tests on a pilot heap leach pad constructed with 3.5 Mt of ore. Construction of the main production pad began in 2010. A final production level of 3 000 $tU_3O_8$/yr (2 545 tU) is envisaged.

Water is to be supplied from a coastal desalination plant with about 55 000 $m^3$/day output requiring 16 MWe from the grid. The desalination facility was inaugurated by AREVA in April 2010 and tests will be carried out until mid-2010, with full production expected in 2011.

*Rössing South/Husab*

The Rössing South deposit is located about 6-7 km south of the Rössing mine, within the central Damara Orogenic Belt (DOB) in a zone characterised by basement domes, regional folding, faulting, and late Damaran intrusive rocks. The Husab project, which includes the Ida Dome to the south, consists of a series of north-northeast trending regional-scale antiforms and synforms. A zone of uraniferous alaskites outcrop at the northern end of the deposit and trend south-west at shallow depth for some 8 km in what is considered an extension of the Rössing mine stratigraphy.

Perth-based Extract Resources Ltd (Kalahari Minerals 40%; Rio Tinto 15.6%) has been undertaking feasibility studies for mining the Rössing South orebody. Drilling was undertaken along the 15 km strike which lies under a cover of about 50 m of alluvial sand. At the end of 2010, a total of over 2 200 holes had been drilled for a total of over 570 000 m, with up to 19 rigs operating on site at any one time. Considerable exploration potential remains because at least a third of the total potential strike length has been yet to be drilled.

In June 2010, the first blasting and mining took place on the site to obtain a 200 t ore sample for milling and metallurgical test work. Late in 2010, an EIA and an environmental management plan (EMP) and a mining licence application were submitted to government.

The EIA was approved early in 2011 and a definitive feasibility study was completed early in 2011. Two pits over zones one and two which will produce 5 800 tU/yr at operating costs of USD 32/lb $U_3O_8$ (USD 83.25/kgU) are envisioned. Capital costs are estimated to be USD 1 480 million and life of mine is 16 years.

Early in 2011, Extract announced that it was engaged in discussions with Rio Tinto regarding the possible combination of the Husab project with the neighbouring Rössing mine. CGNPC Uranium Resources made a cash offer to purchase Kalahari Minerals (a 42.79% shareholder in Extract) at about the same time. This offer was withdrawn in May 2011, but negotiations were restarted later in the year.

*Valencia*

The Valencia deposit (100% owned by Valencia Uranium Pty Ltd, the operating subsidiary of Forsys Metals Corp) is located 35 km along strike from the producing Rössing mine and 40 km north of the Langer Heinrich deposit. Historical work at Valencia was conducted by Goldfields Namibia between 1973 and 1977 but due to low uranium prices at the time the project was considered uneconomic.

Since October 2005, Forsys has conducted a programme of confirmatory work including a ground radiometric survey, infill drilling and geotechnical data gathering in order to develop an updated resource estimate. Additional drilling programmes in 2008 delineated resources to the north, south and east of the main zone pit floor.

A scoping study issued in June 2007 outlined an initial open-pit design and site layout plan, identified waste and tailings disposal areas, access routes and proposed initial extractive solutions. Forsys then completed a pre-feasibility study in May 2009 that included pit optimisation, metallurgical, environmental, economic analyses and an upgraded resource estimate.

In August 2008, Forsys announced that MME had granted a 25 year mining licence No. 149 to Valencia Uranium (Pty) Ltd, allowing full scale development to proceed. Current plans call for the production of approximately 1 350 tU/yr over the life of mine, with first production in late 2013, although no formal announcement has been made. Forsys is continuing with mine planning test work, including heap leaching, and are continuing with exploration of the nearby Namibplaas property to investigate the potential for consolidating the Valencia and Namibplaas resources into a single operation.

George Forrest International made an offer to purchase Forsys in 2008, but the agreement was terminated before it could be concluded. Forsys then engaged Morgan Stanley as financial advisors to conduct a review of strategic options and opportunities available to the company. On completion of the review Morgan Stanley then invited selected interested parties to submit proposals for possible transactions with Forsys.

*Etango (formerly Goanikontes)*

The Etango deposit, situated within the Etango tenement (EPL 3345) in the Erongo province, lies within the central zone of the north-east trending Pan African Damara Orogenic Belt that transects the continent. The main uranium enriched zones are Anomaly A, Oshiveli and Onkelo, previously referred to as the Goanikontes area. These three prospects form a contiguous zone of uranium mineralisation spanning some 6 km. The alaskite ore character is similar to that at the Rössing mine, and occurs from surface to depths of up to 400 m. Other areas in the vicinity are also considered to have potential to host additional uranium resources (e.g. the western flank of the Palmenhorst Dome alone constitutes a prospective strike length of over 10 km).

In 2005, Bannerman Resources Limited acquired the Etango project lease and subsequently obtained and digitised historical drill hole and mapping data, principally from the Namibian Geological Survey and the Geological Survey of South Africa. Results of a pre-feasibility study were released in late 2010, prompting Bannerman to announce that it would proceed with a definitive feasibility study (DFS). The DFS will be completed

by March 2012 and current plans indicate that construction could commence in 2013. Mining will be by open-pit with the ore being processed by heap leaching. Colum test work consistently returned uranium recovery rates of over 90%. Projected life of mine is 15+ years with a production rate of between 2 700 (2 290 tU) and 3 600 t $U_3O_8$ (3 050 tU) per year at costs estimated to between USD 40 (USD 104/kgU) and 45/lb $U_3O_8$ (USD 117/kgU).

An application for a mining licence was lodged in December 2009. Exploration activities are continuing to investigate additional resources in the project area. Negotiations are underway with various parties with a view to joint venture partners.

*Marenica*

In April of 2006, Marenica Energy entered into a joint venture agreement, approved by the (MME) on 31 May 2006, whereby it could earn an 80% interest in the Marenica project. Marenica is situated in a palaeo-channel about 40 km north of Trekkopje. In July 2008, the company produced a 13 000 tU resource estimate in accordance with the JORC code.

Further results from down-hole probe work, announced in 2009, included historical drilling data from the main Marenica resource area as well as data from exploration holes at the regional Springbok prospect. In the third quarter 2009, the exclusive exploration licence No. 3287 was renewed for two years by the MME. In November 2009, Marenica announced an interim resource estimate that was superseded by a resource update included in a scoping study completed in September 2010. This indicated a mine life of 13 years with a production rate of 1 600 tU/yr. Various processing options were investigated with tests showing the ore to be amenable to upgrading and that tank leaching gave the best results.

Negotiations with China's Hanlong Energy Ltd resulted in the signing of a memorandum of understanding and the formation of a strategic alliance.

*Omahola*

Reptile Uranium Namibia (Pty) Ltd (RUN), a wholly owned subsidiary of Australia's Deep Yellow Ltd, has been vigorously exploring for paleodrainage (calcrete-style); metamorphic/metasomatic hardrock and granite/alaskite hosted uranium on its Namibian tenements in 2009 and 2010. This has culminated in the announcement of JORC compliant inferred and indicated uranium resources. Most of these announced are surficial carnotite-in-calcrete resources, including deposits along the Tubas-Tumas-Tubas Red Sand drainage and the Aussinanis drainage. Further work on the Inca deposit also resulted in announcement of JORC compliant resources from an unusual primary magnetite-calcsilicate host, best described as a metasomatite class occurrence. All three styles, alaskite, metasomatite and surficial are being investigated, with a view to establishing a viable resource inventory to fast track mine development. Six distinct mineralised zones (Inca, Ongolo, MS7, Tubas Red Sand, Tubas-Tumas Paleochannel and the Aussinanis area) are now included in the Omahola project.

RUN's mine plan, predicated on open-pit mining and conventional acid leach extraction, has reached the pre-feasibility stage, with a final resource upgrade awaiting the outcome of technical and financial modelling. A pre-feasibility study, completed in 2011, indicated a mine life of 12 years with production of 850 tU/yr. This was based on capital expenditures of USD 340 million with estimated running costs of USD 26/lb $U_3O_8$ (USD 67/kgU). Tests on the Tubas Red Sand ore have shown that it can be beneficiated using advanced hydrocyclone technology.

### *Other exploration prospects*

In December 2006, Nova Energy (Namibia), a subsidiary of Toro Energy Limited, was granted three EPLs for nuclear fuel, base and rare metal exploration. The licences cover areas adjacent to Reptile's Omahola project considered prospective for primary Rössing-type mineralisation and surficial Langer Heinrich-type mineralisation. Toro signed a joint

venture agreement with Reptile, who conducted extensive exploration in the EPLs. Reptile now has a 65% interest in these EPLs.

Xemplar Energy Corporation of Canada has uranium prospects (Warmbad, Cape Cross, Aus-Garub,) along Namibia's Atlantic coast. An airborne radiometric survey flown in 2007 showed radiometric anomalies on 14 large alaskite bodies which outcrop over an area of about 40 by 28 km. Considered to have potential to host high tonnage, low-grade occurrences, a total of 71 000 m of drilling has been carried out on eight major zones. Xemplar is endeavouring to engage a strategic partner to develop the Warmbad project to its full potential.

Through its Namibian subsidiary, Namura Mineral Resources (Pty) Ltd., Xemplar also holds three EPLs in north-west Namibia, some 20 km inland from the Atlantic coast (Cape Cross). Intensive and systematic ground exploration during 2009/2010 identified uranium mineralisation both in calcrete channels and in alaskites. Detailed in-fill investigations during 2011 are aimed at identifying specific targets for drilling investigations.

## Uranium resources

Uranium resources of Namibia, including both identified and undiscovered, occur in a number of geological environments and consequently are hosted in several deposit types. Identified resources are mainly associated with intrusive and surficial deposits.

Although not quantitatively assessed, uranium potential is considered greatest in the 5 000 $km^2$ granitic terrain of the Damara Belt, Tertiary to Recent surficial sedimentary terrains in semi-arid areas, where further potential for calcrete deposits is thought to exist, and sandstone basins that include the Permo-Triassic Karoo sediments.

### *Rössing*

At the end of 2010 the total uranium inventory of the Rössing mine amounted to 107 270 tU. This represents an increase of 52% from the 2008 inventory.

### *Langer Heinrich*

The Stage Four resource drilling programme had a significant effect on Langer Heinrich resource and reserves. The resource base actually decreased marginally by 2%, but the detailed drilling raised the reserves by 69%. The confidence of the resource estimate was however greatly enhanced by a large move of resources from the inferred to the indicated category.

### *Trekkopje*

Trekkopje is to be developed as an open-pit mine to exploit a shallow, high-tonnage deposit of low-grade uranium. In 2010, AREVA reported a slight decrease in reasonably assured resources (7.6%) of 42 126 tU. In addition, over 9 000 t of vanadium pentoxide by-product has been defined. This was reported in their 2010 Reference Document submitted to the Autorité des marchés financiers (AMF) of France.

### *Husab*

Intensive exploration activities by Extract Resources led to the identification of three additional zones of mineralisation between Zone 2 and the Ida Dome. This has resulted in a not only a large increase in overall resources but also a substantial increase in the confidence of the estimates. Zones 1 and 2 now have a large component of reasonably assured resources.

### *Valencia*

Work by Forsys in 2009 resulted in a small (6%) increase in total resources and some movement of resources to the indicated category (downward from measured and upward from inferred). In addition Forsys reported inferred resources for their new Namibplaas project of 15 764 tU.

### *Etango*

In October 2010, Banerman Resources updated Etango resources, including those from the Hyena and Ondjamba areas. This update represented a 32.5% increase over previously reported resources. The Etango project JORC compliant Mineral Resources Estimate using the Ordinary Kriged Method amounts to 12 900 t $U_3O_8$ measured (62.7 Mt at 205 ppm $U_3O_8$), 54 600 t $U_3O_8$ indicated (273.5 Mt at 200 ppm $U_3O_8$), and 29 000 t $U_3O_8$ inferred (164.6 Mt at 176 ppm $U_3O_8$).

### *Marenica*

In September 2010, Marenica Energy reported JORC compliant updated resources amounting to 4 689 tU indicated (47.7 Mt at 98 ppm U) and 48 305 tU inferred (600 Mt at 81 ppm U), effectively doubling the indicated resources and trebling the inferred resources reported in 2009.

### *Omahola*

Intensive exploration activities by Deep Yellow have increased reasonably assured resources and inferred resources over tenfold in this project from 3 000 tU reported in 2009 to 42 600 tU in 2011 which are JORC compliant.

## Uranium production

### *Historical review*

From the date of first production in July 1976 to 2010, the Rossing mine had produced a cumulative total of over 100 000 tU. Commercial production began at Langer Heinrich in 2007 and as noted above, several other prospective mines are under development.

*Rössing*

Based on a detailed feasibility study the mine life has been extended to 2023. Production jumped dramatically from 3 046 t $U_3O_8$ (2 583 tU) in 2007 to 4 108 t $U_3O_8$ (3 484 tU) in 2008 and then to 4 150 t $U_3O_8$ (3 519 tU) in 2009. Technical problems and depletion of ore in the bottom of the current SJ pit caused production to fall to 3 628 t $U_3O_8$ (3 077 tU) in 2010. Mining the SK orebody has commenced to replace the loss of output from the original pit. Production levels are expected to remain static until 2013 while extensive stripping operations take place to expose additional ore to the north-west and south of the SJ pit. The heap leach trial pads continue to operate to develop the most effective techniques and in 2010 contributed 18.6 tU to mine production.

Negotiations are underway with Extract Resources examining the options for merging the Husab Project with the Rössing operations.

*Langer Heinrich*

Full scale development of the mining operation proceeded after licensing and commissioning of Langer Heinrich began in late 2006 after a bankable feasibility study 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 a further 340 tU could be produced over an additional 4 years using the accumulated low-grade (0.027% U) stockpile.

During the 2008/2009 financial year production amounted to 2.7 Mlb $U_3O_8$ (1 040 tU), compared to 1.71 Mlb $U_3O_8$ (660 tU) in 2007/2008, an increase of over 60%. Stage II construction, designed to expand annual production to 3.7 Mlb $U_3O_8$ (1 425 tU), was completed in June 2009 and commissioning was underway in the following months. Plans for a further expansion (Stage III) to increase annual production to 5.2 Mlb $U_3O_8$ (2 000 tU) at an estimated capital cost of USD 141 million were also approved. Construction was completed and by the end of 2011 and production had exceeded 90% of nameplate capacity. Full production is expected to be achieved early in 2012. The Stage 4 Feasibility Study is at an advanced stage with completion of the study expected in early 2012. If implemented, this expansion is expected to boost production to almost 3 850 tU/yr.

### *Future production centres*

Commercial production at Trekkopje was initially expected to start in 2011 but was first delayed until 2012 and then to 2013. Although the ore is low-grade (averaging 0.013% U), most is located at shallow depth and production costs should therefore be relatively low. A mining licence was granted in June 2008 and a trial mine and pilot heap leach plant were constructed in 2008 and operated in 2009. Production is targeted at 1 600 tU/yr initially, with potential to scale up to 2 545 tU/yr. Small quantities of vanadium by-product will also be produced. Heap leaching processing is expected to be used over the 12-year operating life of the facility.

Early in 2009 the trial mine and pilot plant employed about 140 people, not including contractors. At the beginning of 2010 Areva employed 250 people at Trekkopje. A number of social actions to benefit the surrounding communities, particularly training initiatives, have also been initiated.

**Uranium production centre technical details**

(as of 1 January 2011)

| | Centre #1 | Centre #2 | Centre #3 |
|---|---|---|---|
| Name of production centre | Rössing | Langer Heinrich | Trekkopje |
| Production centre classification | Existing | Existing | Committed |
| Date of first production | 1976 | 2006 | 2013 |
| Source of ore: | | | |
| Deposit name(s) | SJ, SK & SH | Langer Heinrich | Trekkopje, Klein Trekkopje |
| Deposit type(s) | Intrusive | Calcrete | Calcrete |
| Recoverable resources (tU) | 90 100 | 60 900 | 33 700 |
| Grade (% U) | 0.03 | 0.05 | 0.011 |
| Mining operation: | | | |
| Type (OP/UG/ISL) | OP | OP | OP |
| Size (tonnes ore/day) | 40 000 | 20 000 | 30 800 |
| Average mining recovery (%) | 85 | 90 | 90 |
| Processing plant: | | | |
| Acid/alkaline | Acid | Alkaline | Alkaline |
| Type (IX/SX) | IX/SX | IX | HL/IX |
| Size (tonnes ore/day) | 30 000 | 10 000 | 25 000 |
| Average process recovery (%) | 85 | 85 | 80 |
| Nominal production capacity (tU/year) | 4 000 | 2 000 | 1 600 |
| Plans for expansion | Yes | 3 850 | Yes |
| Other remarks | | | |

**Uranium production centre technical details** (*continued*)

(as of 1 January 2011)

| | Centre #4 | Centre #5 | Centre #6 |
|---|---|---|---|
| Name of production centre | Husab | Valencia | Etango |
| Production centre classification | Planned | Planned | Planned |
| Date of first production | 2015 | 2016 | 2016 |
| Source of ore: | | | |
| Deposit name(s) | Zones 1 & 2 | Valencia | Etango |
| Deposit type(s) | Intrusive | Intrusive | Intrusive |
| Recoverable resources (tU) | 158 500 | 23 700 | 85 000 |
| Grade (% U) | 0.034% | 0.021% | 0.016% |
| Mining operation: | | | |
| Type (OP/UG/ISL) | OP | OP | OP |
| Size (tonnes ore/day) | 42 000 | 32 000 | 55 000 |
| Average mining recovery (%) | 88% | 77% | 78% |
| Processing plant: | | | |
| Acid/alkaline | Acid | Acid | Acid |
| Type (IX/SX) | IX/SX | IX/SX | HL/SX |
| Size (tonnes ore/day) | 42 000 | 24 800 | 55 000 |
| Average process recovery (%) | 88% | 85% | 85% |
| Nominal production capacity (tU/year) | 5 800 | 1 350 | 2 300 – 3 000 |
| Plans for expansion | | | |
| Other remarks | | | |

Valencia, located 35 km east of Rössing, is another project with near-term production potential. No mine development schedule has been announced but production levels of 1 350 tU/yr are envisaged. Strategic partners are being sought to bring the mine into production.

Extract Resources completed a definitive feasibility study of the Husab (Rössing South) deposit in 2011 and announced that production levels of 5 800 tU/yr could be achieved with a mine life of 16 years. Achieving this level of production would make it one of the three largest uranium mines in the world. If project approval is given, time to commissioning is estimated to take 33 months. As yet no firm plans have been announced.

### *Employment in existing production centres*

Employment at the Rössing mine amounted to 1 592 employees and over 1 000 contractors onsite in 2010. Langer Heinrich employed an average of 600 employees, roughly half of which are contractors. Other projects continue in the exploration phase of development.

## Environmental activities and socio-cultural issues

The Rössing mine began production in 1976 and has been in operation since. Community development has always been a part of work at the mine, beginning with the development of the town of Arandis in 1975-76 and the establishment of the Rössing Foundation in 1978.

In 2004 the Namibian government launched a partnership known as Vision 2030 that aims to improve the quality of life of all Namibians to be on par with similar nations

by 2030. Rössing's community engagement is geared towards this vision and the mine is supporting the education, science and technology, health and development, sustainable agriculture (through work undertaken by the Rössing Foundation) and the peace and social justice components of this partnership.

The Rössing Foundation was established in 1978 by Rössing Uranium Ltd through a Deed of Trust to implement and facilitate corporate social responsibilities within the communities of Namibia. The Foundation currently has strong presence in Erongo region but support has extended to other regions (Oshana, Omahaheke and Khomas).

The Foundation's Deed of Trust stipulates furthering the education of all Namibians in order to achieve greater national productivity and to enhance lifelong learning, creating opportunities for Namibian people to employ their education, promoting the advancement of the living standards of all the people in Namibia and doing any act or thing, which in the opinion of the trustees, shall benefit Namibia.

The focus of foundation activities from 2006 to date has been in the Erongo region (75% of the resources) on education, the Arandis sustainable development plan, small scale miners, community based natural resource management (CBNRM) and the Erongo development fund. Activities in Oshana include education and CBNRM and in Omaheke, an outreach programme.

During 2010, Rössing Uranium provided financial and/or technical support to the Uranium Institute, an organisation launched in 2009 to improve the quality of healthcare, environmental management and radiation safety in the uranium industry. It also provides support to the Arandis town council, the Arandis out of school youth skill development programme (youth unemployment is one of the main challenges in Arandis), small scale mining in the Erongo region, the community based natural resource management programme and local biodiversity programmes.

The Chamber of Mines Uranium Institute is supported both financially and technically by its Class A members – Rössing Uranium, Langer Heinrich and Trekkopje; prospective Class A members – Swakop Uranium and Bannerman Resources; as well as its Class B members – Reptile Uranium, Valencia and Zhonghe Exploration.

Bannerman Resources provides substantial support annually to the Erongo Development Foundation and also launched its Learner Assist Program in 2011 whereby over 300 underprivileged school children in the Erongo region of Namibia are supported with their education. Bannerman Resources during 2011 co-ordinated an initiative together with the Hospitality Association of Namibia whereby the mining and tourism industry are working jointly on several tourism projects in the Erongo region.

### *Rössing*

Since 2007 Rössing Uranium has conducted a number of environmental impact assessments related to the planned mine expansion, covering a potential acid plant and related sulphur handling and the extension of mining activities to a satellite open pit. Ongoing assessments cover a potential heap leach plant with associated waste storage facilities.

To ensure the welfare and safety of the staff, a variety of monitoring activities are carried out, covering radiation protection, sealed sources and their control, medical surveillance, air quality (including greenhouse gas emissions), water utilisation and seepage management, wastes, dust, biodiversity and occupational hazards in all Rössing operations.

Effluent management includes water recycling. Fresh water is added to the processing plant and the waste water, together with a much larger volume of recycled water, is used to pump tailings to the tailings dam. Some water is lost from the tailings dam due to evaporation and storage within tailings material. Over 60% of the waste water pumped to the dam is recovered and returned to the processing plant. No waste water is

discharged into the environment and between 60% and 70% of the fresh water used is recycled each year.

Given concerns with fresh water supply, especially considering the cumulative effect of the planned increase in uranium mining in the Erongo region, the consumption of fresh water by bulk users and the status of aquifers countrywide are continuously monitored by the Namibia Water Corporation Ltd and the Ministry of Agriculture, Water and Forestry's Department of Water Affairs. The results of monitoring are provided to bulk users and basin management committees.

The total closure cost projected for the Rössing mine in 2023 stands at just over NAD 1 065 million (Namibian dollars: USD 160 million). This includes retrenchment and training costs, demolition and tailings rehabilitation, long-term seepage control and monitoring costs. The provision for closure in the independent Rössing environmental rehabilitation trust fund stood at NAD 163 million (USD 24.5 million) at the end of 2010, and will be increased in the coming years to provide fully for the time of mine closure. A new mine plan is being developed to extend the life of mine beyond 2023 and this closure cost projection will be updated in line with this plan.

During 2010, a restoration methodology was developed and a pilot area for rehabilitation activities was selected. Trial activities began in late 2010 and are to be continued during 2011. Continuous rehabilitation activities during 2010 include demolition of the redundant acid plant.

To ensure and optimise electricity consumption by tracking and optimising system efficiencies, a power efficiency department was established in 2008.

The implementation of minimum environmental and occupational health standards and the initiation of a strategic environmental assessment (SEA) of the Erongo region have been identified as priority tasks. The SEA will be translated into a strategic environmental plan to provide scientifically based insights to the government to assist in the management of the uranium industry.

The mine's footprint was extended 10 ha to amount to a total of 2 408 ha at the end of 2010. Mining the SK orebody will add a further 14 ha by the end of 2013 when mining is expected to be completed.

### *Langer Heinrich*

Paladin developed and implemented an environmental management system (EMS) and in April 2009 received ISO 14001 certification for its EMS following certification audits. As part of the EMS, environmental management plans (EMPs) for site operations have been prepared and submitted for review to government and other stakeholders. The EMPs are regularly updated and revised as part of a continual improvement process.

The operational EMP for Langer Heinrich was reviewed by the respective government departments and international financial lending institutions as part of project financing. A revised EMP, including the Stage II expansion, was also approved by government. An EIA process for the proposed Stage III expansion was launched in early 2009. Stakeholder consultations were conducted and a scoping report was submitted to government in May 2009. The EIA for the planned Stage 4 expansion was submitted in 2011.

A standard for water use and water quality was developed to promote efficient, safe and sustainable uses and to protect water resources and ecosystems around the site. Detailed water balances, flow models and water management strategies were developed and implemented with specialists engaged to provide input on the design, construction, operation and management of water and water infrastructure. The design and water management strategies have also been subject to external technical peer review and audit to provide assurance that the water management systems meet international standards.

A mine closure standard has also been developed to ensure that the facilities are left in a safe and stable manner to minimise environmental impacts. The closure planning process progressed during 2009 with the establishment of a steering committee which has developed a closure strategy and began preparation of a detailed draft closure plan.

In 2007, the Chamber of Mines of Namibia established a Uranium Stewardship Committee (USC) with the support of Rössing and Langer Heinrich. The USC contributes to emerging policy debates on the expansion of the industry, the safe, efficient and productive development of mines, a better understanding of the global context in which the industry operates and to stakeholder and public confidence. The USC established an environment of "policy certainty", supporting efforts to develop a stable investment climate, helping develop dedicated regulatory and compliance arrangements, and evaluating the effectiveness of updated intervention strategies.

### *Bannerman Resources*

Bannerman Resources' rehabilitation of exploration drilling sites and tracks developed during the exploration process in its two exploration tenements (EPL 3345 and 3346) is above 90% complete and rehabilitation efforts have now also been directed to areas disturbed by the public within the Naukluft National Park. The Radiation Management Plan of Bannerman Resources was approved by the National Regulator in early 2011 and the exploration company and its contractors are proud to have worked in excess of two years without a lost time injury. Bannerman Resources have done a detailed environmental and social impact assessment of their proposed mining site as part of the Definitive Feasibility Study of the Etango Project.

## Uranium requirements

Namibia has no reactor-related uranium requirements since it has no reactors and no firm plans to develop nuclear generating capacity.

## National policies relating to uranium

In Namibia, all mineral rights are vested in the state and are regulated by the Minerals (Prospecting and Mining) Act of 1992. This act was promulgated soon after independence in order to repeal old legislation inherited from the colonial regime. The act is currently under review and will accede to policies which are being formulated in the forthcoming uranium policy and the declaration that uranium, among other minerals, is a strategic mineral. Revision has reached an advanced stage and, once completed, will be submitted to the legal drafters for finalisation and preparation for submission to parliament. It is anticipated that this exercise will be completed in 2011.

In 2007, the government of Namibia instituted a moratorium on uranium exploration licences for an indefinite term. At the time, the price of uranium had reached a level that had stimulated exploration for the mineral worldwide, in particular in Namibia. The government stated that the moratorium would give it time to reconsider its policies towards uranium following the upswing in demand, citing water and energy concerns.

In 2009, the South African Institute for Environmental Assessment was contracted by the government to undertake a SEA for the so-called central Namibian uranium rush. Funded by the German government, the final report was submitted to the Namibian government in early 2011. A diverse team of scientists developed and assessed three scenarios and examined all aspects of each scenario.

Positive impacts noted include stimulating the Namibian economy, skills development and infrastructure development. A number of constraints to development were also identified, such as water shortages, lack of skills, capacity of physical infrastructure and environmental protection. The SEA noted that the uranium rush could

have a number of negative impacts in the areas of natural physical resources, biodiversity, health, infrastructure and tourism and good governance will be critical in minimising these impacts.

Uranium is defined as a controlled mineral and section 102 of the Minerals Act deals with the export, processing, possession and enrichment of uranium. There is no particular policy or set of regulations that deals with uranium production or the nuclear fuel cycle and Namibia is collaborating with Finland to develop appropriate governance. A project concept in this respect was progressed under the IAEA technical co-operation programme RAF3006. In November 2010, the MME held a stakeholders workshop to solicit input on development of a uranium policy. Policy development is ongoing and is expected to be completed by end 2011, along with revisions to the Minerals Act. The aim of the policy will be to develop an effective regulatory framework to ensure proper management of exploration, extraction and development of nuclear fuel minerals.

The Epangelo Mining Company was established in July 2008. The Namibian government is the sole shareholder. In April 2011, the government declared uranium, copper, gold, zinc and coal to be strategic minerals and that Epangelo Mining has exclusive exploration and mining rights on these minerals. A new Minerals Bill and mineral policy will be finalised in the near future to formalise the situation with regard to Epangelo mining and the rights to the strategic minerals. To appease concern among companies currently active in Namibia the government stated that existing licences held by private companies would be honoured. The MME also stated that private companies were welcome to negotiate for a share of interest in ventures but that Epangelo would maintain a majority shareholding.

**Uranium exploration and development expenditures and drilling effort – domestic***

(NAD)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry** exploration expenditures | 258 330 615 | 230 561 283 | 222 176 017 | 157 148 118 |
| Government exploration expenditures | NA | NA | NA | NA |
| Industry** development expenditures | 97 850 700 | 124 682 000 | 28 503 450 | 103 400 000 |
| Government development expenditures | NA | NA | NA | NA |
| Total expenditures | 356 181 315 | 355 243 283 | 250 679 467 | 260 548 118 |
| Industry** exploration drilling (m) | 240 670 | 206 905 | 174 760 | 145 755 |
| Industry** exploration holes drilled | 2 756 | 2 061 | 2 077 | 1 911 |
| Government exploration drilling (m) | NA | NA | NA | NA |
| Government exploration holes drilled | NA | NA | NA | NA |
| Industry** development drilling (m) | 130 785 | 126 130 | 63 310 | 75 000 |
| Industry** development exploration holes drilled | 7 639 | 2 983 | 1 388 | 1 400 |
| Government development drilling (m) | NA | NA | NA | NA |
| Government development exploration holes drilled | NA | NA | NA | NA |
| Subtotal exploration drilling (m) | 240 670 | 206 905 | 174 760 | 145 755 |
| Subtotal exploration holes drilled | 2 756 | 2 061 | 2 077 | 1 911 |
| Subtotal development drilling (m) | 130 785 | 126 130 | 63 310 | 75 000 |
| Subtotal development holes drilled | 7 639 | 2 983 | 1 388 | 1 400 |
| Total drilling (m) | 371 455 | 333 008 | 238 070 | 220 755 |
| Total number of holes | 10 395 | 5 044 | 3 465 | 3 311 |

* Rössing, Valencia, Bannerman and Reptile only.

** 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 |
|---|---|---|---|---|
| Unconformity-related | | | | |
| Sandstone | | | | |
| Hematite breccia complex | | | | |
| Quartz-pebble conglomerate | | | | |
| Vein | | | | |
| Intrusive | | 5 933 | 149 738 | 266 967 |
| Volcanic and caldera-related | | | | |
| Metasomatite | | | | 2 454 |
| Other* | | | 85 113 | 93 176 |
| Total | | 5 933 | 234 851 | 362 597 |

* 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.

### 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 | 0 | 0 | |
| Open-pit mining (OP) | 0 | 5 933 | 201 149 | 325 612 | 78-85 |
| *In situ* leaching | 0 | 0 | 0 | 0 | 0 |
| Heap leaching | 0 | 0 | 33 702 | 36 985 | 80 |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 5 933 | 234 851 | 362 597 | |

* Also known as stope leaching or block leaching.

### Inferred conventional resources by deposit type

(tonnes U)

| Deposit type | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU |
|---|---|---|---|---|
| Unconformity-related | | | | |
| Sandstone | | | | |
| Hematite breccia complex | | | | |
| Quartz-pebble conglomerate | | | | |
| Vein | | | | |
| Intrusive | | 732 | 16 663 | 91 919 |
| Volcanic and caldera-related | | | | |
| Metasomatite | | | | 1 659 |
| Other* | | | 9 458 | 61 915 |
| Total | | 732 | 26 121 | 155 493 |

* 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.

### 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 | 0 | 0 | |
| Open-pit mining (OP) | 0 | 732 | 26 120 | 121 680 | 78-85 |
| *In situ* leaching | 0 | 0 | 0 | 0 | |
| Heap leaching | 0 | 0 | 0 | 33 814 | 80 |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 732 | 26 120 | 155 493 | |

* Also known as stope leaching or block leaching.

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining* | 91 098 | 4 365 | 4 626 | 4 503 | 104 592 | 3 864 |
| Underground mining* | | | | | | |
| *In situ* leaching | | | | | | |
| Co-product/by-product | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 91 098 | 4 365 | 4 626 | 4 503 | 104 592 | 3 864 |

* Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 91 098 | 4 365 | 4 626 | 4 503 | 104 592 | 3 864 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** | 0 | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching | 0 | 0 | 0 | 0 | 0 | 0 |
| U recovered from phosphates | 0 | 0 | 0 | 0 | 0 | 0 |
| Other methods*** | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 91 098 | 4 365 | 4 626 | 4 503 | 104 592 | 3 864 |

* 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 2010

| Domestic | | | | Foreign | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | | |
| (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) |
| NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

### Uranium industry employment at existing production centres

(person-years)

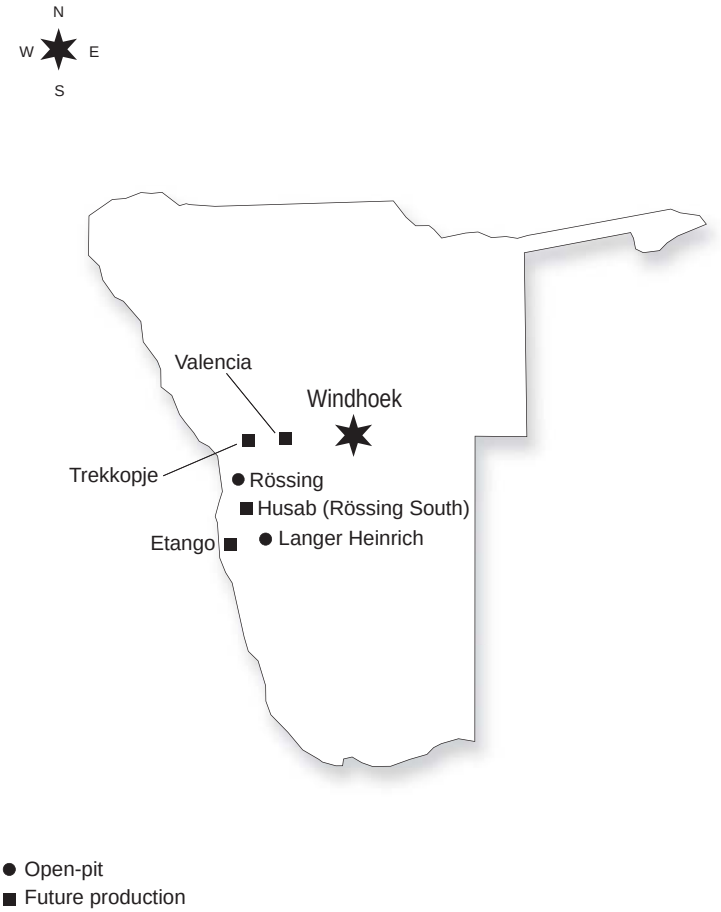
| | | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|---|
| Total staff employment | Rössing | 1 307 | 1 415 | 1 592 | 1 800 |
| Employment directly related to uranium production | Rössing | 981 | 1 044 | 1 165 | 1 200 |
| Staff employment | Langer Heinrich | 198 | 210 | 270 | 315 |
| Contractors directly related to uranium production | Langer Heinrich | 200 | 184 | 289 | 329 |
| Staff employment | Trekkopje | 130 | NA | NA | NA |
| Contractors directly related to uranium production | Trekkopje | | | | |
| Total employment | All | >2 543 | >2 781 | >3 142 | >3 647 |

### Short-term production capability

(tonnes U/year)

| 2011 | | | | 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 |
| 0 | 0 | 3 585 | 3 585 | 0 | 0 | 6 000 | 17 000 | 0 | 0 | 7 000 | 20 000 |

| 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 |
| 0 | 0 | 3 200 | 19 000 | 0 | 0 | 2 500 | 14 000 | 0 | 0 | 2 500 | 7 500 |





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# Niger*

## Uranium exploration and mine development

### *Historical review*

Uranium exploration in the Arlit area, initiated in 1956 by the Commissariat à l'Energie Atomique (CEA), was subsequently undertaken by COGEMA. Discovery of mineralised areas eventually led to the mining of the Arlette, Artois and Ariege deposits by the Société des Mines de l'Aïr (Somaïr), and the Akouta and Akola deposits by the Société des Mines d'Akouta (Cominak). Exploration along the north-west extension of the Arlette flexure fault resulted in the discovery of the Taza deposit. The Société Minière de Tassa N'Taghalgue (SMTT) was organised to own the deposit, but in 1986 assigned part of the mining rights to Somaïr.

In subsequent years, both Somaïr and Cominak were involved in exploration solely for the purpose of better evaluating known deposits. Somaïr delineated the Taza Nord deposit, while Cominak evaluated a mineralised area located south-east of the Akola deposit.

Since 1993, both Somaïr and Cominak have conducted significant drilling programmes. Part of the drilling results led to reassessment of the resource estimates of the Takriza and Tamou deposits by Somaïr and further evaluation of the South Akouta and Akola deposits by Cominak. The remainder of SMTT's rights were assigned to Somaïr in 1996 and SMTT was subsequently dissolved.

### *Recent and ongoing uranium exploration and mine development activities*

Since 2006, uranium exploration in Niger has been revitalised. A total of six new exploration permits were granted in that year and by 2011 uranium exploration activities were being carried out on 160 concessions by foreign companies.

*Somaïr*

Heap leach lixiviation treatment of low-grade stockpiles (i.e. <0.014% U) was resumed in 2009 with expectations to produce up to 900 tU/yr with this process.

*Cominak*

Further delineation of the southern part of the Ebba deposit continues. This deposit is located south of the previously mined Akouta and Akola deposits, in an area covered by a mining permit granted by the government of Niger in 2006.

*Imouraren*

A mining licence was granted to AREVA in 2009 and the operating company Imouraren SA was created between AREVA and Société du Patrimoine des Mines du Niger (SOPAMIN). SOPAMIN holds the state's shares in existing uranium companies in Niger and is responsible for commercial transactions, such as uranium sales. Later in 2009, the

* Secretariat report based on company reports and information provided by the government of Niger.

South Korean company KEPCO gained an indirect interest in the company. The current consortium is AREVA NC Expansion (85% AREVA, 15% KEPCO) holding a 66.65% interest and the balance of 33.35% is held by Niger.

*Somina*

A new company Société des Mines d'Azelik (SOMINA) was created in 2007 to mine the Azelik/Teguidda deposit. First production from this deposit was announced at the end of December 2010. Total RAR and inferred recoverable resources amount to 15 900 tU.

*Others*

GoviEx holds exploration properties of 2 300 $km^2$ near the Arlit mine, as well as 2 000 $km^2$ near Agadez. In August 2008, Cameco bought an 11% share of GoviEX, with options to increase that share to 48%. As of January 2011, NI 43-101 compliant identified resources of nearly 40 000 tU have been reported for the Marianne/Marilyn deposits and MAD South area.

URU Metals Limited (previously Niger Uranium Limited) reported a SAMREC compliant inferred resource of 1 654 tU. Exploration drilling of approximately 5 600 m was completed in 2010 and an additional 7 000 m as a follow-up of prospective areas was planned.

In 2007, Trendfield, a Chinese company, formed the UREX joint venture with Artemis Resources (Australia) to explore the Tagaza deposits adjacent to Teguidda. Also in 2007, Mumbai-based Taurian Resources Private Limited obtained licences with rights to over 3 000 $km^2$ in the Arlit region. Subsequent to the granting of these licences, no exploration activity has been publicly reported by either company.

In 2009, Korea Resources Corp. (KORES) agreed to buy 400 tU/yr from the government of Niger beginning in 2010 and to take a 5% share of the Teguidda mine in central Niger from Trendfield.

In 2010, Gazprombank NGS, a Moscow-based company was awarded a licence to explore for uranium in the Agadez region of northern Niger. According to a statement made by the government the company will invest USD 5 million in the project.

In December 2010, Paladin completed the takeover of NGM Resources Ltd (NGM), the owner of the local company Indo Energy Ltd which held concessions in the Agadez region. NGM Resources had announced an inferred mineral resource of 4 320 tU. Paladin indicates that they have developed an exploration programme to identify higher grade uranium mineralisation in the Lower Carboniferous stratigraphies of the area.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

The total identified conventional resources for Niger, as of the end of 2011, amount to 445 500 tU, which is approximately a 60% increase from that reported in 2009. This increase is primarily attributed to additional resources defined at the Imouraren deposit and some smaller contributions from the Azelik and Madaouela deposits. The uranium deposits in Niger are all considered sandstone hosted-type with average grades of 0.07 to 0.39% U.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

Total speculative and prognosticated resources in Niger, as of the end of 2011, are 64 900 tU associated with the Azelik, Adrar Emoles, Tin Negouren concessions, and Agadez projects/deposits. This is an increase of 163% compared to 2009.

## Uranium production

### *Historical review*

Uranium has been produced from sandstone deposits in Niger since 1970 and 1978 by Somaïr and Cominak. The Société Minière de Tassa N'Taghalgue (SMTT) assigned its mining rights to Somaïr in 1996 and was subsequently dissolved. In 2007, Société des Mines d'Azelik (SOMINA) was created to mine the Azelik/Teguidda deposit and first production was achieved at the end of December 2010.

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

The two long-standing uranium production centres in Niger operated by Somaïr and Cominak. In 2009, a facility to process low-grade ores through heap leaching was launched at Somaïr which provides the potential to increase production by an additional 900 tU. The Teguidda/Azelik deposit, owned by Somina was reportedly developed with a USD 99 million loan from the China National Nuclear Corporation (CNNC), or SinoU. Limited production began in late 2010 and at full production, expected in 2012, the mine has a projected production capability of 700 tU/yr. This will bring the current total production capability of Niger to 5 400 tU/year, up from 4 500 tU/yr in 2009.

**Uranium production centre technical details**

(as of 1 January 2011)

| | Centre #1 | | Centre #2 | Centre #3 | Centre #4 |
|---|---|---|---|---|---|
| Name of production centre | Arlit (Somair) | | Akouta (Cominak) | Azelik (Somina) | Imouraren |
| Production centre classification | Existing | | Existing | Existing | Committed |
| Date of first production (year) | 1970 | 2009 | 1978 | 2010 | 2014 |
| Source of ore: | | | | | |
| Deposit name(s) | Tamou/Artois Tamgak | Low Grade Stockpiles | Akouta/Akola Ebba | Azelik | Imouraren |
| Deposit type(s) | Sandstone | Sandstone | Sandstone | Sandstone | Sandstone |
| Recoverable resources (tU) | 42 200 | 5 500 | 47 700 | 15 600 | 279 000 |
| Grade (% U) | 0.25 | 0.07 | 0.39 | | 0.07 |
| Mining operation: | | | | | |
| Type (OP/UG/ISL) | OP | HL | UG | OP/UG | OP |
| Size (tonnes ore/day) | | | | | |
| Average mining recovery (%) | | | | | |
| Processing plant: | | | | | |
| Acid/alkaline | Acid | Acid | Acid | Alkaline | |
| Type (IX/SX) | SX | SX | SX | | |
| Size (tonnes ore/day) | 1 900 | 3 800 | 1 900 | 1 600 | 5 000 |
| Average process recovery (%) | 95 | 65 | 95 | 87 | |
| Nominal production capacity (tU/year) | 1 900 | 1 000 | 1 800 | 700 | 5 000 |
| Plans for expansion | Yes | | | | |
| Other remarks | 3 000 tU in 2012 (HL) | | | | |

### *Ownership structure of the uranium industry*

The ownership structure of Niger's three production companies and committed production centre is defined below.

| Somaïr | Cominak | Somina | Imouraren |
|---|---|---|---|
| 36.6% SOPAMIN (Niger) | 31% SOPAMIN (Niger) | 37.2% CNUC (China) | 33.35% Niger |
| 63.4% AREVA NC | 34% AREVA NC (France) | 33% SOPAMIN (Niger) | 56.65% AREVA |
| | 25% OURD (Japan) | 24.8% ZXJOY invest (China) | 10% KEPCO |
| | 10% Enusa (Spain) | 5% KORES | |

### *Employment in the uranium industry*

Approximately 1 175 are employed at the Somaïr mine and 1 140 at the Cominak mine. It is reported that 99% of the workers at these two mines are Nigerien. Employment at the Azelik mine is projected to be around 600 employees for a 700 tU/yr operation. The Imouraren Project currently employs 299 in 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*

*AREVA NC*

On 4 May 2009, development of the Imouraren mine was launched with an initial investment of more than USD 1.6 billion. Once up to full production capacity, it should be producing 5 000 tU/yr for 35 years. Production is currently scheduled to start in 2014.

## Environmental activities and socio-cultural issues

On 6 December 2011, AREVA announced the creation of the Health Observatory for the Agadez Region (OSRA), one year after setting up a similar institution in Gabon. Like the observatory in Gabon, OSRA is to monitor the health of former workers in AREVA uranium mines in Niger, as well as the health of the local population. In cases of illness attributable to occupational factors, the cost of corresponding health care is to be covered by AREVA. Other such observatories associated with other mining facilities operated by AREVA are planned.

## Uranium requirements

There are currently no uranium requirements in Niger. News reports indicate that Niger is considering a civilian nuclear reactor for their energy needs and as a means to assist economic improvement in the country.

## 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 its uranium industry. In July 2011, President Issoufo 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.

### Uranium exploration and development expenditures and drilling effort – domestic

(CFA Francs millions)

| | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|
| Industry* exploration expenditures | 27 688 | 68 210 | 9 504 | 27 325 |
| Government exploration expenditures | | | | |
| Industry* development expenditures | 59 693 | 74 890 | 234 111 | 132 294 |
| Government development expenditures | | | | |
| Total expenditures | 87 381 | 143 100 | 243 615 | 159 619 |
| Industry* exploration drilling (m) | | | | |
| Industry* exploration holes drilled | | | | |
| Government exploration drilling (m) | | | | |
| Government exploration holes drilled | | | | |
| Industry* development drilling (m) | | | | |
| Industry* development holes drilled | | | | |
| Government development drilling (m) | | | | |
| Government development holes drilled | | | | |
| Subtotal exploration drilling (m) | | | | |
| Subtotal exploration holes drilled | | | | |
| Subtotal development drilling (m) | | | | |
| Subtotal development holes drilled | | | | |
| Total drilling (m) | | | | |
| Total number of holes drilled | | | | |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | 5 500 | 5 500 | 339 000 | 340 600 | |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | | | | |
| Metasomatite | | | | | |
| Other* | | | | | |
| Total | 5 500 | 5 500 | 339 000 | 340 600 | |

*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.

### 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 | 38 300 | 38 300 | 85 |
| Open-pit mining (OP) | 5 500 | 5 500 | 300 700 | 300 700 | 95 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 1 600 | 75 |
| Total | 5 500 | 5 500 | 339 000 | 340 600 | |

### 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 | 38 300 | 38 300 | 85 |
| Conventional from OP | 0 | 0 | 295 200 | 295 200 | 95 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 5 500 | 5 500 | 5 500 | 5 500 | 70 |
| Unspecified | 0 | 0 | 0 | 0 | 75 |
| Total | 5 500 | 5 500 | 339 000 | 340 600 | |

* Also known as stope leaching or block leaching.

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

### Inferred conventional resources by deposit type

(tonnes U)

| Deposit type | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | 0 | 0 | 82 000 | 104 900 | |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | | | | |
| Metasomatite | | | | | |
| Other* | | | | | |
| Total | 0 | 0 | 80 200 | 104 900 | |

* 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.

### 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 | 46 300 | 46 300 | 85 |
| Open-pit mining (OP) | 0 | 0 | 20 400 | 38 800 | 95 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | 70 |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 15 300 | 19 800 | 75 |
| Total | 0 | 0 | 82 000 | 104 900 | |

### 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 | 46 300 | 46 300 | 85 |
| Conventional from OP | 0 | 0 | 20 400 | 38 800 | 95 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 15 300 | 19 800 | 75 |
| Total | 0 | 0 | 82 000 | 104 900 | |

* 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 |
| | 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | | | | | | |
| Sandstone | 103 911 | 2 993 | 3 245 | 4 197 | 114 346 | 4 264 |
| Hematite breccia complex | | | | | | |
| Quartz-pebble conglomerate | | | | | | |
| Vein | | | | | | |
| Intrusive | | | | | | |
| Volcanic and caldera-related | | | | | | |
| Metasomatite | | | | | | |
| Other* | | | | | | |
| Total | 103 911 | 2 993 | 3 245 | 4 197 | 114 346 | 4 264 |

* 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.

## Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 46 221 | 1 704 | 1 808 | 2 650 | 52 383 | 2 726 |
| Underground mining[1] | 57 690 | 1 289 | 1 437 | 1 547 | 61 963 | 1 538 |
| *In situ* leaching | | | | | | |
| Co-product/by-product | | | | | | |
| Total | 103 911 | 2 993 | 3 245 | 4 197 | 114 346 | 4 264 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 103 911 | 2 993 | 3 245 | 4 197 | 114 346 | 4 264 |
| In-place leaching* | | | | | | |
| Heap leaching** | | | | | | |
| U recovered from phosphate rocks | | | | | | |
| Other methods*** | | | | | | |
| Total | 103 911 | 2 993 | 3 245 | 4 197 | 114 346 | 4 264 |

* 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.

### Uranium industry employment at existing production centres

(person-years)

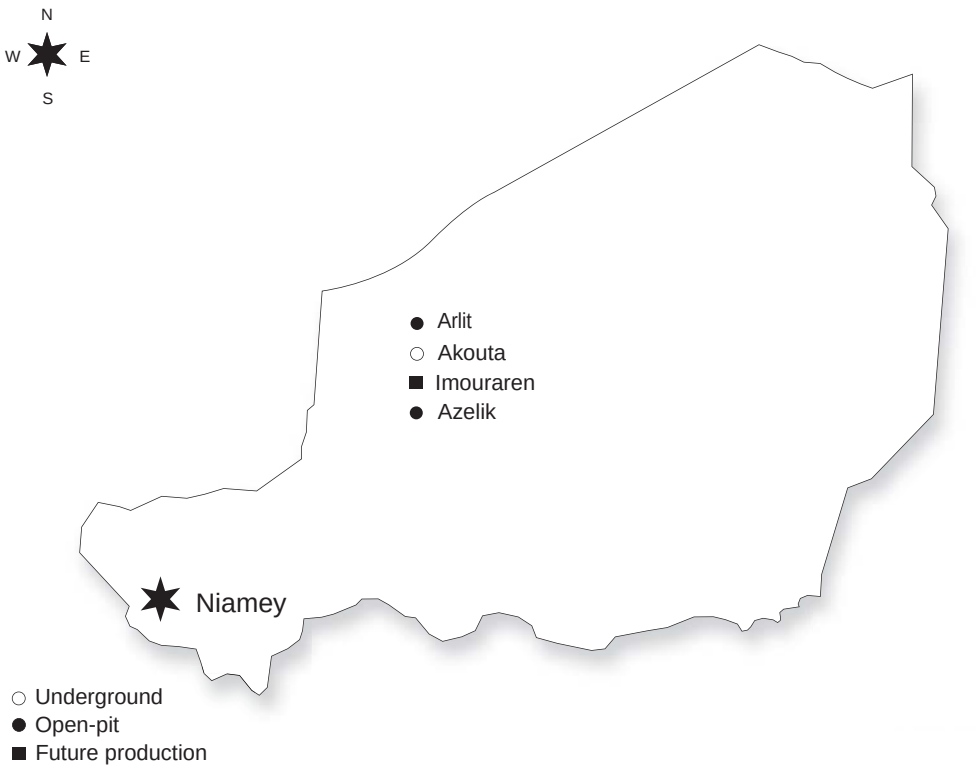
| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 2 156 | 2 764 | 2 981 | 3 231 |
| Employment directly related to uranium production | NA | NA | NA | NA |

### Short-term production capability

(tonnes U/year)

| 2011 | | | | 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 |
| NA | NA | 5 400 | 5 400 | 1 000 | 1 000 | 5 400 | 11 500 | 1 000 | 1 000 | 11 500 | 11 500 |

| 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 |
| NA | NA | 10 500 | 10 500 | NA | NA | 7 500 | 7 500 | NA | NA | 7 500 | 7 500 |



# Peru

## Uranium exploration and mine development

### *Historical review*

The Macusani Uraniferous District (Department of Puno) is located in south-east Peru. The uraniferous mineralisation is found in acid volcanic rocks from the Mio-Pliocene age (10 to 4 m.a.) in Macusani's tectonic depression into basement rocks of Palaeozoic age.

Radiometric prospecting has revealed over 40 uraniferous areas, the most important being Chapi, Chilcuno-VI, "Pinocho", Cerro Concharrumio, Cerro Calvario, etc.

Uranium mineralisation consists of: pitchblende, gummite, autunite and meta-autunite, filling sub-vertical to sub-horizontal fractures, with impregnation on both sides of the fracture. Host rocks are the lapilli tuffs of the Quenamari Volcanic formation.

Considering all the areas, Chapi is the most important site, and detailed radiometry, emanometry, trench and gallery work and diamond drilling have been performed there. The mineralisation is in sub-vertical fractures distributed in structural lineaments 15 to 150 m wide and 20 to 30 m thick. The grades vary between 0.03% and 0.75% U, with an average of 0.1% U. Based on the exploration results, and both the geological and emanometry information, a minimum potential of 10 000 tU has been assigned to Chapi site and 30 000 to the entire Macusani Uraniferous District.

### *Recent and ongoing uranium exploration and mine development activities*

Since 2003, several private companies have restarted the exploration in the Tertiary volcanic environment in both the Macusani and the Santa Lucia-Rio Blanco area (a distance of 250 km) in order to explore and develop uranium resources through different prospects in the Macusani Uraniferous District, Puno province, including Macusani, Santa Lucia-Rio Blanco and Pampacolca (Arequipa). However, no information is available on exploration expenditures or drilling efforts.

Uranium potential in the rest of the country is important, and the Instituto Peruano De Energia Nuclear (IPEN) through its promotional activities highlights new areas of interest, such as the permo-triasic magmatism in San Ramón granite (eastern cordillera) and the Corongo (Miocene age) region of central Peru, where some work has already demonstrated potential for uranium occurrences.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

The identified uranium resources of Peru are primarily located in the Macusani area, Puno province. See the relevant table for details.

These are resources identified and recognised by IPEN. With the entry of several uranium exploration companies in the country (Macusani Yellowcake and Vena Resources, in joint venture with Cameco), the resources have been increased through the development of new areas of uranium exploration in the Macusani District. However, IPEN has not yet incorporated these resource estimates into national totals. This is discussed further in Chapter 1.

**Macusani Uranium District identified resources**

(tU, *in situ*)

| Prospect | RAR | IR | Total |
|---|---|---|---|
| Chapi | 1 670 | 1 720 | 3 390 |
| Chilcuno-vi | 80 | 20 | 100 |
| Pinocho | 40 | 30 | 70 |
| Concharumio | 0 | 90 | 90 |
| Total | 1 790 | 1 860 | 3 650 |

### *Undiscovered conventional resources (prognosticated and speculative resources)*

Undiscovered conventional resource in the Mascusani Uranium District are estimated to total 26 350 tU. Of this total, 6 610 tU in the Chapi deposit area are classified as prognosticated resources and 19 740 tU are classified as speculative resources, based on the distribution of the Tertiary volcanic host rock in the Macusani Uraniferous District. An additional 20 000 tU of low-grade prognosticated conventional uranium resources are estimated to occur in two other localities in Peru. Small occurrences at 39 other localities noted below are not included in the national total of undiscovered resources.

| Macusani Uranium District (MUD) | |
|---|---|
| Chapi | 6 610 tU |
| Rest of MUD* | 19 740 tU |
| Total | 26 350 tU |
| At country level: | |
| Permo-triasic granites** | 20 000 tU |
| 39 locations*** | 5 600 tU |
| Total | 25 600 tU |

***** Extension of 1 000 $km^2$, distribution of tertiary volcanic rocks with uranium associate, MUD.

** Granites with radioactive anomalies: located in the departments of Junín and Ancash, average of 50 ppm uranium.

*** Other: in the rest of the country, uranium deposits associated with hydrothermal deposits (Cu-Pb-Ni-W).

## Uranium production and requirements

Peru has never produced uranium and reported no plans to do so. Additionally, Peru has no uranium requirements nor reported any formal plans to develop a nuclear generation capacity.

## Environmental activities and socio-cultural issues

Companies active in the Mancuni region are in the exploration stage and have little environmental impact, as the work only consists of accessing the area and drilling operations. Local communities participate in monitoring the activities of the companies. The Peru-Canada Mineral Resources Reform Project (PERCAN) is working with the Ministry of Mines and Energy to develop an environmental guide for uranium exploration which is expected to be completed by the end of 2011.

## National policies relating to uranium

Exploration and mining activities, formerly conducted by government, entered into a privatisation process with passage in 1992 of the Law of Mining Investment Promotion.

This legislation aims to provide stability and a guaranteed framework for long-term investments, including uranium. The reactivation of interest in uranium exploration in the country in recent years has resulted in foreign private companies commencing exploration in the areas where IPEN had performed prospecting and exploration work. Technical information gathered by IPEN has been made available to the private companies.

IPEN is active in the promotion of investment in uranium mining in the country by investigating new areas other than the Macusani region and increasing the potential for further uranium discoveries.

The Technical Office of the 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 in the process of being developed.

Currently, there are five active junior mining companies, all from Canada: Vena Resources/Cameco, Southern Andes Energy Inc, Macusani Yellowcake, Fission Energy Corp and Wealth Minerals Ltd.

**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 (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | | | | | |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | 1 790 | | | *In situ* |
| Metasomatite | | | | | |
| Other* | | | | | |
| Total | | 1 790 | | | |

* 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.

**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) | | | | | |
| Open-pit mining (OP) | | 1 790 | | | *In situ* |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| Co-product and by-product | | | | | |
| Unspecified | | | | | |
| Total | | 1 790 | | | |

### 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 | | | | | |
| Conventional from OP | | | | | |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| In-place leaching* | | | | | |
| Heap leaching** from UG | | | | | |
| Heap leaching** from OP | | 1 790 | | | *In situ* |
| Unspecified | | | | | |
| Total | | 1 790 | | | |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | | | | | |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | 1 860 | | | *In situ* |
| Metasomatite | | | | | |
| Other* | | | | | |
| Total | | 1 860 | | | |

* 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.

### 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) | | | | | |
| Open-pit mining (OP) | | 1 860 | | | *In situ* |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| Co-product and by-product | | | | | |
| Unspecified | | | | | |
| Total | | 1 860 | | | |

**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 | | | | | |
| Conventional from OP | | | | | |
| *In situ* leaching acid | | | | | |
| *In situ* leaching alkaline | | | | | |
| In-place leaching* | | | | | |
| Heap leaching** from UG | | | | | |
| Heap leaching** from OP | | 1 860 | | | *In situ* |
| Unspecified | | | | | |
| Total | | 1 860 | | | |

* 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 |
| 6 610 | 20 000 | 20 000 |

**Speculative conventional resources**

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 130/kgU | <USD 260/kgU | Unassigned |
| 19 740 | 19 740 | |

# Poland

## Uranium exploration and mine development

### *Historical review*

Prospecting for uranium accumulations in Poland began in 1948. The industrial plant in Kowary (Lower-Silesian Voivodeship) was then established, which was involved in exploitation and processing of uranium deposits.

Research from 1956 by Polish Geological Institute concerned Carboniferous formations of the Upper Silesian coal basin and phosphorite formations, as well as research in boreholes in the Polish lowlands. As a result of this research, signs of uranium mineralisation were discovered in lower Ordovician formations of the Podlasie Depression ('Rajsk' deposit) and in Triassic formations of the Perybaltic Syneclize and the Sudetes (Okrzeszyn, Grzmiąca, Wambierzyce). Approximately 20 tU were extracted from the Kopaliny-Kletno deposit.

In the Ladek and Snieznik Klodzki metamorphic rocks small occurrences of uranium mineralisation and the Kopaliny-Kletno deposit were discovered.

### *Recent and ongoing uranium exploration and mine development activities*

There are no current (up-to-date) documented uranium deposits in Poland, and no concessions for uranium granted. There are some perspective indications of uranium resources but there are currently no prospects for the discovery of uranium that could be economically exploited.

In 2009, the Polish government decided to introduce nuclear energy and the Polish nuclear energy programme is under preparation. One of its topics to be researched is the possibility of mining uranium resources in Poland. This research programme is to be conducted during the next years.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

| Region | Resources in place (t) | Uranium content (%) |
|---|---|---|
| "Rajsk" deposit (Podlasie Depression) | 5 320 | 0.025 |
| Okrzeszyn (Sudetes) | 937.6 | 0.05-0.11 |
| Grzmiąca (Sudetes) | 792 | 0.05 |
| Wambierzyce (Sudetes) | 217.5 | 0.0236 |

The data from the above table outlines information from old geological investigations which do not fulfil current economic conditions. Recent reinterpretation of geological data made in 2009-2010, shows that Poland is not endowed with identified conventional resources of economic interest. Without more precise exploration of these resources, there would appear to be no possibility for profitable exploitation.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

| Region | Speculative resources for depth to 1 000 m (t) |
|---|---|
| Perybaltic Syneclise | 20 000 |

## Uranium production

### *Historical review*

In 1948, a government operated industrial plant was established in Kowary (Lower-Silesian Voivodeship) to process ore mined from local uranium deposits.

Exploitation of vein deposits in the Karkonosko-izerski Block and metamorphic deposits in the Ladek and Snieznik Klodzki continued until 1967. Data concerning production from these uranium deposits are presented in the following table.

| | Deposit name | Uranium resources (t) | Exploited (t) |
|---|---|---|---|
| 1 | Wolnosc | 94.0 | 94.0 |
| 2 | Miedzianka | 14.7 | 14.7 |
| 3 | Podgorze | 280.0 | 199.0 |
| 4 | Rubezal | 0.5 | 0.5 |
| 5 | Mniszkow | 4.5 | 4.5 |
| 6 | Wiktoria | 0.28 | 0.28 |
| 7 | Majewo | 0.96 | 0.0 |
| 8 | Wolowa Gora | 2.5 | 2.5 |
| 9 | Radoniow | 345.0 | 214.0 |
| 10 | Wojcieszyce | 14.4 | 12.3 |

Exploitation of vein deposits in the Karkonosko-Izerski Block (Wolnosc, Miedzianka, Podgorze, Rubezal, Mniszkow, Wiktoria, Majewo, Wolowa Gora, Radoniow, Wojcieszyce) and metamorphic in Ladek and Snieznik Klodzki (where small uranium mineralisations and the Kopaliny-Kletno deposit were discovered) took place up to 1967, when the deposits were almost completely depleted. During this time, all uranium production was exported to USSR.

It is estimated that between 1948 and 1967 there were approximately 650 tU was mined in the Sudetes of Poland.

Chemical treatment of low-grade ores started in Kowary in 1969 at the only uranium processing plant in Poland. The processing of low-grade ore continued until 1972. Operations resulted in a significant volume of waste which was disposed of in a tailings pond.

In Ladek and Snieznik Klodzki metamorphic rocks, a few spots with uranium mineralisation and the "Kopaliny-Kletno" deposit were discovered. There were approximately 20 tU extracted from this deposit.

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

Currently in Poland no concessions for uranium granted.

## Environmental activities and socio-cultural issues

All activities associated with uranium mining and processing in Poland were performed between 1948 and 1976 and the companies associated with this activity no longer exist. However, there is still a need to remediate the environment in the area around the sites where the mines operated. The Geological and Mining Law stipulates that the State Treasury is accountable for liabilities from all past uranium production activities in Poland. Therefore, the government is responsible for funding remediation, either from the national or the district Environmental Protection Fund.

The regional authorities of the Voivodship and its special inspectorates or officers are responsible for different aspects of remediation. The local authorities have to approve the remediation plans and supervise their execution and effects. The inspectorates of the Environmental Protection of Voivodship are responsible in general for environmental monitoring. Radiological monitoring, considered as part of this overall monitoring programme, is performed under the responsibility of the President of the National Atomic Energy Agency.

Since 1996, Poland has taken part in the PHARE Multi-country Environmental Sector Programme on "Remediation Concepts for the Uranium Mining Operation in Central and Eastern European Countries" (CEEC). In the framework of this Programme, an inventory and a common database for the CEEC have been developed. According to this inventory, the situation in Poland is characterised by a large number of small-scale liabilities from uranium exploration, localised over several places in the country and generally causing minor impacts on the environment.

Only a limited number of issues related to mining and milling are considered to be causing serious impacts. The most important is the tailings pound in Kowary. The 1.3 ha tailing pond is a hydrological construction closed on three sides by a dam that has been modified a number of times in the past. The dam itself is 300 m long (the sum of three sides) and has a maximum height of 12 m. As a result of uranium processing activities, the tailings pond has been filled with about 250 000 t of fine-grained gneisses and schists with average uranium content of 30 ppm. In the early 1970s, the Wroclaw University of Technology (WUT) received, by governmental decision, the ownership of both the area and facilities of the former uranium mining company. Subsequently, a company owned by WUT has continued to use the existing chemical plant for various experimental processes on rare earth metals, chemical production and galvanic processes. As a result, about 300 t of remnants of rare metals processing and 5 000 $m^3$ of post-galvanic fluids, with up to 30 t of solids with high content of aluminium, nickel, zinc and sodium sulphates, have been disposed of in the pond.

The remediation programme of the tailings pond was prepared in 1997 by the WUT and successfully carried out under the PHARE programme until 2003. The specific objectives of this programme are related to the construction of drainage systems, the design and construction of the tailings pond cover and the final site reclamation.

## Uranium requirements

Not specified.

### *Supply and procurement strategy*

Not specified.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

The approximate amount of uranium requirements for LWR type reactors proposed in the government programme under development assumes that the first nuclear power unit with power 1 000 MWe or 1 500 MWe (all data about power are shown in net values) will be in operation from 2020. The second unit is assumed to be operated from 2023 with power 1 000/1 500 MWe, the third with power 1 000/1 500 MWe from 2026 and the fourth unit with power 1 000/1 500 MWe from 2029 (according to data from the programme of nuclear power implementation in Poland).

### *Uranium stocks*

NA.

### *Uranium prices*

NA.

### Uranium exploration and development expenditures and drilling effort – domestic

(PLN [Polish zloty])

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 0 | 0 | 0 | 0 |
| Government exploration expenditures | 0 | 0 | 300 000 | 60 000 |
| Industry* development expenditures | 0 | 0 | 0 | 0 |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 0 | 0 | 300 000 | 60 000 |
| Industry* exploration drilling (m) | 0 | 0 | 0 | 0 |
| Industry* exploration holes drilled | 0 | 0 | 0 | 0 |
| Government exploration drilling (m) | 0 | 0 | 0 | 0 |
| Government exploration holes drilled | 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) | 0 | 0 | 0 | 0 |
| Subtotal exploration holes drilled | 0 | 0 | 0 | 0 |
| Subtotal development drilling (m) | 0 | 0 | 0 | 0 |
| Subtotal development holes drilled | 0 | 0 | 0 | 0 |
| Total drilling (m) | 0 | 0 | 0 | 0 |
| Total number of holes drilled | 0 | 0 | 0 | 0 |

* Non-government.

### Historical uranium production by deposit type

(tonnes U in concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | NA | 0 | 0 | 0 | NA | 0 |
| Sandstone | NA | 0 | 0 | 0 | NA | 0 |
| Hematite breccia complex | NA | 0 | 0 | 0 | NA | 0 |
| Quartz-pebble conglomerate | NA | 0 | 0 | 0 | NA | 0 |
| Vein | 650 | 0 | 0 | 0 | 650 | 0 |
| Intrusive | NA | 0 | 0 | 0 | NA | 0 |
| Volcanic and caldera-related | NA | 0 | 0 | 0 | NA | 0 |
| Metasomatite | NA | 0 | 0 | 0 | NA | 0 |
| Other* | NA | 0 | 0 | 0 | NA | 0 |
| Total | NA | 0 | 0 | 0 | NA | 0 |

* 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.

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | NA | 0 | 0 | 0 | NA | 0 |
| Underground mining[1] | 650 | 0 | 0 | 0 | 650 | 0 |
| *In situ* leaching | NA | 0 | 0 | 0 | NA | 0 |
| Co-product/by-product | NA | 0 | 0 | 0 | NA | 0 |
| Total | NA | 0 | 0 | 0 | NA | 0 |

1. Pre-2008 totals may include uranium recovered by heap and in-place leaching.

### Net nuclear electricity generation

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 0 | 0 |

### Installed nuclear generating capacity to 2035

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 000* | 1 650** | 2 000** | 3 300** | 4 500* | 7 000** | 7 000 | 10 000 |

* According to the Programme of Polish Nuclear Power Implementation.

** Data from Programme of Polish Nuclear Power Implementation – Figure 4.4.

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 0 | 0 | 0 | 0 | 0 | 0 | 740* | 1 220* | 400 | 525 | 790 | 900 | 900 | 1 000 |

Note: Assuming 1 TWh requires 23 tonnes Unat.

* Reactor initial fuel loading.

### 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 | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 0 | 0 |

# Portugal

## Uranium exploration and mine development

### *Historical review*

The first uranium-radium deposits in Portugal were found in 1907 and the first mining concession (Rosmaneira) was granted in 1909. Radium was mined at Urgeiriça until 1944 and uranium between 1944 and 1951. Between 1945 and 1962 a foreign privately owned enterprise, Companhia Portuguesa de Radium (CPR) extracted and processed ores from Urgeiriça and other mines in the Beira Alta (central Portugal) region. CPR also carried out regional exploration.

In 1954, the Portuguese government created the Junta de Energia Nuclear (JEN) and in 1955 started an extensive exploration programme of the territory, successfully increasing the resource inventory and discovering about 100 deposits of medium and small size.

See the 2007 Red Book for additional information.

### *Recent and ongoing uranium exploration and mine development activities*

No activity at home or abroad.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

No change since the 2009 edition of the Red Book.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

No change since the 2009 edition of the Red Book.

### *Unconventional resources and other materials*

No change since the 2009 edition of the Red Book.

## Uranium production

### *Historical review*

The Beiras deposits together with Urgeiriça ore mill treatment plant were managed as an integrated uranium production centre, producing about 1 123 tU from 22 concessions between 1951 and 1962. In July 1985, a new capacity expansion to 200 000 t/yr was implemented. A total of 825 tU was produced at the Urgeiriça plant and the pilot plant at Senhora das Fontes. Ore processing was stopped at the Urgeiriça mill in 1999 and the facility was decommissioned in March 2001.

Although the Alto Alentejo deposits, which include the largest national ore body (Nisa, with roughly 3 500 tU) could support another production centre, no development has taken place. The last attempt to start production in this area was abandoned in 1999 after a positive environmental assessment but a negative economic appraisal.

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

Former production centres have been demolished and reclaimed. No future production centres are planned.

## Environmental activities and socio-cultural issues

### *Site rehabilitation*

During 2009 and 2010, the only uranium activities in Portugal were related to the rehabilitation and monitoring of closed mine sites.

In Portugal, Empresa de Desenvolvimento Mineiro (EDM), the state-owned company responsible for dealing with mining legacy in general, has carried out remediation work on several sites. This work has required expenditures amounting to a total of more than EUR 6.2 million.

In this respect, the most important work performed has been the rehabilitation of the mine site and the tailings pond of Senhora das Fontes, where a pilot mine and plant has been operating for 20 years. At the Urgeiriça site some areas have been opened to the public as leisure areas.

Monitoring of the radioactive impact has continued for the main sites and Euratom has inspected the ongoing activity and checked the quality of work done on site.

| Mine site | Expenditure x EUR 1 000 | | |
|---|---|---|---|
| | 2009 | 2010 | Total |
| Senhora das Fontes | 104 | 1 778 | 1 882 |
| Bica | 0 | 133 | 133 |
| Cunha Baixa | 33 | 138 | 171 |
| Urgeiriça – old tailings pond and industrial area projects | 462 | 251 | 713 |
| Urgeiriça – new tailings pond | 0 | 113 | 113 |
| 20 small rehabilitation projects | 251 | 438 | 689 |
| Safety works in several uranium mines | 1 005 | 630 | 1 635 |
| Monitoring | 547 | 347 | 894 |
| Total | 2 403 | 3 828 | 6 231 |

## Uranium requirements

Portugal has no uranium requirements.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

The new government elected by the end of 2009 has the same prime minister and the same majority in parliament. Energy policy in the government programme follows the same main lines as previously and a new energy strategy (Energia 2020) reaffirms the importance of renewable energy (mainly wind and hydropower) and energy efficiency as a means of reducing the external energy dependence, its impact on the trade balance and meeting commitments made with respect to the Kyoto Protocol agreement. Once again nuclear energy is not considered in the energy mix until 2020.

### *Uranium stocks*

No change of stocks since the 2009 edition of the Red Book.

**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 (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | |
| Sandstone | 0 | 0 | 0 | 0 | |
| Hematite breccia complex | 0 | 0 | 0 | 0 | |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | |
| Vein | 0 | 4 500 | 6 000 | 6 000 | 75 |
| Intrusive | 0 | 0 | 0 | 0 | |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | |
| Metasomatite | 0 | 0 | 0 | 0 | |
| Other* | 0 | 0 | 0 | 0 | |
| Total | 0 | 4 500 | 6 000 | 6 000 | |

* 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.

**Reasonably assured conventional resources by production method**

(tonnes U)

| Production method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Underground mining (UG) | 0 | 0 | 500 | 500 | 80 |
| Open-pit mining (OP) | 0 | 4 500 | 5 500 | 5 500 | 75 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 4 500 | 6 000 | 6 000 | |

**Reasonably assured conventional resources by processing method**

(tonnes U)

| Processing method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Conventional from UG | 0 | 0 | 500 | 500 | 80 |
| Conventional from OP | 0 | 4 500 | 5 500 | 5 500 | 75 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 4 500 | 6 000 | 6 000 | |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | |
| Sandstone | 0 | 0 | 0 | 0 | |
| Hematite breccia complex | 0 | 0 | 0 | 0 | |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | |
| Vein | 0 | 1 000 | 1 000 | 1 000 | 75 |
| Intrusive | 0 | 0 | 0 | 0 | |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | |
| Metasomatite | 0 | 0 | 0 | 0 | |
| Other* | 0 | 0 | 0 | 0 | |
| Total | 0 | 1 000 | 1 000 | 1 000 | |

* 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.

### 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 | 0 | 0 | |
| Open-pit mining (OP) | 0 | 1 000 | 1 000 | 1 000 | 75 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 1 000 | 1 000 | 1 000 | |

### Inferred conventional resources by processing method

(tonnes U)

| Processing method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Conventional from UG | 0 | 0 | 0 | 0 | |
| Conventional from OP | 0 | 1 000 | 1 000 | 1 000 | 75 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 1 000 | 1 000 | 1 000 | |

* 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 |
| 1 000 | 1 500 | 0 |

### Speculative conventional resources

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 130/kgU | <USD 260/kgU | Unassigned |
| NR | NR | 0 |

NR = Not reported.

### Historical uranium production by deposit type

(tonnes U in concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 | 0 |
| Vein | 3 720 | 0 | 0 | 0 | 0 | 3 720 |
| Intrusive | 0 | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 3 720 | 0 | 0 | 0 | 0 | 3 720 |

* 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.

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 1 810 | 0 | 0 | 0 | 1 810 | 0 |
| Underground mining[1] | 1 326 | 0 | 0 | 0 | 1 326 | 0 |
| *In situ* leaching | 584 | 0 | 0 | 0 | 584 | 0 |
| Co-product/by-product | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 3 720 | 0 | 0 | 0 | 3 720 | 0 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 3 136 | 0 | 0 | 0 | 3 136 | 0 |
| In-place leaching* | 250 | 0 | 0 | 0 | 250 | 0 |
| Heap leaching** | 321 | 0 | 0 | 0 | 321 | 0 |
| U recovered from phosphate rocks | | 0 | 0 | 0 | | 0 |
| Other methods*** | 13 | 0 | 0 | 0 | 13 | 0 |
| Total | 3 720 | 0 | 0 | 0 | 3 720 | 0 |

* Also known as stope leaching or block leaching.

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

*** Includes mine water treatment and environmental restoration.

**Total uranium stocks**

(tonnes natural U-equivalent)

| Holder | Natural uranium stocks in concentrates | Enriched uranium stocks | Enrichment tails | LWR reprocessed uranium stocks | Total |
|---|---|---|---|---|---|
| Government | 168 | 0 | 0 | 0 | 168 |
| Producer | 0 | 0 | 0 | 0 | 0 |
| Utility | 0 | 0 | 0 | 0 | 0 |
| Total | 168 | 0 | 0 | 0 | 168 |

# Russian Federation

## 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 the Russian Federation. 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 sandstone basal-channel type deposits are being developed for uranium production by ISL mining.
- The Elkon district that contains large deposits of metasomatite type deposits that are planned to be mined.

### *Recent and ongoing uranium exploration and mine development activities*

There are two types of uranium exploration activities in the Russian Federation – prospecting aimed at new deposit discovery and exploration of previously discovered deposits with a view to increasing resource endowments.

Uranium prospecting in the Russian Federation is financed from the state budget by the Federal Agency for Subsoil Use (Rosnedra). In 2009, the budget for uranium prospecting amounted to RUB 873 million (new Russian rubles), and in 2010 it decreased by 18% to RUB 719 million.

In 2009-2010, the most uranium prospecting was performed in the Republics of Kalmykia and Buryatia, with the aim of identifying sandstone type uranium mineralisation amenable for ISL mining. Prospecting in Trans-Baikal district was aimed at the identification of uranium deposits suitable for underground (UG) mining.

The executing organisations were the territorial subsidiaries of the Urangeo, as well as Sosnovgeo, Koltsovgeology and Chitageologorazvedka.

In Kalmykia, as a result of prospecting activities within the Eravninskaya area, near surface uranium mineralisation was identified. In Buryatia (Vitim uranium district), exploration of the Dulesminskoe and Amalatskoe uranium occurrences and prospecting for new uranium bearing paleovalleys continued.

Prospecting carried out in the Trans-Baikal district (north of Lake Baikal) within the Akitkansky and Chara areas resulted in identification of a number of small uranium occurrences.

As a result of uranium prospecting activities in 2009, prognosticated resources increased by 5 000 tU, and speculative resources by 68 000 tU. In 2010, these categories were increased by an additional 4 800 tU and 71 000 tU, respectively.

In 2011, Rosnedra allocated RUB 710 million for uranium exploration. Most of the funds are to be used to finance prospecting in the regions located near the operating uranium mining enterprises, as well as in promising regions of eastern Siberia.

In 2009-2010, subsidiaries of uranium holding company Atomredmetzoloto (ARMZ), performed exploration and resource estimation of uranium deposits being prepared for development.

In 2009, ARMZ's uranium exploration budget increased 8.5 times and reached RUB 1 083 million, and in 2010 it increased by a further 56% to RUB 1 687 million. The 2011, ARMZ's exploration programme was provided RUB 1 635 million.

The funding was directed toward:

- exploration of all licensed ARMZ deposits in the Khiagda ore field of the Vitim district (the Istochnoe, Dybryn, Namaru, Koretkonde and Kolichikan deposits);
- completing preliminary exploration of the Khokhlovskoe deposit in the Transural district;
- exploration of the Severnoe deposit and Yuzhnaya zone deposits in the Elkon district;
- completing first stage exploration of the Berezovoye deposit in the Trans-Baikal district;
- estimating resources in the Yuzhnaya zone deposits of the Elkon district (Republic of Sakha – Yakutia) and the Olovskoye deposit (Trans-Baikal district) in accordance with the JORC Code.

Most of the exploration was performed by Rusburmash, ARMZ's drilling company.

### *National uranium exploration activities outside the Russian Federation*

In 2009-2010, ARMZ through its joint ventures with Kazatomprom (Akbastau and Zarechnoye in Kazakhstan) performed exploration in areas 3 and 4 of the Budennovskoye and the South Zarechnoye deposits, respectively, which resulted in updated resource figures. Uranium resources of area 1 and 3 of the Budennovskoye deposit, as well as Zarechnoe deposit, were estimated under the NI 43-101 code.

In Namibia, SWA Uranium Mines, an ARMZ joint venture with VTB Capital Namibia (Pty) Ltd. and Arlan, performed exploration for calcrete type uranium mineralisation.

In Armenia, an Armenian-Russian Mining Co. joint performed uranium exploration in licensed areas.

### *Recent mine development activities*

Mine development activities included pilot operation of mines under construction and project development work for the planned mines.

*Pilot operations*

In the Republic of Buryatia pilot ISL mining operations were completed at the Khiagda deposit and commercial production was begun. Production amounted to 97 tU in 2009 and 135 tU in 2010. Commercial production at Khiagda is expected to reach 1 000 tU/yr in 2015 and 1 800 tU/yr in 2019.

In 2009, a year-round bridge across the River Vitim was constructed to ensure uninterrupted deliveries to the Khiagda mine site. An acid warehouse was also built and a 37 km road providing access to the mine site was reconstructed.

In 2010, R&D work aimed at ISL was also performed at Khiagda. The construction of a new processing plant with an annual capacity of 1 000 tU and sulphuric acid production facilities continued.

*Project developments*

Project development activities were performed for deposits in the Elkon uranium district and the Trans-Baikal district. In November 2007, ARMZ established the Elkon Mining Company (Republic of Sakha – Yakutia) to develop these deposits. The Elkon district currently ranks second in the world in terms of uranium resources.

At the moment, work at Elkon is focusing on a number of front-end engineering design efforts to develop highly efficient, up-to-date ore mining and processing practices. Current activities include the development of radiometric sorting, gold and uranium ore processing, environmental activities, exploration aimed at optimal siting of building facilities and computation of the project's technical and economic parameters.

During 2009 and 2010, pre-feasibility engineering surveys were completed and pilot metallurgical tests were performed resulting in the development of a principal ore processing scheme. Exploration efforts continued, as well as other R&D activities aimed at developing state-of-the-art and highly efficient ore mining and processing technologies prior to the construction of mining and processing facilities.

In December 2007, ARMZ established the Gornoe Mining Company (Trans-Baikal Territory) to develop the Gornoe and Berezovoe deposits. During 2009 and 2010, the company continued to develop pre-project documentation, including necessary surveys and pilot operations, as well as continued exploration of the Berezovoe deposit. In December 2007, ARMZ also established the Olovskaya Company (Trans-Baikal district) to develop the Olovskoe deposit. During 2009 and 2010, the company performed pre-feasibility studies and an environmental impact assessment (EIA).

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

During 2009 and 2010, a comprehensive technical and economic re-evaluation of uranium resources was undertaken.

Uranium resources from two uranium-rare earth element (REE) deposits were added to Russia's resource base. As a result of the re-evaluation, resources recoverable at a cost of <USD 40/kg were reclassified to the category <USD 80/kg and some resources were reclassified from a cost category of <USD 80/kg to the higher cost category of <USD 130/kg.

As of 1 January 2011, recoverable uranium resources in the Russian Federation attributable to category RAR + inferred amounted to 650 300 tU. Compared to 1 January 2009, this is an increase of 84 000 tU. *In situ* resources (without mining and processing loss deductions) amounted to 821 500 tU.

The resource increase was primarily due to:

- the inclusion of resources from two complex uranium-REE deposits in the Tuva Republic and in the Trans-Baikal Territory; and
- the addition of resources from a complex uranium-vanadium metasomatite type deposit located in the Republic of Karelia.

RAR amounted to 218 300 tU, 79% of which are recoverable at a cost of <USD 130/kg and only 6% are recoverable at a cost of <USD 80/kg. The majority of these resources may be mined by the conventional underground mining method. Almost 30% of RAR are in the proximity of operational and under construction mines and 38% are attributed to future production centres.

Inferred resources amount to 432 000 tU, about 10% of which are recoverable at a cost of <USD 80/kg. The majority of such resources may be mined by the conventional underground mining method.

As a result of the re-evaluation, resources of two complex uranium-REE deposits (metasomatite type, open-pit mining method) were added to the Russian state balance on uranium resources in the highest cost category of <USD 260/kg.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

As of 1 January 2011, prognosticated resources amounted to 191 800 tU and speculative resources totalled 772 000 tU.

The majority of the prognosticated resources are located in the Trans-Baikal Territory (the Streltsovsk and East Trans-Baikal uranium districts), the Republic of Buryatia (Vitim district), the Republic of Sakha – Yakutia (Elkon district) and the Republic of Kalmykia. There are also some prognosticated resources located in the Kurgan Region (the Transural uranium district).

## Uranium production

### *Historical review*

The first Russian uranium mine was the Lermontov Complex, presently referred to as the Lermontov State Enterprise "Almaz". Almaz is located 1.5 km from the town of Lermontov, in the Stavropol region/district. The Beshtau and Byk vein type deposits, which are currently depleted, were the source of ore. Their original resources totalled 5 300 tU, at an average grade of 0.1% U and they were extracted using 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, stope or block leaching was also used. 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 was produced by open-pit mining of the small Sanarskoye deposit in the Transural district. The Malyshevsk Mining Enterprise was the operator of this project.

The Joint Stock Company "Priargunsky Mining-Chemical Production Association" (Priargunsky) has been the largest uranium production centre in the Russian Federation in the last decade. The Priargunsky production centre is located in the Chita region, 10-20 km from the town of Krasnokamensk, which has a population of about 60 000. The production is derived from 19 volcanic deposits in the Streltsovsk uranium district, which has an overall average grade of about 0.2% U. Mining has been conducted since 1968 using two open-pits (both now depleted) and four underground mines (mines 1, 2 and Glubokiy are still active). Milling and processing has been carried out since 1974 at the local hydrometallurgical plant using sulphuric acid leaching, with subsequent recovery by ion exchange. Since the 1990s, low-grade ore has been processed by heap and stope/block leaching.

To date, about 140 000 tU has been produced from ores of the Streltsovsk deposits at the Priargunsky mining complex, making it the largest uranium production centre in the world. Cumulative production through 2010 in the Russian Federation totalled 146 862 tU, making it the world's fifth largest uranium producer.

### *Status of production capability*

Uranium production in the Russian Federation is carried out by daughter mining companies of the ARMZ Uranium Holding Company (Atomredmetzoloto).

In 2010, uranium production amounted to 3 562 tU, of which 2 920 tU was produced using the conventional underground mining method (including 2 649 tU produced at the processing plant from primary ore and 271 tU from the ore processed by heap leaching), and 642 tU using the ISL method.

The Priargunsky Mining and Chemical Works (Trans-Baikal Territory) remains the key uranium centre in the Russian Federation. The resource base is the volcanic type uranium deposits of the Streltsovsk district with current *in situ* resources amounting to a total of about 115 000 tU (as of 1 January 2011).

In 2010, Priargunsky produced 2 920 tU. Ore is mined from three underground mines and the bulk is processed at the local hydrometallurgical plant using conventional sulfuric acid leaching technology and ion-exchange resin sorption (271 tU was produced by heap leaching).

During 2009 and 2010, a new sulfuric acid plant was put into operation at Priargunsky. Construction of mine No. 6 was completed and construction of mine No. 8 underway.

Since 2004, Dalur (Kurgan Region) has been developing the Dalmatovskoye deposit using the sulfuric acid ISL mining method, and since 2007 a pilot ISL operation at the Khokhlovskoe deposit is also under development.

In 2010, Dalur produced 507 tU. During 2009 and 2010, construction of mining and local processing facilities at Ust-Uksyansky and central blocks of the Dalmatovskoye deposit was completed. As a result, Dalmatovskoye deposit was put at full-scale operation.

A pilot ISL production centre was completed at the Khiagdinskoye deposit (Republic of Buryatia). During 2009 and 2010, a number of projects were completed at the Khiagda mine, including modernisation of its railroad base, construction of a new processing plant and sulfuric acid production facilities. In 2010, 135 tU were produced at Khiagda.

## Uranium production centre technical details

(as of 1 January 2011)

| | Centre #1 | Centre #2 | Centre #3 | Centre #4 | Centre #5 | Centre #6 |
|---|---|---|---|---|---|---|
| Name of production centre | Priargunsky Mining Combine (Priargunsky) | Dalur | Khiagda | Elkon Mining and Metallurgical Complex (Elkon) | Gornoe Uranium Mining Company (Gornoe) | Olovskaya Mining and Chemical Company (Olovskaya) |
| Production centre classification | Existing | Existing | Committed | Planned | Planned | Planned |
| Date of first production (year) | 1968 | 2004 | 2010 | 2020 | 2014 | 2016 |
| Source of ore: | | | | | | |
| Deposit name(s) | Antei, Streltsovskoe, Oktyabrskoe, etc. | Dalmatovskoe Khokhlovskoe | Khiagda, Vershinnoe, etc | Yuzhnoe, Severnoe, etc | Gornoe, Beryozovoe | Olovskoe |
| Deposit type(s) | Volcanic, in caldera | Sandstone basal channel | Sandstone basal channel | Metasomatite | Granite-related | Volcanic |
| Recoverable resources (tU) | 101 550 | 13 870 | 31 119 | 271 310 | 3 230 | 8 210 |
| Grade (% U) | 0.16 | 0.04 | 0.05 | 0.15 | 0.2 | 0.082 |
| Mining operation: | | | | | | |
| Type (OP/UG/ISL) | UG, HL | ISL | ISL | UG | UG, HL, IPL | UG, HL |
| Size (tonnes ore/day) | 6 700 | NA | NA | 5 500 | NA | 3 000 |
| Average mining recovery (%) | 95 | 75 | 75 | 85 | 70 | 70 |
| Processing plant: | | | | | | |
| Acid/alkaline | Acid | Acid | Acid | Acid | Acid | Acid |
| Type (IX/SX) | IX | IX | IX | IX | IX | IX |
| Size (tonnes ore/day) | 4 700 | No data | No data | No data | No data | No data |
| Average process recovery (%) | 95 | 98 | 98 | 95 | 95 | 95 |
| Nominal production capacity (tU/year) | 3 000 | 800 | 1 800 | 5 000 | 300 | 600 |
| Plans for expansion (yes/no) | Yes | No | Yes | Yes | No | No |
| Other remarks | | | Under construction | | | |

### *Employment in the uranium industry*

In 2010, the Russian uranium industry employed 10 650 people, of which 8 670 worked for Priargunsky. Of the Priargunsky employees, 4 330 were directly involved in uranium production and processing, while the rest worked in auxiliary and service companies (coal production, power plant, etc).

### *Future production centres*

In late 2007, uranium mining companies Elkon, Olovskaya and Gornoe were established to develop standby deposits in South Yakutia and the Trans-Baikal Territory.

A pre-feasibility study towards construction of uranium production centre at Elkon has been completed and annual production capacity of up to 5 000 tU is anticipated. The Elkon *in situ* resources total 319 000 tU. The proposed production complex will involve underground mining, radiometric sorting, milling, processing and uranium concentrate production.

In 2009-2010, design, metallurgical and mine site survey work was completed and exploration of the Elkon deposits continued. Resource estimation under the JORC Code for the Yuzhnaya Zone deposits of the Elkon district was also completed.

Development of the Gornoe and Berezovoe deposits in the Krasnochikoy district of the Trans-Baikal Territory deposits by the Gornoe Company continued. Conventional mining method combined with block and heap leaching will be used, with annual production capacity is expected to amount to 300 tU. Pre-feasibility and environmental studies are currently being performing at Gornoe.

The Olovskaya company was established to develop the Olovskoe deposit in the Chernyshevsky district of the Trans-Baikal Territory. The company proposes to construct an open-pit and underground mine, as well as a heap leaching site for processing the recovered ore and a processing hydrometallurgical plant. The capacity of the future enterprise will be 600 tU/year. During 2009 and 2010, the company completed pre-design surveys at the site, as well as a pre-feasibility and environmental study.

## Uranium requirements

As of 1 January 2011, 10 NPPs in the Russian Federation with 32 reactors were in operation with a total installed (gross) capacity of 24.2 GWe, including 16 water-cooled VVER reactors (10 VVER-1000, 6 VVER-440), 15 uranium-graphite channel type reactors (11 RBMK-1000 and 4 EGP-6RBMK) and 1 fast breeder reactor (BN-600). In 2010, nuclear power generation reached 170.1 TWh (gross), an increase of 4.2% over 2009, providing a 16% share of the total electrical generation. The current annual requirements of Russian nuclear reactors are 4 500 tU.

The plan for the next few years is to construct an average of two units per year. Under the low development scenario for the period 2011-2020, the average forecast is to commission two power units with the installed capacity of 1 100 MW per year. After 2020 and before 2035, the number of commissioning power units will average one unit per year.

Under the high development scenario, after 2013 the number of power units under construction will increase, and two power units with a capacity of 1 100 MW are expected to be commissioned per year on average.

Uranium requirements are to be met by a combination of domestic production, production in Kazakhstan, uranium stockpiles, secondary sources and imported uranium-containing material.

### Uranium exploration and development expenditures and drilling effort – domestic

(RUB millions)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 120.7 | 1 083 | 1 686.5 | 1 634.8 |
| Government exploration expenditures | 1 267 | 872.9 | 719 | 710 |
| Industry* development expenditures | 3 831.5 | 5 330.8 | 9 319 | 10 905 |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 5 219.2 | 7 286.7 | 11 724.5 | 13 249.8 |
| Industry* exploration drilling (m) | 95 000 | 157 500 | 114 200 | 130 800 |
| Industry* exploration holes drilled | NA | NA | NA | NA |
| Government exploration drilling (m) | 134 260 | 95 920 | 79 000 | 75 200 |
| Government exploration holes drilled | 746 | 518 | 440 | 430 |
| Industry* development drilling (m) | NA | NA | NA | NA |
| Industry* development holes drilled | 216 | 390 | 376 | NA |
| Government development drilling (m) | 0 | 0 | 0 | 0 |
| Government development holes drilled | 0 | 0 | 0 | 0 |
| Subtotal exploration drilling (m) | 229 260 | 253 420 | 193 200 | 206 000 |
| Subtotal exploration holes drilled | 746 | 518 | 440 | 430 |
| Subtotal development drilling (m) | NA | NA | NA | NA |
| Subtotal development holes drilled | 216 | 390 | 376 | NA |
| Total drilling (m) | 229 260 | 253 420 | 193 200 | 206 000 |
| Total number of holes drilled | 962 | 908 | 816 | 430 |

* Non-government.

### Uranium exploration and development expenditures – non-domestic

(RUB millions)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 764.7 | 1 816.7 | 2 000** | 2 000** |
| Government exploration expenditures | 0 | 0 | 0 | 0 |
| Industry* development expenditures | 406.7 | 1 160.7 | 1 500** | 1 500** |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 1 171.4 | 2 977.4 | 3 500** | 3 500** |

***** Non-government.

****** Secretariat estimate.

### 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 | 0 | 11 800 | 11 800 | 11 800 | |
| Vein | 0 | 0 | 1 500 | 1 500 | |
| Volcanic and caldera-related | 0 | 0 | 91 900 | 91 900 | |
| Metasomatite | 0 | 0 | 58 800 | 104 200 | |
| Other* | 0 | 0 | 8 900 | 8 900 | |
| Total | 0 | 11 800 | 172 900 | 218 300 | |

* 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.

### 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 | 137 100 | 137 100 | 85 |
| Open-pit mining (OP) | 0 | 0 | 0 | 45 400 | 65 |
| *In situ* leaching acid | 0 | 11 800 | 11 800 | 11 800 | 75 |
| Unspecified | 0 | 0 | 24 000 | 24 000 | 75 |
| Total | 0 | 11 800 | 172 900 | 218 300 | |

### 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 | 123 500 | 123 500 | 85 |
| *In situ* leaching acid | 0 | 11 800 | 11 800 | 11 800 | 75 |
| In-place leaching* | 0 | 0 | 500 | 500 | 70 |
| Heap leaching** from UG | 0 | 0 | 13 100 | 13 100 | 70 |
| Co-product and by-product | 0 | 0 | 0 | 45 400 | 65 |
| Unspecified | 0 | 0 | 24 000 | 24 000 | 75 |
| Total | 0 | 11 800 | 172 900 | 218 300 | |

* Also known as stope leaching or block leaching.

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

### 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 | 0 | 43 600 | 43 600 | 66 900 | |
| Vein | 0 | 0 | 2 700 | 5 700 | |
| Volcanic and caldera-related | 0 | 0 | 32 700 | 60 100 | |
| Metasomatite | 0 | 0 | 232 500 | 288 100 | |
| Other* | 0 | 0 | 2 800 | 11 200 | |
| Total | 0 | 43 600 | 314 300 | 432 000 | |

* 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.

### 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 | 247 200 | 282 600 | 85 |
| Open-pit mining (OP) | 0 | 0 | 300 | 34 700 | 65 |
| *In situ* leaching acid | 0 | 43 600 | 43 600 | 44 900 | 75 |
| Unspecified | 0 | 0 | 23 200 | 69 800 | 75 |
| Total | 0 | 43 600 | 314 300 | 432 000 | 0 |

### 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 | 241 300 | 273 000 | 85 |
| *In situ* leaching acid | 0 | 43 600 | 43 600 | 44 900 | 75 |
| In-place leaching* | 0 | 0 | 2 100 | 2 100 | 70 |
| Heap leaching** from UG | 0 | 0 | 3 800 | 7 500 | 70 |
| Heap leaching** from OP | 0 | 0 | 300 | 300 | |
| Co-product and by-product | 0 | 0 | 0 | 34 400 | 65 |
| Unspecified | 0 | 0 | 23 200 | 69 800 | 75 |
| Total | 0 | 43 600 | 314 300 | 432 000 | |

* 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 |
| 0 | 191 800 | 191 800 |

### Speculative conventional resources

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 130/kgU | <USD 260/kgU | Unassigned |
| | | 772 000 |

### Historical uranium production by deposit type

(tonnes U in concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Sandstone | 4 634 | 471 | 560 | 642 | 6 307 | 718 |
| Volcanic and caldera-related | 131 580 | 3 050 | 3 005 | 2 920 | 140 555 | 2 646 |
| Total | 136 214 | 3 521 | 3 565 | 3 562 | 146 862 | 3 364 |

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 38 655 | 0 | 0 | 0 | 38 655 | 0 |
| Underground mining[1] | 92 925 | 3 050 | 3 005 | 2 920 | 101 900 | 2 646 |
| *In situ* leaching | 4 634 | 471 | 560 | 642 | 6 307 | 718 |
| Total | 136 214 | 3 521 | 3 565 | 3 562 | 146 862 | 3 364 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 129 431 | 2 831 | 2 798 | 2 649 | 137 709 | 2 382 |
| In-place leaching* | 241 | 0 | 0 | 0 | 241 | 0 |
| Heap leaching** | 1 908 | 219 | 207 | 271 | 2 605 | 264 |
| *In situ* leaching | 4 634 | 471 | 560 | 642 | 6 307 | 718 |
| Total | 136 214 | 3 521 | 3 565 | 3 562 | 146 862 | 3 364 |

* 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 2010

| Domestic | | | | Foreign | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | | |
| (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) |
| 3 562 | 100 | | | | | | | 3 562 | 100 |

### Uranium industry employment at existing production centres

(person-years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 12 870 | 9 975 | 10 650 | 10 650 |
| Employment directly related to uranium production | 5 120 | 4 650 | 4 810 | 4 810 |

### Short-term production capability

(tonnes U/year)

| 2011 | | | | 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 |
| 720 | 720 | 3 360 | 3 360 | 1 780 | 1 780 | 4 480 | 4 790 | 2 650 | 2 650 | 5 840 | 6 610 |

| 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 |
| 2 620 | 2 620 | 6 410 | 7 270 | 2 260 | 5 530 | 2 620 | 11 240 | 2 250 | 2 250 | 5 450 | 10 450 |

### Nuclear electricity generation

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh gross) | 163.3 | 170.1 |

**Installed nuclear generating capacity to 2035**

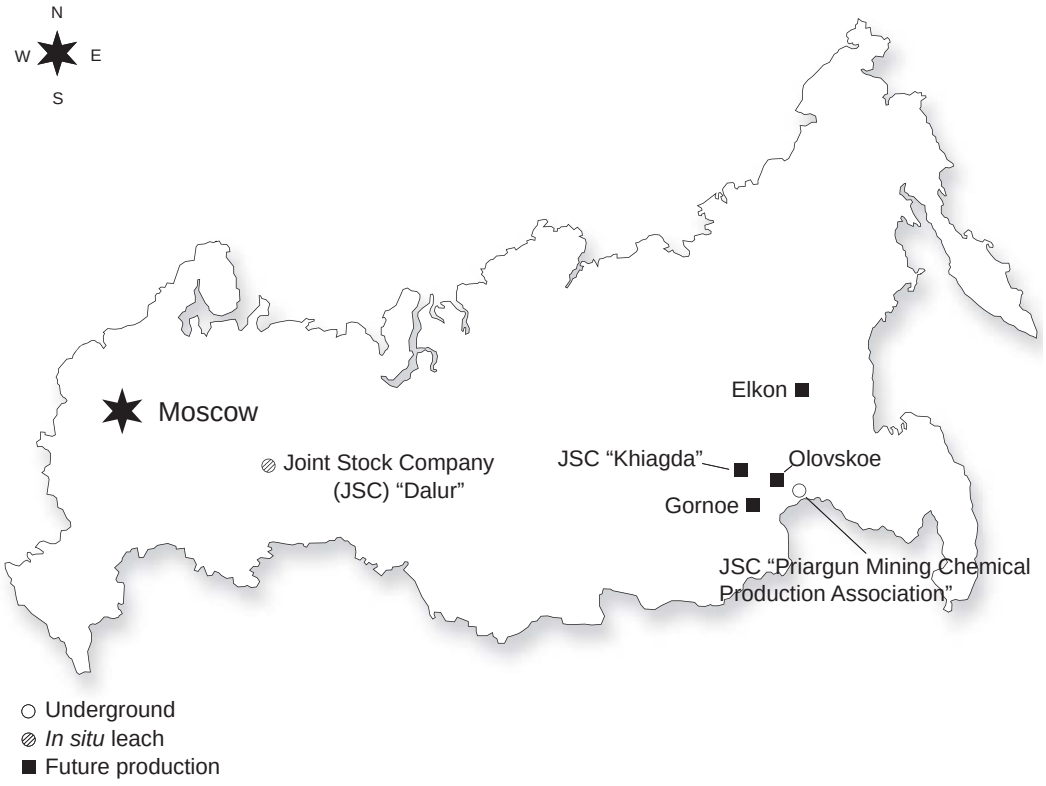
(MWe gross)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 200 | 24 200 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 24 200 | 24 200 | 29 500 | 29 500 | 30 800 | 37 100 | 31 700 | 45 700 | 31 000 | 50 800 | 31 800 | 58 200 |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 500 | 4 500 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 4 500 | 4 500 | 5 800 | 5 800 | 5 900 | 7 000 | 6 000 | 8 700 | 5 900 | 9 600 | 6 100 | 11 100 |






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# Slovak Republic

## Uranium exploration and mine development

### *Historical review*

Beginning in 1947, uranium exploration (surface radiometric prospecting) has been performed within the Slovak Republic in different regions. Surface and aero radiometric techniques, along with prospecting, borehole logging, geoelectric and geomagnetic prospecting and hydrogeochemistry were used to determine six regions of uranium mineralisation. Based on the results of this early work it was concluded that the Slovak Republic had only small uranium resources of economic interest. Between 1985 and 1990, state exploration activities in the eastern part of Slovak Ore Mountains led to the estimation of economic reserves at the Kosice deposit. No uranium exploration occurred between 1990 and 2005. During 1990-2003, an attenuation programme for exploration and mining took place, followed by the termination of mining (1989-1990) and state funded exploration work.

### *Recent and ongoing uranium exploration and mine development activities*

In 2005, the private Canadian company Tournigan Gold Corporation acquired an exploration licence covering the area where uranium mineralisation had been discovered near Kosice in eastern Slovak Republic. In July 2009, an independent preliminary assessment was issued that contained an indicated resource estimate of 14 745 lbs $U_3O_8$ (5 670 tU) grading at 0.48% U and an inferred resource estimate of 17 898 lbs $U_3O_8$ (6 885 tU) grading at 0.18% U using a cut-off grade of 0.05% U. Ludovika Energy Ltd (a subsidiary of Tournigan) is continuing exploration in six eastern Slovak Republic prospecting areas at present. These resources will not be included in the Slovakian national resource totals until the Commission for Reserves Classification reviews the data when exploration is finished, typically at the time that the company developing the resource makes a decision to mine the deposit. This issue is discussed further in Chapter 1.

A total of 14 exploration licences for radioactive minerals are active at present in the Slovak Republic. Other exploration companies involved are Beckov Minerals Ltd (related company of Ultra Uranium, Canada), performing exploration on two areas in western Slovak Republic and Crown Energy Ltd (related company of GB Energy, Australia) performing exploration of three prospecting areas of eastern Slovak Republic. Present prospecting activities of other exploration licence holders are unknown.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

At present, total inferred uranium resources contained in two registered uranium deposits amount to a total of 10 049 tonnes of uranium.

| Deposit | Organisation | Ore resources (t) | U content (t) |
|---|---|---|---|
| Košice I | Ludovika Energy Ltd. | 1 396 000 | 6 561 |
| Novoveská Huta | Ludovika Energy Ltd. | 3 876 000 | 3 488 |

### *Undiscovered conventional resources (prognosticated and speculative resources)*

Prognosticated resources are estimated in areas surrounding identified deposits. For example, prognosticated resources in the Novoveská Huta area are estimated from the determination of 12 Mt of uranium ore grading at 0.06% U.

| Deposit | Estimated grade | Ore resources (t) | Contained tU |
|---|---|---|---|
| Košice I | 0.13% U | 1 713 000 | 2 227 |
| Novoveská Huta | 0.06% U | 12 040 000 | 7 224 |

## Uranium production

### *Historical review*

During the first period of uranium exploration (1954-1957) a small amount (1.4 tU) was mined in the Novoveská Huta – Hnilcik region. From 1961 to 1990, 210 tU were mined, mainly from Novoveská Huta as a by-product of copper mining, but also from the Muran, Kravany, Svabovce and Vikartovce deposits.

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

There is no uranium mining in the Slovak Republic at present.

## Environmental activities and socio-cultural issues

Environmental activities cover monitoring activities in the historical mining area of the Novoveská Huta deposit. Monitoring includes chemical analyses of mine water outflow as well as geochemical and geological engineering evaluations of the condition of tailings and waste rock piles.

Partial monitoring of such factors is part of a national environmental monitoring network that is focused on natural or anthropogenic geological hazards (as indicated by the acronym ČMS GF). Selected mining sites are monitored, including the above mentioned area.

Several studies and environmental evaluations of radioactive materials and the impacts of mining in this locality were conducted in the past:

- Thorne M C., M. Kelly, A. C. Baker, D. Holton (2000), Remediation of Uranium Liabilities in Slovakia. Final Report (AEA Technology, UK).
- Daniel, J., E. Mašlár, I. Mašlárová (2001), Effectiveness of Remediation of Uranium Activities on Slovakian Territory (*Účinnosť revitalizácie po uránovej činnosti na území Slovenska*), Ministry of the Environment of the Slovak Republic, Uranpres JSC.
- Daniel, J., I. Mašlárová, E. Mašlár, V. Daniel, K. Danielová, F. Mihál' (2005), Evaluation on Geological Works for U Ores in Selected Regions of the Western Carpathians in the Territory of Slovakia (*Zhodnotenie geologických prác na U rudy vo vybraných oblastiach Západných Karpát na území Slovenska*). Final report, Ministry of the Environment of the Slovak Republic, Uranpres JSC.
- Bezák, J., A. Donát (1996), Mine Waste Piles and Settling Pits – Evaluation of Natural Radioactivity of Selected Deposit Sites (*Haldy a odkaliská – zhodnotenie prirodzenej rádioaktivity vybraných ložísk nerastných surovín*). Ministry of the Environment of the Slovak Republic, Uranpres JSC.

Waste rock management must be performed according to the Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the management of waste from extractive industries and amending Directive 2004/35/EC. In the Slovak Republic, related legislation is NR SR (National Council of the Slovak Republic) Act No. 514/2008 Col. on the management of waste from extractive industries and the Decree of the MŽP SR (Ministry of the Environment of the Slovak Republic) No. 255/2010 Col., which executes the act on the management of waste from extractive industries.

## Uranium requirements

The Slovak Republic has two NPPs (Bohunice and Mochovce) with a total of four pressurised water reactors, type WWER 440. Two reactors are in operation at each site. An additional two reactors are currently under construction at Mochovce (units 3 and 4). As of 31 December 2011, the total installed capacity of the Slovak Republic's NPPs amounted to 1 820 MW.

During 2010, a power up-rating project of Bohunice units 3 and 4 was successfully completed and after scheduled outages, both operated continually at increased power (107% of the nominal power). Units 1 and 2 of Mochovce have been operating at increased power (107% of the nominal power) since 2008.

Design and development work for the use of nuclear fuel with higher enrichment (up to 4.87% $U_{235}$) is also underway and first loading of this fuel is scheduled on Mochovce units 1 and 2 in 2011 and on units 3 and 4 at Bohunice in 2012.

In April 2010, Slovenské Elektrárne signed a contract with Russian company TVEL for the supply of fresh fuel for Mochovce units 3 and 4 currently under construction. This contract covers the period from 2012 to 2017 and provides for the supply of fuel assemblies for the initial core loading of both units, as well as five subsequent reloads.

### *Supply and procurement strategy*

Slovenské Elektrárne purchases complete fuel assemblies for all operating units from the Russian manufacturer. Therefore there is no special contract on uranium, conversion or enrichment services.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

*Energy Policy of the Slovak Republic (Resolution of the Government of the Slovak Republic No. 29/2006)*

One of the priorities set to facilitate meeting objectives of the energy policy is to utilise domestic primary energy sources for electricity and heat production on an economically effective basis.

*Energy Security Strategy of the Slovak Republic (Resolution of the Government of the Slovak Republic No. 732/2008)*

The objective of the energy security strategy is to achieve a competitive, secure, reliable and efficient supply of all forms of energy at reasonable costs that protect the consumer and the environment and promote sustainable development, security of supply and technical safety.

The high share of nuclear energy in the energy mix of the Slovak Republic relies on dependable sources of sufficient numbers of fuel elements, which are only at this time offered in Europe by the Russian Federation and France. It is considered that in the future, these fuel element producers could require from customers a counter-value in the form of uranium as a certain form of payment.

Legislative and economic support for the efficient and rational use of domestic uranium resources is needed to considerably reduce dependency on imported energy sources, whose market prices are sharply rising over the past years. Rising uranium prices and thus nuclear fuel can privilege those states which will be able to supply their own uranium and require only its further processing to produce fuel.

If the anticipated situation occurs, it will be necessary to create appropriate legislative conditions for the extraction of uranium by amending relevant laws and strategic documents, including the Raw Materials Policy, since domestic deposits of uranium ore are located near Kosice and Spisska Nova Ves – Novoveská Huta. The possibility of extracting uranium in the Slovak Republic is also to be assessed from the perspective of maximum environmental protection. Mining projects must be harmonised with the development of documentation by concerned municipalities and regional governments in conformity with the applicable legislation.

In order to meet targets of the Energy Security Strategy, it is necessary to assess the feasibility of the extraction of uranium in the Slovak Republic. It is important to rationally and effectively support the use of domestic energy sources with the aim of decreasing dependency on imports.

**Uranium exploration and development expenditures and drilling effort – domestic**

(EUR millions)

| | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|
| Industry* exploration expenditures | 4.8 | 5.3 | 4.3 | 2.9 |
| Government exploration expenditures | | | | |
| Industry* development expenditures | | | | |
| Government development expenditures | | | | |
| Total expenditures | | | | |
| Industry* exploration drilling (m) | 13 800 | 14 330 | 5 620 | 5 630 |
| Industry* exploration holes drilled | 40 | 36 | 20 | 25 |
| Government exploration drilling (m) | | | | |
| Government exploration holes drilled | | | | |
| Industry* development drilling (m) | | | | |
| Industry* development holes drilled | | | | |
| Government development drilling (m) | | | | |
| Government development holes drilled | | | | |
| Subtotal exploration drilling (m) | | | | |
| Subtotal exploration holes drilled | | | | |
| Subtotal development drilling (m) | | | | |
| Subtotal development holes drilled | | | | |
| Total drilling (m) | | | | |
| Total number of holes drilled | | | | |

Note: 2011 expected expenditures not provided.

* Non-government.

### Inferred conventional resources by deposit type

(tonnes U)

| Deposit type | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU |
|---|---|---|---|---|
| Unconformity-related | | | | |
| Sandstone | | | | |
| Hematite breccia complex | | | | |
| Quartz-pebble conglomerate | | | | |
| Vein | | | | |
| Intrusive | | | | |
| Volcanic and caldera-related | | 6 561 | 10 049 | |
| Metasomatite | | | | |
| Other* | | | | |
| Total | | 6 561 | 10 049 | |

* 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.

### 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) | | 6 561 | 10 049 | | 85-95 |
| Open-pit mining (OP) | | | | | |
| *In situ* leaching | | | | | |
| Co-product and by-product | | | | | |
| Unspecified | | | | | |
| Total | | 6 561 | 10 049 | | |

### 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 | | 6 561 | 10 049 | | |
| In-place leaching* | | | | | |
| Heap leaching** | | | | | |
| Total | | 6 561 | 10 049 | | |

* 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 |
| 2 227 | 7 224 | |

## Historical uranium production by deposit type

(tonnes U in concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | | | | | | |
| Sandstone | | | | | | |
| Hematite breccia complex | | | | | | |
| Quartz-pebble conglomerate | | | | | | |
| Vein | | | | | | |
| Intrusive | | | | | | |
| Volcanic and caldera-related | 211 | | | | | |
| Metasomatite | | | | | | |
| Other* | | | | | | |
| Total | 211 | | | | | |

* 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.

## Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 50[2] | | | | | |
| Underground mining[1] | 161[2] | | | | | |
| *In situ* leaching | - | | | | | |
| Co-product/by-product | - | | | | | |
| Total | 211 | | | | | |

1. Pre-2008 totals may include uranium recovered by heap and in-place leaching.

2. Estimate.

## Historical uranium production by processing method

(tonnes U in concentrates)

| Processing method | Total through end of 2007[1] | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 211 | | | | | |
| In-place leaching* | - | | | | | |
| Heap leaching** | - | | | | | |
| U recovered from phosphate rocks | - | | | | | |
| Other methods*** | - | | | | | |
| Total | 211 | | | | | |

1. Pre-2008 totals may include uranium recovered by heap and in-place leaching.

* 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.

**Net nuclear electricity generation**

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 13.1 | 13.5 |

**Installed nuclear generating capacity to 2035**

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 762 | 1 818 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 1 818 | 1 818 | 2 638 | 2 782 | 2 638 | 3 804 | 2 638 | 3 804 | 2 638 | 3 804 | 2 638 | 3 804 |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 363 | 372 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 391 | 391 | 505 | 522 | 506 | 538 | 506 | 539 | 506 | 538 | 506 | 539 |

**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 | 0 | 0 | 0 | NA | |
| Producer | 0 | 0 | 0 | NA | |
| Utility | 0 | 0 | 0 | NA | |
| Total | 0 | 0 | 0 | NA | |

# South Africa*

## Uranium exploration and mine development

### *Historical review*

South Africa has been an important player in the international market since it first started producing uranium in 1952. It has been steadily and consistently been producing uranium since then, albeit at a lower level in recent years. Seven of the 13 deposit types defined in the Red Book are found in South Africa, namely quartz-pebble conglomerate, sandstone, coal-hosted, intrusive, surficial, vein and phosphorite deposits. The major part of the resource base is hosted by the quartz-pebble conglomerates and derived tailings, with significant amounts of resources in the sandstone and coal-hosted deposits.

* Secretariat report based on data submitted by country, company information and past Red Books.

The other deposit types make a relatively small contribution to the national uranium resource inventory. Virtually all of South Africa's historical uranium production was derived from quartz-pebble conglomerate deposits with a small proportion being from the Palabora copper-bearing carbonatite. All current production is sourced from the quartz-pebble conglomerate deposits.

The majority of past production was as a by-product of gold, or to a minor extent, copper. Only two primary uranium producers have existed in South Africa. The first was the Beisa mine in the Free State in the early 1980s and the latter was the Dominion Reefs Uranium Mine near Klerksdorp which operated in the late 2000s.

There are six distinct uranium provinces in South Africa. The oldest are the Palaeozoic aged Mozaan Basin in the north-east and the slightly younger Witwatersrand Basin in the centre. The Precambrian aged Palabora and Pilanesberg carbonatite complexes lie in the north, with the Precambrian to Cambrian granite complexes in the north-west. The sandstone deposits of the Karoo in the south central parts, and the coal-hosted deposits of the Springbok Flats are of Permo Triassic age. The youngest are the Tertiary to Recent surficial deposits in the Northwest Cape and the phosphorite deposits off the south-west coast.

The recent surge in the uranium price stimulated significant company interest in South Africa. Much of the ground over the Witwatersrand Basin was held by existing mining companies and they did extensive re-evaluations of their uranium resource holdings. Of great interest was the resources held in the vast tailings dams created by over 100 years of gold mining. Gold Fields, Rand Uranium, Harmony and AngloGold Ashanti launched detailed feasibility studies into these resources.

Available ground with known uranium occurrences such as that in the Karoo Basin and Springbok Flats was snatched up by companies such as UraMin and Holgoun Energy. UraMin was subsequently taken over by AREVA, acquiring the Trekkopjie deposit in Namibia and the Rystkuil Channel in the Karoo Basin. Smaller companies obtained prospecting licences over smaller known deposits in the Karoo Basin as well as deposits in the granitic and surficial terrains in the north-west of the country.

### *Recent and ongoing uranium exploration and mine development activities*

The uranium price slumped substantially to about one third of its peak in 2007. At the start of 2011 the price rallied back to about a half of the price at the peak in 2007. The Fukushima accident effectively quashed that rally and the spot price is now largely range bound between USD 50 and 55/lb $U_3O_8$. As a result a number of companies have curtailed their exploration programmes or put them on hold.

Gold Fields is extending the feasibility study of its tailings resources in the Far West Rand in light of the volatility of the uranium price. Gold Fields also owns the old Beisa mine in the Free State but has not announced any plans to consider restarting uranium production. Rand Uranium has decided not to proceed with its uranium project and has been taken over by Gold One. Harmony is re-evaluating its feasibility study of recovering its Free State uranium resources. Mintails has shelved all plans with regards to its uranium resources on the West Rand. DRD gold is concentrating on its gold reclamation activities on the East Rand. Wits Gold has reported substantial inferred resources in its projects in the Free State and near Potchefstroom, but the projects are in very early stages of development and no commitment to uranium production is possible at this stage.

AREVA carried out investigations into the Rystkuil Channel deposits, but when the price slumped activities ceased without any reportable resources being proven. Holgoun Energy carried out an extensive feasibility study on the Springbok Flats deposits and reported about 84 000 tU of inferred resources. They reportedly proceeded with a bankable feasibility study in 2011.

On the production side AngloGold Ashanti is continuing with the refurbishment and upgrading of the South Uranium Plant at their Vaal River Operations. These will be completed during 2012 and will increase their production capacity from 600 to 800 $tU_3O_8$/y. AngloGold Ashanti is also carrying out metallurgical tests to enhance uranium recovery from low-grade tailings deposits. First Uranium has brought its uranium plant on line at the Ezulwini Mine, has completed the third gold plant module at Mine Waste Solutions (MWS) and commenced construction of two uranium plant modules in 2011. Shiva Uranium took over the Dominion Reefs Uranium Mine early in 2010 and announced that production would commence within months, but no public reports of development activities or uranium production have been made since.

## Uranium resources

All resources reported are Secretariat estimates derived from publicly available reports of various types.

The different data sources used have resulted in resource reductions compared to those reported in the 2009 Red Book, but this is in part a reflection of the declining gold mining industry in South Africa. In 2007, South Africa produced 254.7 t of gold which was 10.3% of the world's total production. By 2009, production had declined to 204.9 t, 7.97% of the world's total. A large proportion of South Africa's uranium resources are directly related to the economic viability of the nation's gold industry.

### *Identified conventional resources (reasonably assured and inferred resources)*

By far the largest proportion (83%) of South Africa's identified uranium resources are hosted by the quartz-pebble conglomerates of the Witwatersrand Basin and their associated tailings dams. The former accounts for 49% of national identified resources, the slimes 34% and the coal-hosted deposits the remaining 17%. It must be noted that this is a conservative estimate because the Karoo sandstone deposits have not been included because of a lack of public information. Previous estimates have indicated that the Karoo probably hosts about 35 000 to 40 000 tU, but the data is now too outdated to report with any degree of confidence.

The association of the resources with the gold mining industry means that the rand to USD exchange rate, gold price, uranium price, as well as mining and extraction technology costs have a significant influence on South Africa's uranium resources. In spite of a somewhat more favourable uranium price than in the previous two decades, uranium still only contributes about 10% of the total revenue from ore mined in a Witwatersrand gold mine.

The resources in the Springbok Flats are substantial but are currently only considered to be inferred. Ongoing work on this project is aimed at determining the economic viability of a multiproduct operation generating coal, electricity and uranium.

Older known deposits in the Witwatersrand have significant inferred resources, but the data that they are based on are too old and unreliable to be reported with any degree of certainty. Ongoing work will no doubt convert a substantial amount of these resources into reportable categories.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

These resources are unchanged from the 2009 Red Book as none of the publicly available resource data match the definitions of these categories. The published resources excluded from the inferred resources could be considered part of these resources but their cost categorisation would be highly uncertain.

### *Unconventional resources and other materials*

A field of manganiferous phosphate nodules has been identified off the west and south-west coast of South Africa on the continental shelf. The nodules contain low grades of uranium and are currently considered uneconomic with respect to both phosphate and uranium. However, worldwide renewed interest in phosphate hosted uranium deposits may engender future investigation.

## Uranium production

### *Historical review*

South Africa has been a consistent producer of uranium since 1952, but its international importance has declined in recent years. In the late 1970s and early 1980s it was ranked the second or third largest producer in the world, but by 2009 had dropped to eleventh. Peak production was achieved at over 6 000 tU/yr in the early 1980s when it produced 14% of total world output.

Production has now declined below 600 tU/yr, less than 1.5% of world production. Indications are that production levels will increase in the future to help meet international demand. The planned growth in South Africa's nuclear generating capacity is also an influencing factor.

### *Status of production capability and recent and ongoing activities*

Both current producers, AngloGold Ashanti and First Uranium are implementing plans to expand production at their existing operations. AngloGold Ashanti's Vaal River Operation has been exploiting the Vaal Reef for the last 60 years and has been producing uranium since 1953 when its first uranium plant was commissioned. At its peak in the early 1980s three uranium plants were operational. In subsequent years two of these plants were shut down and currently only the South Uranium Plant is operational.

The plant was being wound down to close in 2009, but the surge in the uranium price prompted refurbishment and enhancement of the plant. Production is to be boosted from 600 tU/yr to over 800 tU/yr. A conventional acid leaching, ion exchange, solvent extraction and ammonium diuranate precipitation process is followed. The ore is treated in the uranium plant before being passed to the gold plant. This so-called "reverse leaching" process enables better gold recoveries. The ammonium diuranate slurry is shipped to NUFCOR in tankers where it is calcined to uranium oxide ($U_3O_8$) and sold on the international market.

First Uranium has the Ezulwini Mine which exploits underground gold and uranium reefs as well as surface tailings, and MWS which treats old slimes dams in the Klerksdorp area for gold and uranium. The processes employed to extract uranium are the same as at the Vaal River Operation. The Ezulwini uranium plant was commissioned early in 2010 whereas the uranium plant at MWS is under construction and will be commissioned in 2012. Uranium production of between 100 and 125 tU from both plants is the target for 2012 and is planned to be increased to about 800 tU/yr. The current life of mine is until 2029, but expansion opportunities exist. Ezulwini is also looking at opportunities to toll-process uranium bearing ores from neighbouring properties.

Shiva Uranium announced plans to bring the Dominion Reefs Uranium Mine back into production. Other companies such as Gold Fields, Rand Uranium and Harmony are actively investigating options to begin production from their uranium resources.

Outside the Witwatersrand Basin, Holgoun Energy is engaged in a bankable feasibility study for exploiting the coal-hosted deposits of the Springbok Flats.

### *Ownership structure of the uranium industry*

There were no significant changes in ownership of uranium resources and producing operations in the last two years.

*AngloGold Ashanti*'s primary stock exchange listing is on the JSE Limited (Johannesburg). It is also listed on the exchanges in New York, London, Australia and Ghana as well as on Euronext Paris and Euronext Brussels. In South Africa, AngloGold Ashanti operates six wholly owned underground mines which are located in two geographical regions in the Witwatersrand Basin. The most important are Vaal River Operations gold mines which produce uranium as a by-product. The Tau Lekoa mine was sold to Simmer & Jack in 2010.

*Ezulwini Mining Company* (Pty) Ltd. ("EMC") and *Mine Waste Solutions* (Pty) Ltd are wholly owned subsidiaries of First Uranium Corporation, (TSX:FIU, JSE:FUM) a publicly owned company, which was listed on the Toronto Stock Exchange in 2007.

*Harmony Gold*'s primary listing is on the JSE Limited (share code: HAR) in South Africa. Harmony's ordinary shares are also listed on stock exchanges in London (HRM), Paris (HG) and Berlin (HAM1), and are quoted in the form of American depositary receipts on the New York and Nasdaq exchanges (HMY), and as international depositary receipts on the Brussels exchange (HMY).

*Gold Fields* is listed on JSE Limited (primary listing), the New York Stock Exchange (NYSE) and the Dubai International Financial Exchange (DIFX), the New Euronext in Brussels (NYX) and Swiss Exchange (SWX).

*Witwatersrand Consolidated Gold Resources (*Wits Gold Ltd*)* is listed on the main boards of the JSE Limited (South Africa) and the TSX (Canada) under the symbol WGR. Wits Gold also has a Level 1 ADR (American depository receipt) programme backed by the Bank of New York Mellon (OTC: WIWTY.PK). The company is an active gold exploration company with substantial mineral resources in the Witwatersrand Basin.

### *Employment in the uranium industry*

*AngloGold Ashanti*, in its Vaal River Operations, employed 229 workers in 2008; 221 workers in 2009 and 213 workers in 2010 at their surface uranium operations.

*First Uranium Corporation.* At present the combined employee base for Ezulwini and MWS is approximately 2 500, with a planned capacity of 5 000 once both projects are fully operational. For Ezulwini Mining Company (Pty) Ltd, the employment of people directly related to the mining of the uranium-bearing Middle Elsburg Reef package has steadily increased from 564 employees to an estimated 1 100 employees in 2011. MWS currently employs 1 450 workers.

### *Future production centres*

No firm plans for future production centres have been announced but a number of companies are seriously considering their options, particularly with regard to exploiting existing tailings dam resources and the Springbok Flats deposits.

Shiva Uranium has announced imminent production from the recently acquired Dominion Reefs Uranium Mine, but as yet no information regarding uranium or gold production has been made public.

**Uranium production centre technical details**

(as of 1 January 2011)

| | Centre #1 | Centre #2 | Centre #3 | Centre #4 |
|---|---|---|---|---|
| Name of production centre | AngloGold Ashanti. South Uranium Plant | First Uranium. Ezulwini Mine | First Uranium. Mine Waste Solutions | Shiva Uranium Dominion Reefs Uranium Mine |
| Production centre classification | Existing | Existing | Existing | Existing |
| Date of first production (year) | 1979 | 2009 | 2012 | 2007 |
| Source of ore: | | | | |
| Deposit name(s) | Wits Basin | Middle Elsburg Reef | Hartebeestfontein, Buffelsfontein & Stilfontein Tailings Dams | Dominion Reefs |
| Deposit type(s) | Quartz-pebble conglomerate | Quartz pebble conglomerate | Tailings | Quartz pebble conglomerate |
| Recoverable resources (tU) | 69 000 | 81 000 | 23 800 | 82 400 |
| Grade (% U) | 0.037 | 0.074 | 0.008 | 0.08 |
| Mining operation: | | | | |
| Type (OP/UG/ISL) | UG | UG | Tailings reprocessing | UG |
| Size (tonnes ore/day) | 6 649 | 1 500 | 1 500 | NA |
| Average mining recovery (%) | 60-80 | 80 | 80 | NA |
| Processing plant: | | | | |
| Acid/alkaline | Acid | Acid | Acid | Acid |
| Type (IX/SX) | CCD/CCIX/SX | IX/SX | IX/SX | IX/SX |
| Size (tonnes ore/day) | 6 649 tpd | 3 333 tpd | 4 440 tpd | NA |
| Average process recovery (%) | 75 | | | |
| Nominal production capacity (tU/year) | 554 | 500 | 300 | NA |
| Plans for expansion (yes/no) | Yes | Yes | Yes | No |
| Other remarks | Uranium plant being refurbished and enlarged from 600 tU/yr to 800 tU/yr. | None | None | Mine being reopened |

## Secondary sources of uranium

### *Production and/or use of mixed oxide fuels*

South African has never produced or used mixed oxide fuels.

### *Production and/or use of re-enriched tails*

South Africa currently does not have a uranium enrichment industry. South Africa's only uranium enrichment plant at Pelindaba was decommissioned and dismantled in 1997/1998.

### *Production and/or use of reprocessed uranium*

No reprocessed uranium is produced or utilised in South Africa.

## Environmental activities and socio-cultural issues

As required by the South African Department of Mineral Resources (DMR), and as part of the permitting process, each active mining company involved in uranium activities has

to have approved environmental management programmes (EMPs), a social and labour plan (SLP), a financial closure liability assessment and provision mechanisms in place for all operations under the Mineral and Petroleum Resources Development Act (MPRDA) in order to secure mining rights.

For each company, an EIA was conducted over an extended period to encompass seasonal climatic changes and compiled in accordance with the guidelines set out by the relevant national regulatory bodies and in consultation with interested and affected parties.

Independent specialist studies conducted include: geo-hydrological assessment, soil survey, land-use survey, archaeological assessment, air quality assessment, visual impact survey, fauna and flora assessment, wetland assessment and geological assessment.

All these mining companies have been actively involved in the community for years and current programmes involve the subsidisation of retirement villages and providing support to primary and secondary schools.

Some companies have established a formal public "Environmental Forum" that meets on a quarterly basis to discuss environmental issues relating to their respective area of responsibility. This creates an opportunity for direct communication between the public, representatives of the different affected areas and the company.

In addition to the Department of Mineral Resources (DMR), the Department of Water Affairs, the South Africa Nuclear Energy Corporation Ltd (NECSA), and the National Nuclear Regulator (The National Nuclear Regulator Act No. 47 of 1999 and the Nuclear Energy Act No. 46 of 1999) perform regulatory functions pertaining to all mining companies involved in uranium activities.

## Uranium requirements

Koeberg is South Africa's only NPP. It has two light-water thermal reactors; Koeberg I commissioned in 1984 and Koeberg II in 1985, with a combined installed capacity of 1 840 MW. Together, they require ~292 tU/yr.

In 2007, the South African state utility (Eskom) announced plans to boost its nuclear electricity generation capacity from 1.8 GWe to 20 GWe by 2025, including deployment of several pebble bed modular reactors (PBMR) then under development. This plan was stopped in 2008 due to lack of funds. Government has subsequently drawn up an Integrated Resource Plan 2010 (IRP2010) which includes 9.6 GWe of nuclear generating capacity by 2030. The Fukushima accident has raised safety concerns which need to be addressed and this may delay the planned programme. The planned new build and the existing Koeberg NPP would require a total of just under 2 000 tU/yr. Assuming an 80-year life for new Generation III reactors, total lifetime uranium requirements would amount to about 150 000 tU.

### *Supply and procurement strategy*

The government published a nuclear energy policy in 2008, which among other things mandated the South African Nuclear Energy Corporation (NECSA) to investigate the feasibility and viability of all phases of the nuclear fuel cycle. The intention is to ensure as much security of supply for the national nuclear energy programme as is economically possible. These investigations are ongoing as are investigations into strategies aimed at ensuring the sustainable and effective utilisation of local uranium sources to the benefit of the local mining industry and the nuclear generation programme.

In 2007, the South African government declared uranium "a strategic mineral". The intent of this declaration is uncertain at present. A working group is in the process of creating an exact definition of what a strategic mineral is and what the implications will be from government and private company perspectives. Section 15.1 of the national

Nuclear Energy Policy makes it clear that mining of uranium will be conditional on production being made available for domestic use as and when needed, but emphasises that this will be at prevailing market prices.

## Uranium policies, uranium stocks and uranium prices

South Africa government's nuclear energy policy and strategy aim to secure South Africa's supply of uranium for 40 to 60 years. This, allied with the IRP2010 provides a plan for South Africa's future nuclear generation capacity and nuclear fuel cycle activities.

The National Nuclear Regulator Act No. 47 of 1999 and the Nuclear Energy Act No. 46 of 1999 are the basis of South Africa's national policies relating to the prospecting for and mining of uranium, the state's role, foreign participation, as well as the export of uranium and the disposal of spent nuclear fuel.

NECSA, a state-owned company, regulates the acquisition and possession of nuclear fuel, the import and export of such fuel and prescribes measures regarding the disposal of radioactive waste and the storage of irradiated nuclear material. It is also actively investigating all aspects of the implementation of nuclear fuel cycle activities in South Africa.

Concerns about the disposal of spent fuel and transportation hazardous materials, the potential for accidents and high construction and start-up costs all weigh against nuclear energy. However, global climate change concerns and competitive lifetime electricity generation costs have made nuclear power an increasingly attractive option. South Africa's nuclear proponents agree that the risks need to be addressed but that the country needs to push ahead with nuclear development.

The earthquake followed by tsunami that precipitated the nuclear accident at Fukushima in Japan in March 2011 has resulted in general reviews of nuclear safety, including South Africa. The process and outcomes of these reviews may impede planned nuclear energy growth, in turn inhibiting uranium mine development.

South African government policies also encourage local beneficiation of mineral resources. The beneficiation (value added) of uranium comes with responsibilities and sensitivities in safety and environmental management and has to be pursued within the country's national and international obligations.

### *Uranium stocks*

Eskom, the South African state utility, has increased its strategic stock levels to mitigate the current supply/demand imbalance. However, the information and figures are not available as they are classified as confidential.

### *Uranium prices*

NA.

**Uranium exploration and development expenditures – non-domestic**

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 0 | 0 | 0 | 0 |
| Government exploration expenditures | 0 | 0 | 0 | 0 |
| Industry* development expenditures | 0 | 0 | 0 | 0 |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 0 | 0 | 0 | 0 |

* Non-government.

## Uranium exploration and development expenditures and drilling effort – domestic

(ZAR [South African rand])

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 20 411 642 | 37 051 489 | 22 353 842 | 22 582 560 |
| Government exploration expenditures | 0 | 0 | 0 | 0 |
| Industry* development expenditures | 66 347 000 | 78 053 639 | 120 230 330 | 14 964 883 |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 86 758 642 | 115 105 128 | 142 584 172 | 37 547 443 |
| Industry* exploration drilling (m) | 24 463.25 | 14 598.94 | 14 843 | 61 000 |
| Industry* exploration holes drilled | 273 | 4 | 80 | 11 |
| Government exploration drilling (m) | 0 | 0 | 0 | 0 |
| Government exploration holes drilled | 0 | 0 | 0 | 0 |
| Industry* development drilling (m) | 0 | 50 | 31 325 | 36 048 |
| Industry* development holes drilled | 0 | 3 | 528 | 507 |
| Government development drilling (m) | 0 | 0 | 0 | 0 |
| Government development holes drilled | 0 | 0 | 0 | 0 |
| Subtotal exploration drilling (m) | 24 463.25 | 14 598.94 | 14 843 | 61 000 |
| Subtotal exploration holes drilled | 273 | 4 | 80 | 11 |
| Subtotal development drilling (m) | 0 | 50 | 31 325 | 36 048 |
| Subtotal development holes drilled | 0 | 3 | 528 | 507 |
| Total drilling (m) | 24 463.25 | 14 648.94 | 46 168 | 97 048 |
| Total number of holes drilled | 273 | 7 | 608 | 518 |

Note: Wits Gold expenditure figures not readily available.

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 43 588 | 65 382 | 87 176 | 75 |
| Vein | 0 | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 52 842 | 79 263 | 105 684 | 75 |
| Total | 0 | 96 430 | 144 645 | 192 860 | 75 |

* Includes mine tails, 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.

### 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 | 0 | 0 | NA |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | NA |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | NA |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | NA |
| Co-product and by-product | 0 | 96 430 | 144 645 | 192 860 | 75 |
| Unspecified | 0 | 0 | 0 | 0 | NA |
| Total | 0 | 96 430 | 144 645 | 192 860 | 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 (%) |
|---|---|---|---|---|---|
| Conventional from UG | 0 | 96 430 | 144 645 | 192 860 | 75 |
| Conventional from OP | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | 0 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | 0 |
| Unspecified | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 96 430 | 144 645 | 192 860 | 75 |

Note: Reverse leach with counter current decantation thickening, counter current ion exchange and solvent extraction plus ADU precipitation.

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 46 986 | 70 479 | 93 972 | 75 |
| Vein | 0 | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 42 620 | 63 929 | 85 239 | 75 |
| Total | 0 | 89 606 | 134 408 | 179 211 | 75 |

* Includes mine tails, 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.

### 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 | 0 | 0 | NA |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | NA |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | NA |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | NA |
| Co-product and by-product | 0 | 89 606 | 134 408 | 179 211 | 75 |
| Unspecified | 0 | 0 | 0 | 0 | NA |
| Total | 0 | 89 606 | 134 408 | 179 211 | 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 (%) |
|---|---|---|---|---|---|
| Conventional from UG | 0 | 89 606 | 134 408 | 179 211 | 75 |
| Conventional from OP | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | 0 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | 0 |
| Unspecified | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 89 606 | 134 408 | 179 211 | 75 |

Note: Reverse leach with counter current decantation thickening, counter current ion exchange and solvent extraction plus ADU precipitation.

* 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 |
| 34 900 | 110 300 | 110 300 |

### Speculative conventional resources

(tonnes U)

| Cost ranges | | |
|---|---|---|
| <USD 130/kgU | <USD 260/kgU | Unassigned |
| 0 | 0 | 1 112 900 |

## Historical uranium production by deposit type

(tonnes U in concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 155 679 | 566 | 563 | 582 | 157 390 | 615 |
| Vein | 0 | 0 | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 155 679 | 566 | 563 | 582 | 157 390 | 615 |

* 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.

## Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 0 | 0 | 0 | 0 | 0 | 0 |
| Underground mining[1] | 0 | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching | 0 | 0 | 0 | 0 | 0 | 0 |
| Co-product/by-product | 155 679 | 566 | 563 | 582 | 157 390 | 615 |
| Total | 155 679 | 566 | 563 | 582 | 157 390 | 615 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 155 679 | 566 | 563 | 582 | 157 390 | 615 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** | 0 | 0 | 0 | 0 | 0 | 0 |
| U recovered from phosphate rocks | 0 | 0 | 0 | 0 | 0 | 0 |
| Other methods*** | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 155 679 | 566 | 563 | 582 | 157 390 | 615 |

* 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 2010

| Domestic | | | | Foreign | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | | |
| (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) |
| 0 | 0 | 578 | 100 | 0 | 0 | NA | NA | | NA |

### Short-term production capability

(tonnes U/year)

| 2011 | | | | 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 |
| 0 | 0 | 615 | 0 | 0 | 0 | 1 588 | 770 | 0 | 0 | 2 686 | 770 |

| 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 | 2 795 | 770 | 0 | 0 | 1 386 | 770 | | 0 | 1 381 | 770 |

### Uranium industry employment at existing production centres

(person-years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 3 364 | 4 494 | 4 825 | 4 327 |
| Employment directly related to uranium production | 731 | 902 | 1 286 | 1 278 |

### Mixed oxide fuel production and use

(tonnes natural U equivalent)

| Mixed oxide (MOX) fuel | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (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 |

### Re-enriched tails production and use

(tonnes natural U equivalent)

| Re-enriched tails | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Production | 0 | 0 | 0 | 0 | 0 | 0 |
| Use | 0 | 0 | 0 | 0 | 0 | 0 |

### Reprocessed uranium use

(tonnes natural U equivalent)

| Reprocessed uranium | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Production | 0 | 0 | 0 | 0 | 0 | 0 |
| Use | 0 | 0 | 0 | 0 | 0 | 0 |

### Net nuclear electricity generation

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 228.944 | 232.812 |

### Installed nuclear generating capacity to 2035

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 840 | 1 840 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 1 840 | 1 840 | 1 840 | 1 840 | 1 840 | 1 840 | 1 840 | 7 200 | 1 840 | 14 400 | 1 840 | 20 000 |

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

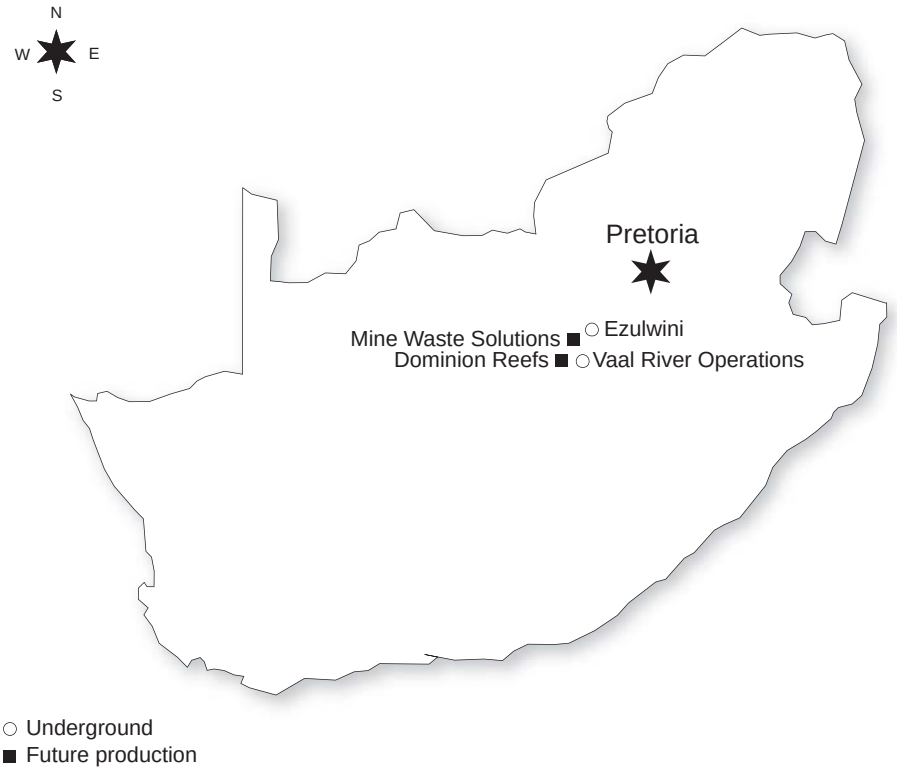
(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 292 | 292 | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 292 | 292 | 292 | 292 | 292 | 292 | 292 | 1 188 | 292 | 2 376 | 292 | 3 300 |

### Total uranium stocks

(tonnes natural U-equivalent)

| Holder | Natural uranium stocks in concentrates | Enriched uranium stocks | Enrichment tails | LWR reprocessed uranium stocks | Total |
|---|---|---|---|---|---|
| Government | NA | NA | NA | NA | NA |
| Producer | NA | NA | NA | NA | NA |
| Utility | NA | NA | NA | NA | NA |
| Total | NA | NA | NA | NA | NA |





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# 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. Exploration activities by the Empresa Nacional del Uranio, S.A. (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 Resources has been granted a total of 20 exploration licences spanning the provinces of Salamanca and Cáceres covering a total of 66 400 ha. The 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.

In April 2009, the Council of Ministers approved a collaboration agreement signed between Berkeley and ENUSA to complete a feasibility study over the following 18 months on the state reserves within the Salamanca province. Through this agreement Berkeley can purchase up to 90% of the assets, including exploration and exploitation of the identified resources and processing at the existing Quercus plant.

Shortly after Ministerial Cabinet approval of the agreement between Berkeley and ENUSA in April 2009, the Mining Domain Feasibility Study (MDFS) on the state reserves in the Salamanca province commenced. The MDFS has included the verification of historical ENUSA data and subsequent mineral resource estimates of the Aguila, Alameda and Villar deposits in compliance with the JORC Code. The current mineral resource inventory for these areas amounts to 51.5 Mlb of $U_3O_8$ or 19 808 tU (with a 200 ppm $U_3O_8$ cut-off grade).

Using in-house staff and a team of international consultants, the MDFS also includes mining studies, environmental assessments, radiological impact assessments, hydrological studies, beneficiation test work, waste management and rehabilitation studies and financial modelling.

In addition to the MDFS, Berkeley has also been prospecting its granted exploration permits and as a result has increased its mineral resource inventory to 31.7 Mlb of $U_3O_8$ or 12 192 tU (200 ppm $U_3O_8$ cut off) during the period to the end of 2010, giving the company a total mineral resource inventory of 83.2 Mlb $U_3O_8$ (32 000 tU).

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

The total RAR increased from 4 900 tU to 14 000 tU and are reported as recoverable by open-pit mining. Inferred resources are not reported as the figures are not currently available, but they are also recoverable by open-pit mining. The RAR data incorporate mining (recovery factor: 0.85) and milling losses (recovery factor: 0.75).

### *Undiscovered conventional resources (prognosticated and speculative resources)*

No resources for these categories are reported.

## Uranium production

### *Historical review*

Production started in 1959 at the Andujar plant, Jaen 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. The processing plant finished the production of uranium concentrates from stockpiled ore in November 2002. A plan for decommissioning was presented to regulatory authorities in 2005. Due to the agreement between ENUSA and Berkeley, this decommissioning plan is on standby until results of the feasibility study that is now in process for the possible future use of the Quercus plant are available.

### *Ownership structure of the uranium industry*

The only production facility in Spain belongs to the company ENUSA Industrias Avanzadas, S.A., 60% owned by Sociedad de Participaciones Industriales (SEPI) and 40% by the Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT).

### *Employment in the uranium industry*

Employment at the Fe mine totalled 25 at the end of the year 2010. All of these workers are dedicated to the surveillance and decommissioning programmes.

### *Future production centres*

By the end of December 2011, other than the possible reopening of the Quercus plant and related mines, no new production centres are being considered.

## 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 uranium production facilities in Spain are as follows:

- Fábrica de Uranio de Andujar (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) until 2004. In this year, a long-term stewardship and monitoring programme began 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 three-year surveillance programme was initiated, ending in 2010. Results are being evaluated by regulatory authorities in order to determine if the surveillance period should be extended.
- 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 spread out 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. Approval for a surveillance programme of at least five years is expected in late 2011.
- 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. Due to the agreement between ENUSA and Berkeley this decommissioning plan is on standby until results of the feasibility study now in process for the possible future use of the Quercus plant are available. During this time a surveillance and maintenance programme has been applied for the plant and associated facilities.

## Uranium requirements

The net capacity of Spain's eight operating nuclear reactors is about 7.42 GWe. No new reactors are expected to be built in the near future.

Through 2010 and 2011, the Spanish government approved ten-year licence extensions for Ascó units 1 and 2, Almaraz units 1 and 2, Vandellós unit 2 and the lone Cofrentes unit, after a favourable report by the Nuclear Safety Council. The Ministry of Industry, Energy and Tourism has expressed its intention to partially revoke the current operation licence of Santa María de Garoña nuclear power plant – which expires in 2013, after 42 years of operation – leaving open the possibility of an extension of its lifetime until 2019.

### *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 eight operating nuclear reactors 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 611 tU (721 $tU_3O_8$). Additional inventories could be maintained depending on uranium market conditions. No information on uranium prices was reported.

**Uranium exploration and development expenditures and drilling effort – domestic**

(EUR)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 4 551 634 | 3 354 110 | 10 222 659 | 14 096 163 |
| Government exploration expenditures | 0 | 0 | 0 | 0 |
| Industry* development expenditures | 0 | 0 | 0 | 0 |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 4 551 634 | 3 354 110 | 10 222 659 | 14 096 163 |
| Industry* exploration drilling (m) | 19 021 | 2 807 | 16 190 | 15 000 |
| Industry* exploration holes drilled | 312 | 206 | 66 | 180 |
| Government exploration drilling (m) | 0 | 0 | 0 | 0 |
| Government exploration holes drilled | 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) | 19 021 | 2 807 | 16 190 | 15 000 |
| Subtotal exploration holes drilled | 312 | 206 | 66 | 180 |
| Subtotal development drilling (m) | 0 | 0 | 0 | 0 |
| Subtotal development holes drilled | 0 | 0 | 0 | 0 |
| Total drilling (m) | 19 021 | 2 807 | 16 190 | 15 000 |
| Total number of holes drilled | 312 | 206 | 66 | 180 |

* Non-government.


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### 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 (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | |
| Sandstone | 0 | 0 | 0 | 0 | |
| Hematite breccia complex | 0 | 0 | 0 | 0 | |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | |
| Vein | 0 | 0 | 0 | 14 000 | |
| Intrusive | 0 | 0 | 0 | 0 | |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | |
| Metasomatite | 0 | 0 | 0 | 0 | |
| Other* | 0 | 0 | 0 | 0 | |
| Total | 0 | 0 | 0 | 14 000 | |

* 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.

### 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 | 0 | 0 | |
| Open-pit mining (OP) | 0 | 0 | 0 | 14 000 | 85% mining; 75% milling |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 0 | 0 | 14 000 | |

### 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 | 0 | 0 | 0 | 14 000 | |
| Conventional from UG | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 0 | 0 | 14 000 | |

* 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 |
|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | NA | NA |
| Intrusive | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 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.

### 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 | 0 | 0 | |
| Open-pit mining (OP) | 0 | 0 | NA | NA | |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 0 | NA | NA | |

### Inferred conventional resources by processing method

(tonnes U)

| Processing method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor (%) |
|---|---|---|---|---|---|
| Conventional from OP | 0 | 0 | NA | NA | |
| Conventional from UG | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 0 | NA | 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.

## Historical uranium production by deposit type

(tonnes U in concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 0 | 0 | 0 | 0 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | 0 | 0 |
| Vein | 5 028 | 0 | 0 | 0 | 5 028 | 0 |
| Intrusive | 0 | 0 | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 5 028 | 0 | 0 | 0 | 5 028 | 0 |

* 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.

## Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 5 028 | 0 | 0 | 0 | 5 028 | 0 |
| Underground mining[1] | 0 | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching | 0 | 0 | 0 | 0 | 0 | 0 |
| Co-product/by-product | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 5 028 | 0 | 0 | 0 | 5 028 | 0 |

1. Pre-2008 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 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | 4 961 | 0 | 0 | 0 | 4 961 | 0 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** | 0 | 0 | 0 | 0 | 0 | 0 |
| U recovered from phosphate rocks | 0 | 0 | 0 | 0 | 0 | 0 |
| Other methods*** | 67 | 0 | 0 | 0 | 67 | 0 |
| Total | 5 028 | 0 | 0 | 0 | 5 028 | 0 |

* Also known as stope leaching or block leaching.

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

*** Includes mine water treatment and environmental restoration.

## Uranium industry employment at existing production centres

(person-years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 43 | 43 | 25 | 23 |
| Employment directly related to uranium production | 0 | 0 | 0 | 0 |

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 679 | 1 388a | 1 322 | 1 322 | 1 350 | 1 350 | 1 350 | 1 350 | 1 350 | 1 350 | NA | NA | NA | NA |

**Total uranium stocks**

(tonnes natural U-equivalent)

| Holder | Natural uranium stocks in concentrates | Enriched uranium stocks | Enrichment tails | LWR reprocessed uranium stocks | Total |
|---|---|---|---|---|---|
| Government | 0 | 0 | 0 | 0 | 0 |
| Producer | 0 | 0 | 0 | 0 | 0 |
| Utility | NA | 611 | 0 | NA | NA |
| Total | NA | 611 | 0 | NA | NA |

# Sweden*

## Uranium exploration and mine development

### *Historical review*

Uranium exploration was first carried out between 1950 and 1985, initially through AB Atomenergi and from 1967 by the Geological Survey of Sweden and associated companies. At the end of 1985, exploration activities were stopped due to the availability of uranium at low prices on the world market. This early work did however result in the delineation of four main uranium provinces in Sweden.

The first is in the Upper Cambrian and Lower Ordovician sediments in southern Sweden and along the border of the Caledonian mountain range in central Sweden. The uranium occurrences are stratiform, in black (alum) shales. Billingen (Vastergotland), where the Ranstad deposits are located, covers an area of more than 500 $km^2$.

The second uranium province Arjeplog-Arvidsjaur-Sorsele, is immediately south of the Arctic Circle. It comprises one deposit, Pleutajokk, and a group of more than 20 occurrences. The individual occurrences are discordant, of a vein or impregnation-type, associated with sodium-metasomatism.

A third province is located north of Ostersund in central Sweden. Several discordant mineralised zones have been discovered in, or adjacent to, a window of Precambrian basement within the metamorphic Caledonides. A fourth province is located near Asele in northern Sweden.

### *Recent and ongoing exploration and mine development activities*

Since 2007, a number of exploration companies have been active in Sweden, in many cases focussing work on areas where discoveries were made during the initial phase of

* Report prepared by Secretariat, based on previous Red Books and company reports.

exploration. Mawson Resources of Canada has reported on a number of small deposits in the Hotagen district of central Sweden. Included are NI 43-101 compliant *in situ* indicated resources of 3.3 Mlbs $U_3O_8$ (1 270 tU) at 0.08% $U_3O_8$ (0.07% U) at the Kläppibäcken Project and NI 43-101 compliant *in situ* inferred resources of 8.8 Mlbs $U_3O_8$ (3 385 tU) at 0.03% $U_3O_8$ (0.02% U) further north at the Duobblon Project. Continental Precious Minerals of Canada reported NI 43-101 compliant *in situ* indicated resources of 4.47 Mlbs $U_3O_8$ (1 720 tU) at 0.24% $U_3O_8$ (0.02% U) at the Lill-Juthatten deposit in central Sweden. Work by these companies and others is ongoing and a number of promising occurrences at these and other projects have been reported.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

Recent exploration activities outlined above have resulted in the addition of 950 tU indicated and 2 540 tU inferred resources to country totals from the Kläppibäcken and Duobblon projects, respectively. Since mining method and costs of recovery have not been specified in these early stage exploration projects, an overall recovery factor of 75% has been applied to both resource figures and both were added to the high cost of production category (USD 130-USD 260/kgU). Resources defined at the Lill-Juthatten have not been added to the country resource figures since this deposit has been reported as part of the national totals since the 1980s.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

Neither prognosticated nor speculative resources are reported in Sweden.

### *Unconventional resources*

In past editions of the Red Book, the potential for very large, low-grade resources of uranium in the alum shale was noted (300 000 tU mineable in the Billingen area of southern Sweden alone), and limited production was undertaken in the 1960s. By the late 1980s however, the cost of production was considered too high for economic production with uranium prices of the time and these deposits were no longer reported in the Red Book.

With renewed interest in uranium owing to strengthening prices since 2003, exploration of the alum shale in central Sweden was resumed with alternative production methods under consideration to reduce costs of production. In March 2009, Continental Precious Metals completed NI 43-101 technical reports on its MMS Viken deposit outlining *in situ* indicated resources of 3 824 tU at 0.016% U and *in situ* inferred resources of 399 100 tU at 0.014% U. The deposit also contains high values of V, Mo and Ni. Continental Resources is investigating mining by a relatively shallow open-pit with bioleaching as a process technology.

In late 2009, Aura Energy applied for significant landholdings to investigate more thoroughly the alum shale. The company initially reported a JORC compliant *in situ* inferred resource at its Häggån Project of 291 Mlbs $U_3O_8$ (111 933 tU) at 0.02% $U_3O_8$ (0.01% U). This was subsequently upgraded to 631 Mlbs $U_3O_8$ (242 714 tU). Further increases can be expected, since the existing resource estimate is based on 15% of the Häggån Project area. Aura Energy is also investigating the use of bioleaching and launched a scoping study on the project, with results expected in early 2012. The deposit also contains high values of V, Mo, Ni and Zn.

Mawson Resources has also conducted work on the Tåsjö Project in recent years, investigating uranium contained in mineralised phosphatic shale with rare earth elements in northern Sweden. The area was discovered in 1957 by the Swedish Atomic Energy Company and subsequently explored in the early 1970s by the Swedish Geological Survey and the Stora Kopparberg and Boliden companies. The size of the exploration

target outlined by the Swedish Atomic Energy Company in the 1960s was confirmed in the last few years by Mawson at about 110 Mlbs $U_3O_8$ (42 300 tU) at 0.05% $U_3O_8$ (0.042% U), although the tonnages and grades are considered conceptual at this time.

Clearly there are large unconventional uranium resources that potentially could be available to the market in future years if costs of production of the bio heap leaching technology under evaluation justify economic production.

## Uranium production

### *Historical review*

In the 1960s, a total of 200 tU were produced from the alum shale deposit in Ranstad that represents all of Sweden's historical production. This mine is now being restored to protect the environment.

### *Status of production capability*

There is currently no uranium production in Sweden.

## Secondary sources of uranium

Sweden does not report the use of mixed oxide fuel or reprocessed uranium.

## Environmental activities and socio-cultural issues

The Ranstad mine was rehabilitated in the 1990s at a total cost of SEK 150 million. An environmental monitoring programme is now being carried out. Local resistance recently blocked efforts to renew uranium exploration in the area.

## Uranium requirements

By the end of 2005, 2 of Sweden's 12 nuclear power reactors, Barsebäck 1 (1999) and Barsebäck 2 (2005), had been retired from service as a result of a 1980 referendum decision to restrict new build of NPPs, bolstered to phase-out nuclear following the Chernobyl accident. The remaining ten reactors require about 1 500 to 2 000 tU annually.

Swedish utilities have been expanding nuclear capacity through power uprates at the existing reactors in an effort to replace the 1 200 MWe (gross) lost when Barsebäck 1 & 2 were closed. By the end of 2010, over 1 000 MWe had been added to the ten reactors that remain in operation.

In Sweden, a tax is applied on the production of electricity at nuclear plants, regulated by the Act on Excise Duties on Thermal Capacity on Nuclear Power Reactors. Originally imposed in the late 1990s, the tax rate was increased in 2006 and again in 2008, amounting to a total of about SEK 4 billion (EUR 435 million).

In 2010, the government narrowly voted in favour of two bills that gave new life to the country's nuclear power programme. The first allows for the construction of replacement reactors once the existing reactors have reached the end of their operational lifetime, effectively overturning earlier decisions to phase-out nuclear power. The replacement reactors must be built on the same site as those operating today and construction can only begin once the older plant is permanently shut down (none of the ten currently operating reactors are expected to be retired from service before 2030). The second bill increases the amount of compensation paid by companies who own nuclear reactors and increases by four times the financial liability of these same owners. Following the Fukushima accident, the government ordered a comprehensive review of the current reactor fleet ahead of the EU stress tests, at the same time indicating that the recent legislative changes would not be reconsidered.

### *Supply and procurement strategy*

The utilities are free to negotiate their own purchases.

## Uranium policies, uranium stocks and uranium prices

Two separate permits under the Minerals Act and the Environmental Code are required to mine uranium deposits in Sweden. In addition, the Nuclear Activities Act contains provisions regulating the right to acquire, possess or deal in any other way with nuclear materials or minerals containing such materials.

Permit applications under the Environmental Code are considered by the government, and permits may only be granted if approval has been recommended by the local authority in whose areas the deposit occurs.

### *Uranium stocks*

The Swedish parliament decided in 1998 to replace the previous obligation that utilities had to keep a stockpile of enriched uranium corresponding to the production of 35 TWh with a reporting mechanism. Sweden reports no information on uranium stocks.

### *Uranium prices*

As Sweden is now part of the deregulated Nordic electricity market, costs of nuclear fuel are no longer reported.

**Uranium exploration and development expenditures and drilling effort – domestic[1]**

(CAD thousands)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | 8 250 | 2 974[2] | 2 349[2] | NA |
| Government exploration expenditures | 0 | 0 | 0 | 0 |
| Industry* development expenditures | 0 | 0 | 0 | 0 |
| Government development expenditures | 0 | 0 | 0 | 0 |
| Total expenditures | 8 250 | 2 974[2] | 2 349[2] | NA |
| Industry* exploration drilling (m) | NA | NA | NA | NA |
| Industry* exploration holes drilled | NA | NA | NA | NA |
| Government exploration drilling (m) | 0 | 0 | 0 | 0 |
| Government exploration holes drilled | 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 | NA | NA | NA | NA |
| 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.

1. Continental Precious Metals and Mawson Resources only.

2. May include expense for other metals.

### 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 | 0 | 0 | |
| Open-pit mining (OP) | 0 | 0 | | | |
| *In situ* leaching | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 4 000 | 4 950 | |
| Total | 0 | 0 | 4 000 | 4 950 | |

### 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 | 0 | 0 | |
| Open-pit mining (OP) | 0 | 0 | | | |
| *In situ* leaching | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 6 000 | 8 540 | |
| Total | 0 | 0 | 6 000 | 8 540 | |

### Net nuclear electricity generation*

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 50.0 | 55.1 |

* *Nuclear Energy Data*, OECD, Paris, 2011.

### Installed nuclear generating capacity to 2035*

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 9 300 | 9 300 | 9 300 | 9 300 | NA | NA | 10 100 | NA | NA | NA | 10 100 | NA | NA | NA |

* *Nuclear Energy Data*, OECD, Paris, 2011.

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 1 550 | 1 580 | NA | NA | NA | 1 900 | NA | 1 900 | NA | 1 900 | NA | 1 900 | NA | 1 900 |

* *Nuclear Energy Data*, OECD, Paris, 2011.

# 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 done by conducting a countrywide airborne geophysical survey for the government between 1976 and 1979. Results revealed a large number of radiometric anomalies in a variety of geological settings.

A uranium exploration programme was subsequently carried out by Uranerzbergbau GmbH between 1978 and 1983, but 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 as well as carbonatite of the Gallapo. Numerous occurrences of surface uranium mineralisation were identified and the potential for several uranium deposit types in the country was recognised.

A large part of the southern Tanzanian geology is comprised of Karoo rocks, terrigenous sediments of a few thousands of meters thickness that accumulated in basins during the Late Paleozoic-Early Mesozoic. The basal series is comprised of glacial deposits, which in turn are overlain by fluvial-deltaic coal-bearing sediments succeeded by arkoses and continental red beds. Transitional carbonaceous shales with coals gradually develop into thick lacustrine series which are topped by Late Permian bone-bearing beds. The Triassic is characterised by a very thick fluvio-deltaic succession of siliciclastics resting with regional unconformity on the Permian. This Early Triassic sequence exhibits well-developed repetitive depositional cycles. Heightened uranium values are observed in the Triassic arenaceous series with diagenetic alteration and subsequent cementation.

### *Recent and ongoing uranium exploration and mine development activities*

Exploration efforts have been focused on the highly uranium prospective Karoo-age sediments of southern Tanzania and paleochannel associated calcrete and sandstone hosted uranium targets within the Bahi catchment of central Tanzania.

The government has issued over 70 licences to foreign companies interested in uranium exploration. In 2007, two overseas companies, British-based Uranium Resources and Australia's Western Metals, undertook joint exploratory drilling that revealed evidence of significant uranium deposits, especially in Lindi and Ruvuma regions. Uranium Resources acquired Western Metals in 2009 and continue with exploration activities on their Mtonya, Rumvuma and Ruhuhu projects. Drilling has been carried out on the first two projects with encouraging results. At Mtonya, a two-phase programme comprising 4 170 m of diamond drilling identified favourable geological environments to facilitate target selection. A 19 hole, 1 382 m reverse circulation drill programme intersected low- to medium-grade uranium mineralisation at shallow depths.

* Secretariat report based on company reports and open source information.

The Ruhuhu project is in the early stages of target identification for sandstone hosted type deposits.

The Mkuju River project is receiving considerable attention. Mantra Resources completed an environmental and social impact assessment in 2011 and submitted the reports to the Tanzanian National Environmental Management Council in support of an application for a mining licence. The project lies within the Selous Game Reserve and is being opposed by local and international conservation bodies. Mantra Resources has been acquired by Atomredmetzoloto (ARMZ) and an operating agreement with Uranium One (51% owned by ARMZ) has given Uranium One operational control of the Mkuju River project. An updated resource estimate in September 2011, based on a total of 82 400 m of reverse circulation drilling in 2 976 holes, 9 020 m of diamond drilling in 173 holes and sampling from 400 trenches, boosted the total resources by over 40%. This estimate will form the basis of a definitive feasibility study to be completed in 2012.

Uranex is still active in Tanzania with its Manyoni, Mkuju, Bahi and Itigi projects. An earlier (2009) resource estimate for the Manyoni project was boosted in May 2010 by 53% to a total of 92 Mt of ore containing 29 Mlbs $U_3O_8$ (11 155 tU) at a grade of 144 ppm $U_3O_8$ (0.01% U). The 2010 estimate was based on an initial 423 hole drilling programme for a total of 5 612 m, supplemented by an in-fill drilling programme. Tests have indicated that the mineralisation is amenable to cost effective heap leaching. The low grade however has resulted in a swing to investigating the higher grade Mkuju project. Drilling has identified sandstone hosted mineralisation with multiple intersections of up to 3 000 ppm $U_3O_8$ (0.3% U). At Bahi and Itigi investigations of extensions to the Manyoni playa depositional environment are ongoing.

East African Resources has prospecting licences over their Madaba-Mkuju properties with sandstone hosted uranium occurrences and at their Eastern Rift property where they are targeting calcrete style mineralisation. Initial exploration work is being conducted on both properties.

Syrah Resources has recently acquired three uranium projects in Tanzania through the acquisition of Jacana Resources. Field investigations of these three projects (Nondwa, Wembere and Tanga) indicate good potential for uranium mineralisation.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

ARMZ's Mkuju River project and Uranex's Manyoni project have updated resources (as of September 2011 and June 2010, respectively) and the RAR have more than trebled to over 30 000 tU. However total identified resources have only increased by 61% because of a substantial shift of resources from inferred to reasonably assured. All the resources are near surface and exploitable by open-pit mining. A feasibility study suggests that Mkuju River resources are available at costs of <USD 130/kgU.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

Undiscovered resources are not reported, however there is a high potential for uranium deposits in several areas, as noted above.

## Uranium production

No uranium has been produced in Tanzania.

### *Future production centres*

The Mkuju River project feasibility study indicates that production levels of almost 2 000 tU/yr are achievable over a mine life of ten years. The mine development schedule

remains uncertain however since the country has not yet hosted uranium mining and the issue of mining in a world heritage game reserve has not yet been resolved. In July 2011, the Tanzanian government reportedly sought approval from the UN World Heritage body UNESCO to re-demarcate the boundaries of the game reserve to accommodate the proposed mine. A decision by UNESCO is expected in mid-2012.

## Environmental activities and socio-cultural issues

The government of Tanzania has recently made efforts 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.

## Uranium requirements

None.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

In 2010, the government of Tanzania 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.

### *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 |
|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 28 739 | 30 076 |
| Hematite breccia complex | 0 | 0 | 0 | 0 |
| Quartz-pebble Conglomerate | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 28 739 | 30 076 |

* 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.

### 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 | 0 | 0 | |
| Open-pit mining (OP) | 0 | 0 | 28 739 | 30 076 | 80 |
| *In situ* leaching | 0 | 0 | 0 | 0 | |
| Co-product and by-product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 0 | 0 | 28 739 | 30 076 | 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 | 0 | 0 | 28 739 | 28 739 | 80 |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** | 0 | 0 | 0 | 1 337 | |
| Total | 0 | 0 | 28 739 | 30 076 | 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 |
|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 0 | 8 010 | 15 603 |
| Hematite breccia complex | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 |
| Other* | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 8 010 | 15 603 |

* 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.

### 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 | 0 | 0 | |
| Open-pit mining (OP) | 0 | 0 | 8 010 | 15 603 | 80 |
| *In situ* leaching | 0 | 0 | 0 | 0 | |
| Co-product and by-product | | | | | |
| Unspecified | | | | | |
| Total | 0 | 0 | 8 010 | 15 603 | 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 | 0 | 0 | 8 010 | 8 010 | 80 |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** | 0 | 0 | 0 | 7 593 | |
| Total | 0 | 0 | 8 010 | 15 603 | 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.

# Turkey

## Uranium exploration and mine development

### *Historical review*

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 rocks and metamorphic. As a result of these activities, some pitchblende mineralisation was found but these occurrences did not form economic deposits. Since 1960, studies have been conducted in sedimentary rocks which surround the crystalline rock and some small ore bodies 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 ore, below the water table, was found in the Köprübaşı area. As a result of recent exploration activities, uranium mineralisation has been discovered in Neogene sediments in the Yozgat-Sorgun region of central Anatolia.

### *Recent and ongoing uranium exploration and mine development activities*

In 2009 and 2010, granite and acidic intrusive rocks and sedimentary rocks were explored for radioactive raw material, over a 10 000 $km^2$ area in the Kütahya-Uşak-Manisa region.

Also in 2010, prospection in 75 $km^2$ area was made on a licensed area owned by ETI Mine.

In 2011, granite and acidic intrusive rocks and sedimentary rocks will be explored for radioactive raw material over a 5 000 $km^2$ around the Kütahya-Uşak-Manisa region.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

- Salihli-Köprübaşı: 2 852 tU in ten ore bodies and at grades of 0.04-0.05% $U_3O_8$ in fluvial Neogene sediments.
- Fakılı: 490 tU at 0.05% $U_3O_8$ in Neogene lacustrine sediments.
- Koçarlı (Küçükçavdar): 208 tU at 0.05% $U_3O_8$ Neogene sediments.

- Demirtepe: 1 729 tU at 0.08% $U_3O_8$ in fracture zones in gneiss.
- Yozgat-Sorgun: 3 850 tU at 0.1% $U_3O_8$ in Eocene deltaic lagoon sediments.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

None reported.

### *Unconventional resources and other materials*

None reported.

## Uranium production

### *Historical review*

No uranium has been produced in Turkey.

## Uranium requirements

None reported.

### *Supply and procurement strategy*

None reported.

**Uranium exploration and development expenditures and drilling effort – domestic**

(USD)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | | | | |
| Government exploration expenditures | 73 500 | 66 000 | 90 500 | 195 000 |
| Industry* development expenditures | | | | |
| Government development expenditures | | | 78 500 | |
| Total expenditures | 73 500 | 66 000 | 169 000 | 195 000 |
| Industry* exploration drilling (m) | | | | |
| Industry* exploration holes drilled | | | | |
| Government exploration drilling (m) | | | | |
| Government exploration holes drilled | | | | |
| Industry* development drilling (m) | | | | |
| Industry* development holes drilled | | | | |
| Government development drilling (m) | | | | |
| Government development holes drilled | | | | |
| Subtotal exploration drilling (m) | | | | |
| Subtotal exploration holes drilled | | | | |
| Subtotal development drilling (m) | | | | |
| Subtotal development holes drilled | | | | |
| Total drilling (m) | | | | |
| Total number of holes drilled | | | | |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | | 7 400 | | | *In situ* |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | 1 729 | | | *In situ* |
| Intrusive | | | | | |
| Volcanic and caldera-related | | | | | |
| Metasomatite | | | | | |
| Other* | | | | | |
| Total | | 9 129 | | | |

* 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.

### 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) | - | - | | | |
| Open-pit mining (OP) | - | 9 129 | | | *In situ* |
| *In situ* leaching acid | - | - | | | |
| *In situ* leaching alkaline | - | - | | | |
| Co-product and by-product | - | - | | | |
| Unspecified | - | - | | | |
| Total | - | 9 129 | | | |

### 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 | - | - | | | |
| Conventional from OP | - | - | | | |
| *In situ* leaching acid | - | - | | | |
| *In situ* leaching alkaline | - | - | | | |
| In-place leaching* | - | - | | | |
| Heap leaching** from UG | - | - | | | |
| Heap leaching** from OP | - | 9 129 | | | *In situ* |
| Unspecified | - | - | | | |
| Total | - | 9 129 | | | |

* 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 |
| NA | NA | NA |

**Speculative conventional resources**

(tonnes U)

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

**Total uranium stocks**

(tonnes natural U-equivalent)

| Holder | Natural uranium stocks in concentrates | Enriched uranium stocks | Enrichment tails | LWR reprocessed uranium stocks | Total |
|---|---|---|---|---|---|
| Government | 1.97 | 0* | 0** | 0 | 1.97 |
| Producer | 0 | 0 | 0 | 0 | 0 |
| Utility | 0 | 0 | 0 | 0 | 0 |
| Total | 1.97 | 0 | 0 | 0 | 1.97 |

* Uranium stocks in fuels are not included.

** Depleted uranium stocks less than 0.001 t are not included.

# Ukraine

## Uranium exploration and mine development

### *Historical review*

Prospecting for uranium in Ukraine began in 1944 as an update of earlier work and mining activities in the North Krivoy Rog ore area. The Pervomayskoye and Zheltorechenskoye uranium deposits were discovered and following mine development, were mined out in 1967 and 1989 respectively.

The first sandstone type deposit (Devladovskoye) was discovered in 1955.

In the mid-1960s, the main geological exploration was concentrated in the Kirovograd ore region for discovery of metasomatite type uranium deposits. The Michurinskoye, Vatutinskoye, Severinskoye, Sentral and Novokonstantinovskoye deposits were discovered as a result of this work.

Metasomatite type deposits comprise the bulk of uranium resources in Ukraine, with uranium content in ores about 0.1-0.2%. These deposits are considered suitable for mining.

The second kind of economic deposits are the sandstone type, but they comprise only a small part of the total resource base. Uranium contents in sandstone deposits range between 0.02 and 0.06%. They are suitable for extraction by ISL.

### *Ongoing uranium exploration and mine development activities*

Using exploration criteria and indications on the basis of international and national practice specialists of Kirovgeology, a new prediction map of Ukraine for uranium was compiled at a scale 1:500 000, where ore areas and potential ore regions and nodes have been distinguished based on potential for finding deposits of different geological types. Ore grades of these prospective deposits are expected to surpass the known metasomatite type deposits.

In 2009-2010, prospecting studies for discovery of deposits of different geological/economic types were conducted.

Prospecting of vein type uranium deposits on the Rozanovskaya square (45 $km^2$) at a scale of 1:25 000:

- Geological prognosticated survey for vein type uranium deposits on the Khmelnisckoy square (450 $km^2$) at a scale of 1:50 000 with evaluation of the Zhdanovskoy, Sokolovskoy and other occurrences was completed.
- Geological prognosticated survey for unconformity type uranium deposits was begun on the Drukhovskoy square (290 $km^2$) at a scale of 1:50 000.

Estimation of the Dibrovskoye rare earth element (REE)-thorium mineralisation within the Pryazov block of the Ukrainian Shield was begun with an assessment of prognosticated uranium and thorium resources.

Continued exploration is being planned for metasomatite type deposits, beginning within the areas of currently operating mines.

Work on estimating thorium presence on the Ukrainian Shield continued in 2009-2010 through compilation of a registration map of thorium occurrences at a scale 1:500 000.

Government and private companies in Ukraine do not conduct any exploration for uranium in other countries. Neither foreign government nor private companies conduct any uranium exploration activities in Ukraine.

## Uranium resources

### *Indentified conventional resources (reasonably assured and inferred resources)*

As on 1 January 2011, identified uranium resources (RAR and IR) recoverable at costs <260 USD/kgU amounted to a total of 224 674 tU. Uranium resources recoverable costs <80 USD/kgU amounted to a total of 61 573 tU. Mining and processing losses are taken into account in these figures.

The main uranium resources of economic interest are concentrated in Ukraine within two types of deposits:

- Metasomatite type mono-metallic deposits located within the Kirovograd block of the Ukrainian Shield. Uranium content in the ore is about 0.1-0.2% U and the deposits are considered suitable for underground mining.
- Sandstone type deposits located within the Dnieper-Bug metallogenic area (17.3 thousand $km^2$). In addition to uranium, molybdenum, selenium and REEs of the lanthanide group occur in these ores. Uranium content in the ore ranges between about 0.01 and 0.06%. These deposits are considered suitable for recovery by ISL.

### *Undiscovered resources (prognosticated and speculative resources)*

After recalculation, undiscovered resources are estimated to amount to 277 500 tU. Of this total, prognosticated resources, mainly confined to the flanks of identified deposits, total 22 540 tU.

Speculative resources amount to 255 000 tU. This figure is produced in consideration of prediction-prospecting work in the central Ukrainian metallogenic area and a 1:500 000 uranium prognostication map compiled by "Kirovgeology." They are subdivided according to geological-production types as follows:

- 133 500 tU of the metasomatite type;
- 20 000 tU in sandstone deposits in the Ukrainian shield;
- 16 500 tU in sandstone (in bitumen) outside the Ukranian shield;
- 40 000 tU in "unconformity" type deposits;
- vein type deposits (30 000 tU);
- 15 000 tU in "intrusive" potassium metasomatite deposits.

## Uranium production

In 1951, the government created the Vostochnyi mining-processing combinat (VostGOK) in the city of Zheltye Vody in the Dnepropetrovsk region to mine and process ores from the Pervomayskoye and Zheltorechenskoye deposits in the North Krivoy Rog area. The Pervomayskoye deposit was completely exhausted in 1967 and the Zheltorechenskoye deposit by 1989.

Today, VostGok operates uranium production facilities in the central Ukrainian ore province mining the Michurinskoye (3 km south of Kirovograd), and Vatutinskoye deposits (near the town Smolino). VostGok is committed to begin mining the Novokonstantinovskoye deposits, which are located 40 km west of Kirovograd and the Severinskoye deposits (4 km north of Kirovograd).

The Michurinskoye deposits were discovered in 1964 and in 1967 construction of the Ingulsky mine began. Average uranium content of these ore bodies is about 0.1% U. Radiometric sorting of mine cars, conducted in the mine, increases the uranium content of ore delivered to the processing plant to about 0.1-0.2%. Two shafts, 7 m in diameter, have been sunk. Ore is hoisted along the northern shaft with two trucks with a loading capacity 11 t. The southern shaft is used for transporting workers and provisions, 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 60-70 m in height at depths of 90 m, 150 m and 240 m below the surface.

The Vatutinskoye deposits were discovered in 1965 and in 1973 construction of the Smolinsky mine began. The industrial area of the Smolinsky mine is situated within the region of the town Smolino, 80 km west of Kirovograd. Transport of mined rocks to the surface is conducted along two paired shafts (the "main" and "helping" shafts) sunk to a depth of 460 m. The lower part of the deposits, extending to a depth of 640 m, was stripped by two blind stems ("Blind-1" and "Blind-2").

Stationary compressor terminals have been installed on the surface of each shaft to produce compressed air used for drill and fire operations. Within each cleaned block, after conducting fire drill operations, ore is moved to loading pocket, unloaded from mine-cars and transported by electric powered trams to the main stem, where it is crushed before being hoisted to the surface. Radiometric ore-dressing, storage, loading to railway carriages and shipping for processing occur on the surface. Mined out spaces are

backfilled by hardening hydro-packing. A total of about 850 persons are involved in this process.

The Novokonstantinovskoy deposit is accessed by three shafts to horizons 480 m and 1 100 m below the surface. At present, the mine is in the development stage. The Severinkovskoy and Podgayscevskoy deposits are accessed by two shafts up to a depth of 650 m.

ISL uranium recovery was practiced in Ukraine beginning in 1961. From 1966 to 1983, uranium in the Devladovskoye and Bratskoye deposits was recovered using sulphuric acid ISL at a depth of about 100 m. At present, monitoring the condition of the mined-out deposits is being conducted. Development of the Safonovskoye and Sadovoye deposits by ISL using alternative leaching chemicals is being planned.

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

*Hydrometallurgical processing plant*

VostGOK's hydrometallurgical processing plant is situated in Zheltye Vody. The annual capacity of the plant is 1.5 Mt ore with 30 to 35 persons employed per shift. Ore is transported to the plant by specially equipped trains from two mines – Ingulskiy (100 km west) and Smolinskiy (150 km west). After crushing and radiometric sorting, the ore is leached in autoclaves using sulphuric acid at a temperature of 150 to 200°C at 20 atmospheres for 4 hours. Acid expenditure is 80 kg/t ore. For uranium extraction ion-exchange resin is applied. After washing with a mixture of sulphuric and nitric acids, the uranium-bearing solution is subjected to further concentration and purification by solvent extraction. Ammonium gas is used for precipitation. Dewatered precipitate is subjected to calcination at 800°c up to obtaining the product of dark colour.

*Innovation techniques in uranium production*

Metasomatite type deposits in Ukraine have a uranium content in ore of about 0.1%, with mineralisation (uraninite, brannerite, coffinite, nasturane) disseminated throughout the volume of ore in steeply dipping ore bodies. Since the mines are located some 100 and 150 km from hydrometallurgical plant transportation costs add to mining and processing costs.

Quarrying is conducted by underground mining, processing is initiated by crushing underground followed by recovery through sulfuric acid in autoclaves. Low-grade uranium ores combined with expensive mining and ore processing techniques makes uranium production unprofitable under current market conditions. In order to decrease production costs, innovation technologies are being introduced, such as underground radiometric sorting, in-place leaching and heap leaching and reprocessing of dumps of operating mines.

Multistage radiometric separators, designed by VostGOK for different size lumps, allow sorting of both mined ore and material in mine dumps. Through sorting, uranium content in ore sent for processing may reach 0.03-0.3% U. The uranium content in "tailings" is 0.006% or less.

If rocks in dumps have an average specific activity at the level of 1 500-1 600 Bk/kg, then the waste materials remaining after radiometric separation have only 350-650 Bk/kg and can be used as second class construction material with specific activity within the limits 370-740 Bk/kg.

Separators may be installed both on the surface and in underground mines. Output of a system of two separators (for different machine classes) is 1 500 thousand tonnes of ore per year.

Three products are obtained during radiometric separation of dump rocks:

- 30% – uranium concentrate with 0.05-0.06% uranium;
- 55% – pure "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 mine condition.

After-crushing uranium concentrate is treated by heap leaching (HL). Recovery of uranium during HL is about 70-75% per year of leaching. The cost of 1 kg of ready product from HL is 62% of the cost of processing this concentrate at the hydrometallurgical plant.

Poor ore bodies with uranium content of 0.04-0.06% are mined by applying the in-place leaching (IPL) method. An optimal technique of explosion has been put in use for disaggregating the ore blocks. Uranium concentration in productive solutions changes from 1 000 mg/l at the beginning to 50 mg/l at the end of leaching the disaggregated ore blocks. The cost of IPL is 58% less than for 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 in the case of highly durable albitites 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 nodes 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.

The heaps either contain ore with a uranium content 0.050-0.080% of concentrate, obtained as a result of dump sorting with uranium content 0.50-0.60%. Heap volume is typically 40.0 thousand tonnes of ore up to a height of 6.0-8.0 m. At the Vatutinskoye deposits the HL site is being built and at the Michurinskoye deposits it is committed for construction. HL sites consist of 4 heaps with total volume of processing 160.0 thousand tonnes of ore per year.

The technology of radiometric ore-dressing at the radiometric processing plants (RPP) available at each uranium pit is being improved. While only two years ago at the Smolinskaya RPP specific activity in "tailings" was 1 900 Bk/kg, now it reaches 1 100 Bk/kg. Applying a new generation of separators will reduce the specific activity of "tailings" to 500-600 Bk/kg, which corresponds to specific activity requirements for second class construction material. In this way sorted "tailings" may be used as construction materials for highways and industry, in this way reducing the volume of wastes from ore mining.

### *Ownership structure of the uranium industry*

All enterprises in the uranium industry (geology, mining, fuel processing) are owned by 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. "Kirovgeology" is responsible for the uranium mineral resource base of Ukraine (geological survey, evaluation and exploration of deposits) and is part of the State Service of Geology and Resources of Ukraine in 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 Ministry of Fuel and Energy.

**Uranium production centre technical details**

(as of 1 January 2011)

| | Centre #1 | Centre #2 | Centre #3 |
|---|---|---|---|
| The name of production centre | Hydrometallurgical plant (HMP) c. Zheltye Vody | Hydrometallurgical plant | Hydrometallurgical plant |
| The condition of production centre | Operating | Planned | Prospective |
| Dates of installation | 1958 | 2015 | |
| Ore supplier: | | | |
| Name of deposits | Michurinskoye central Vatutinskoye | Novokonstantinovskoye | Severinskoye |
| Type of deposit | Metasomatite | Metasomatite | Metasomatite |
| Resources (t U) | 71 684 | 89 885 | 48 120 |
| Grade (% U) | 0.1% | 0.14% | 0.1% |
| Mining operations: | | | |
| Mining method | Underground | Underground | Underground |
| Amount of ore mined per day | 4 500 | 7 500 | 4 200 |
| Ore extraction (%) | 95% | 96% | 96% |
| Technology of the plant (acid/carbonate) | Sulphuric acid | Sulphuric acid | Sulphuric acid |
| Type of extraction (IX/SX/AL) | IX | IX | IX |
| Amount of processing (per 24 hours) for leaching | NA | NA | NA |
| Uranium recovery (%) | 92 | 92 | 92 |
| Nominal output (tU/year) | 1 500 | 1 200 | 2 500 |
| Plans for extension | | | |

## 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 Rep U been used.

## Environmental activities and socio-cultural issues

The main environmental impacts of uranium production at mines result from ore sheds, tailings dumps, radiometric ore-dressing, waste rock dumps, ventilation systems, and transport pathways (railways, technological motor roads). The main environmental impacts from the hydrometallurgical plants and heap-leaching sites are harmful chemical and ore dust emissions, airborne transportation of aerosols and groundwater contamination from tailings impoundments. To assure environmental impacts are minimised, permanent monitoring is being conducted.

At the hydrometallurgical plant (Zheltye Vody) storage of processing wastes (tailings) are stored and recycled water is used in the technological process. Two tailings impoundments, one situated 9 km from the hydrometallurgical plant consisting of two sections (135 and 163 hectares), and the second 0.5 km from the plant (55 hectares), have been used, although the latter is filled to capacity and reclamation is ongoing.

There are issues connected with the decommissioning of uranium mining and uranium processing enterprises. At the now closed Prydnieprovsky chemical, nine tailings impoundments were used (covering a total area of 268 hectares containing 42 Mt of wastes) with total activity of 75 000 Ku and some buildings and other facilities are contaminated with radioactivity. The Cabinet of Ministers initiated a state programme to deal with these issues and remediate the area to an environmentally safe condition with state funds since 2005 amounting to UAH 22.3 million (Ukrainian hryvnia) – about USD 4.5 million.

The total cost of improving radiation 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 imported fuel elements from the Russian Federation (provided by TVEL). Annual fuel loadings of the four operating NPPs (comprised of 13 VVER-1000 units and 2 VVER-440 units) amount to 15 sets of fuel elements at a total cost of about USD 300 million. It is expected that by 2014-2015, 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: 2 VVER-1000 units at Zaporozhskaya, 3 VVER-1000 units at South-Ukrainian, 2 VVER-1000 and 2 VVER-440 units at Rovenskaya and 2 VVER-1000 units at Khmelnitskaya.

The national programme for nuclear energy production foresees by 2030 a 45% to 50% share electricity production by nuclear power. To do so, annual nuclear energy production will have to increase from 75.2 billion KWe/h to 150 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 the decommissioning of 12 NPPs at the end of their operational lifetime.

### Uranium policies, uranium stocks and uranium prices

The Ukrainian government policy is aimed at increasing the production of natural uranium and improving the attractiveness of the sector to foreign investment in order to develop uranium projects in Ukraine. Doing so will be necessary to meet the national policy of increasing domestic uranium mining to meet 100% of Ukrainian NPP requirements.

Resolution N1004, the "Complex Program of Creation Nuclear Fuel 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 N650-p "Some Questions of Liquidation and Organisation of State Merger in the Nuclear Industry". This resolution founded "Nuclear Fuel", by the state merger of all enterprises and scientific-research in institutes connected to the nuclear fuel cycle. The resolution is aimed at improving investment conditions.

### Uranium exploration and development expenditures and drilling effort – domestic

(UAH million as of 1 January 2011)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry exploration expenditures | 0 | 0 | 0 | 0 |
| Government exploration expenditures | 35.4 | 25.8 | 25.3 | 23.5 |
| Subtotal expenditures | 35.4 | 25.8 | 25.3 | 23.5 |
| Subtotal development expenditures | 0 | 0 | 0 | 0 |
| Subtotal expenditures | 35.4 | 25.8 | 25.3 | 23.5 |
| Industry drilling (m) | 0 | 0 | 0 | 0 |
| Number of exploration holes drilled by private companies | 0 | 0 | 0 | 0 |
| Government exploration drilling (m) | 23 316 | 12 660 | 10 165 | 10 700 |
| Number of government exploration holes drilled | 151 | 81 | 67 | 71 |
| Total exploration drilling (m) | 23 316 | 12 660 | 10 165 | 10 700 |
| Total number of exploration holes | 151 | 81 | 67 | 71 |
| Total mining development drilling (m) | 0 | 0 | 0 | 0 |
| Total number of mining development holes | 0 | 0 | 0 | 0 |
| Total drilling (m) | 23 316 | 12 660 | 10 165 | 10 700 |
| Total number of holes drilled | | 81 | 67 | 71 |

### 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 (%) |
|---|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 | 0 |
| Sandstone | 0 | 6 730 | 6 730 | 6 730 | 75 |
| Hematite breccia complex | 0 | 0 | 0 | 0 | |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | |
| Vein | 0 | 0 | 0 | 0 | |
| Intrusive | 0 | 0 | 0 | 0 | |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 | |
| Metasomatite | 2 805 | 37 911 | 80 032 | 136 610 | 88.7 |
| Other* | 0 | 0 | 0 | 0 | |
| Total | 2 805 | 44 641 | 86 662 | 143 340 | |

* 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.

### 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) | 2 805 | 37 911 | 80 032 | 136 610 | 88.7 |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | 0 |
| *In situ* leaching acid | | 6 730 | 6 730 | 6 730 | 75 |
| *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 | 2 805 | 44 641 | 86 762 | 143 340 | |

### 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 | | | | | |
| Conventional from UG | 2 805 | 37 911 | 80 032 | 136 610 | 88.7 |
| *In situ* leaching acid | | 6 730 | 6 730 | 6 730 | 75 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | 0 |
| In-place leaching* | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | 0 |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | 0 |
| Unspecified | 0 | 0 | 0 | 0 | 0 |
| Total | 2 805 | 44 641 | 86 762 | 143 340 | |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | | | | | |
| Sandstone | | 897 | 897 | 897 | 75 |
| Hematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera-related | | | | | |
| Metasomatite | 3 622 | 16 035 | 31 982 | 80 437 | 88.7 |
| Other* | | | | | |
| Total | 3 622 | 16 932 | 32 879 | 81 334 | |

* 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.

### 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) | 3 622 | 16 035 | 31 982 | 8 437 | 88.7 |
| Open-pit mining (OP) | 0 | 0 | 0 | 0 | |
| *In situ* leaching acid | | 897 | 897 | 897 | 75 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| Co-product and by product | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 3 622 | 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 OP | 0 | 0 | 0 | 0 | |
| Conventional from UG | 3 622 | 16 035 | 31 982 | 80 437 | 88.7 |
| *In situ* leaching acid | 0 | 897 | 897 | 897 | 75 |
| *In situ* leaching alkaline | 0 | 0 | 0 | 0 | |
| In-place leaching* | 0 | 0 | 0 | 0 | |
| Heap leaching** from OP | 0 | 0 | 0 | 0 | |
| Heap leaching** from UG | 0 | 0 | 0 | 0 | |
| Unspecified | 0 | 0 | 0 | 0 | |
| Total | 3 622 | 16 932 | 32 879 | 81 334 | |

* 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 <130/kgU | USD <260/kgU |
| 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 deposit type

(tonnes U in concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Unconformity-related | - | - | - | - | - | - |
| Sandstone | 3 925 | - | - | - | 3 925 | 25 |
| Hematite breccia complex | | | | | | |
| Quartz-pebble conglomerate | | | | | | |
| Vein | | | | | | |
| Intrusive | | | | | | |
| Volcanic and caldera-related | | | | | | |
| Metasomatite | 119 632 | 830 | 815 | 837 | 122 114 | 850 |
| Other* | | | | | | |
| Total | 123 557 | 830 | 815 | 837 | 126 039 | 875 |

* 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.

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 10 000 | - | - | - | 10 000 | - |
| Underground mining[1] | 99 632 | 830 | 815 | 837 | 102 114 | 850 |
| *In situ* leaching | 3 925 | - | - | - | 3 925 | 25 |
| Co-product/by-product | 10 000 | - | - | - | - | - |
| Total | 123 557 | 830 | 815 | 837 | 126 039 | 875 |

1. Pre-2008 totals may include uranium recovered by heap and in-place leaching.

### Ownership of uranium production in 2010

| Domestic | | | | Abroad | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | | |
| (t U) | (%) | (t U) | (%) | (t U) | (%) | (t U) | (%) | (t U) | (%) |
| 837 | 100 | | | | | | | 837 | 100 |

### Uranium industry employment at existing production centres

(persons/years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres | 4 260 | 4 350 | 4 310 | NA |
| Direct employment related to uranium production | 1 500 | 1 460 | 1 420 | 1 410 |

### Short-term production capability at existing and committed centres by prime-cost from USD 80/kg (I) and USD 130/kg (II) up to 2035

(tones U/year)

| 2011 | | | | 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 |
| 837 | NA | NA | NA | 810 | 3 230 | NA | NA | NA | NA | 810 | 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 |
| NA | NA | 250 | 5 800 | NA | NA | 170 | 6 400 | NA | NA | NA | NA |

### Net nuclear electricity generation

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generation (TWh net) | 82.92 | 80.15 |

### Installed nuclear generating capacity to 2035

(MWe net)

| 2010 | 2011 | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13.8 | 13.8 | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 15.8 | 17.9 | 16.6 | 20.2 | 18.8 | 26.2 | 20.0 | 26.2 | 26.0 | 30.5 |


URANIUM 2011: RESOURCES, PRODUCTION AND DEMAND, ISBN 978-92-64-17803-8, © OECD 2012

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

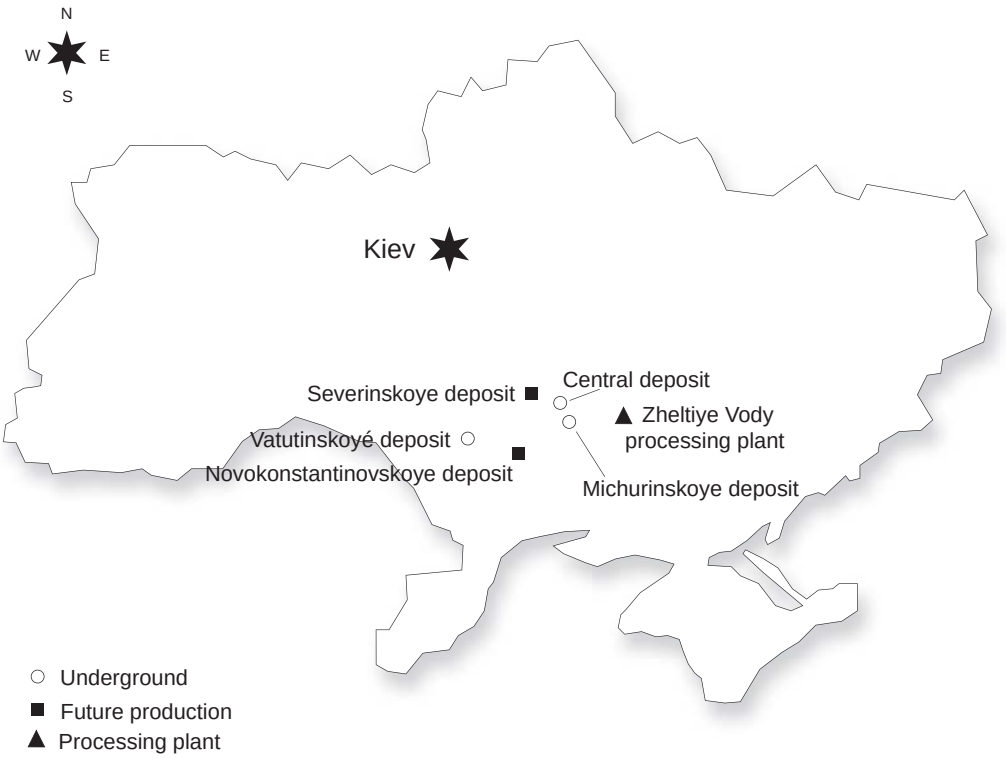
(tonnes U)

| 2010 | 2011 | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 480 | 2 480 | Low | High | Low | High | Low | High | Low | High | Low | High |
| | | 2 840 | 3 230 | 3 020 | 3 600 | 3 020 | 3 660 | 3 600 | 4 800 | 4 800 | 5 300 |

**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 | 0 | 0 | 0 | 0 | 0 |
| Producers | 0 | 0 | 0 | 0 | 0 |
| Consumers | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 0 | 0 |



# 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, 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 brought to an end.

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. A peak total in annual surface drilling was reached in 1978.

Exploration has primarily been for sandstone-type uranium deposits in districts such as the Grants Mineral Belt and Uravan Mineral Belt of the Colorado Plateau and in the Wyoming basins and Texas Gulf Coastal Plain region. Since 1990, sandstone-hosted deposits have been mined in north-western Nebraska.

### *Recent and ongoing uranium exploration and mine development activities*

In the US, expenditures for uranium surface drilling during 2009 were USD 35.4 million, down USD 46.5 million from 2008 expenditures of USD 81.9 million. This 67% decrease in expenditures halted the upward trend from 2004 to 2008, during which there was an overall 673% increase in expenditures. The upward trend was re-established in 2010, with USD 44.6 million in expenditures, a 21% increase from 2009.

**United States uranium drilling activities, 2003-2010**

| Year | Exploration drilling | | Development drilling | | Exploration and development drilling | |
|---|---|---|---|---|---|---|
| | Number of holes | Meters (thousand) | Number of holes | Meters (thousand) | Number of holes | Meters (thousand) |
| 2003 | NA | NA | NA | NA | W | W |
| 2004 | W | W | W | W | 2 185 | 381 |
| 2005 | W | W | W | W | 3 143 | 508 |
| 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 |

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, 2010, Table 1.

The number of holes and total meters drilled decreased from 2008 to 2009, from 9 355 holes and 1 552 656 m to 5 679 holes and 1 140 565 m, respectively. In 2010, the number of holes and total meters drilled increased to 7 209 holes and 1 495 000 m. The increases in 2010 brought total meters drilled to within 96% of the 2008 figure. Regardless of these recent fluctuations, the number of holes drilled more than tripled between 2004 and 2010, from 2 185 to 7 209 holes, and the total meters drilled quadrupled, from 381 to 1 495 m.

In 2009, private industry expenditures for uranium exploration and mine development activities amounted to USD 139.3 million, a 43% decrease from 2008 expenditures of USD 246.4 million. In 2010, expenditures increased slightly by 3% to USD 144.1 million.

In 2009, expenditures on US uranium production, including facility expenses, reached USD 141 million, a 36% decrease from the USD 221 million spent in 2008. In 2010, uranium production expenditures were USD 133.3 million, a 5% decrease from 2009. Expenditures for land also decreased in 2009 by 74% from 2008 to USD 17.3 million, but increased again by 16% to USD 20.2 million in 2010.

Total expenditures for land, exploration, drilling, production and reclamation were USD 280 million in 2009, 40% less than in 2008, and USD 277.3 million in 2010, a 1% decrease from 2009.

**United States uranium expenditures, 2004-2010**

(USD million)

| Year | Drilling | Production | Land and other | | | | Total expenditures |
|---|---|---|---|---|---|---|---|
| | | | Total land and other | Land | Exploration | Reclamation | |
| 2004 | 10.6 | 27.8 | 48.4 | NA | NA | NA | 86.9 |
| 2005 | 18.1 | 58.2 | 59.7 | NA | NA | NA | 136.0 |
| 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 |

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.

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, 2010, Table 8.

In 2009 and 2010, the US government made no exploration and mine development expenditures for uranium in the US or abroad. Data on industry exploration expenditures abroad are not available.

The decreasing trend in development and production expenditures from 2008-2009, marked a turnaround from significant increases in expenditures from 2004 to 2008. Much of the increase in development and production expenditures from 2004 to 2008 was due to the general rise in uranium (and vanadium) prices. Likewise, the overall decrease in uranium prices from 2008 to 2009 lead to a decrease in expenditures. The increase in uranium prices towards the second half of 2010 may have contributed to the increase in development expenditures.

The 2004 to 2008 increase in development and production expenditures stimulated interest in leasing activity for historical uranium reserves properties in several western states. This led to the purchase of uranium mineral rights on these tracts and the formation of new joint ventures to explore and develop prospective new deposits. Encompassed in this activity are thousands of acres located principally in Arizona, California, Colorado, Montana, Nebraska, Nevada, New Mexico, Oregon, South Dakota, Texas, Utah and Wyoming.

Titles to most of the uranium properties and claim blocks with reserves and resources identified by drilling during the 1970s and early 1980s have been acquired by either re-staking, acquisition from previous owners or mergers. Most companies involved are following up acquisitions with in-house evaluations of drilling and geochemical data acquired with the property, new drilling to verify reserves and external expert technical reports to meet financial reporting standards for mining properties. In addition, the uranium industry is assessing the potential of areas bordering many mined-out properties and areas surrounding properties with historically documented resources.

The US Department of Energy (DOE) has 31 active and 1 inactive lease tracts in the Uravan Mineral Belt of western Colorado. The six different leaseholders of these properties can conduct ongoing uranium production on these tracts. As leases become inactive and are returned to the DOE, they are not leased again under the current programme. The DOE is responsible for ensuring that any abandoned uranium production sites on these tracts comply with environmental laws and regulations. After reclamation, the land associated with the DOE lease tracts is eligible for return to the public domain under the administrative jurisdiction of the Bureau of Land Management (Department of the Interior).

Work on these leases continues but typically with just enough effort to meet lease requirements, although one company has filed an exploration plan for its lease. These leases have been held by DOE and its predecessor agencies since 1948 when they were set aside to provide uranium for defence programmes. Past production totals 3 000 tU (7.8 million pounds $U_3O_8$) and about 4-5 times that of vanadium. DOE estimates that 770 tU (2.0 million pounds $U_3O_8$) could be generated annually from the lease tracts in future years. Production from these properties will rely on either open-pit or underground mining with conventional milling.

The western Colorado Plateau ores can be exploited only by conventional mining and milling methods as the ores are often above the water table or are not readily soluble using current US *in situ* leach (ISL) technology which is designed to limit ground-water contamination. Breccia-pipe uranium mineralisation in north-western Arizona has attracted much attention as these deposits are among the highest grade in the US (averaging 0.60% $U_3O_8$, or 0.51% U, during past production). Drilling projects are ongoing at several pipes north of the Grand Canyon. Ore from the breccia-pipe deposits in Arizona and U-V (uranium-vanadium) sandstone deposits in eastern Utah and western Colorado will most likely be shipped to the White Mesa and Shootaring Canyon mills in south-eastern Utah. Uranium mining in these areas will be limited by milling capacity and transportation costs. The White Mesa Mill presently processes “alternate feed material” (uranium-contaminated soils and other materials) while the Shootaring Canyon Mill has a reclamation licence. Converting a reclamation licence to an operating licence is a lengthy process that might take years.

The San Juan Basin of north-western New Mexico contains nearly 40% of US uranium reserves with some ores amenable to ISL recovery, but future development is being influenced by Native American concerns. In 2005, the Navajo Nation banned uranium exploration, mining and processing in “Indian country.” The term “Indian country” as used by the Navajo includes tribal lands and non-tribal lands where mining activities may have an impact on nearby tribal lands or may impact predominately Native American communities on non-tribal lands. Community ground water supplies are of

particular concern. In 2009, a federal appeals court decision recognised the term "Indian country" as legitimate and granted the US Environmental Protection Agency (EPA) regulatory control over injection of lixiviant into ground water for recovery of uranium at the proposed Church Rock ISL mine (formerly the "Section 8" mine). In June 2010, the Federal appeals court reversed the 2009 decision, ruling that the Church Rock mine was not within "Indian country". This ruling put regulatory control back to the state of New Mexico and the state had issued a permit for this activity before the 2009 ruling. In November 2010, the US Supreme Court denied a petition to review a lower court ruling that upheld the mining company's Nuclear Regulatory Commission (NRC) licence to mine by ISL. The company plans to begin uranium production in 2013.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

Estimates of reasonable assured resources (RAR) in the US are unchanged from updated 2009 estimates and, as in past years, inferred resources are not reported separately.

### *Undiscovered conventional resources (prognosticated and speculative resources)*

Estimates of prognosticated (EAR) and speculative resources in the US were carried forward without alteration from 1994 to the 2009 edition of the Red Book. For the 2011 edition of the Red Book entries in these resource categories are discontinued until new undiscovered resource estimates can be completed and older estimates corroborated.

### *Unconventional resources and other materials*

Not available.

## Uranium production

### *Historical review*

Under the Atomic Energy Act of 1946, designed to meet the US government's uranium needs, the Atomic Energy Commission (AEC) from 1947 to 1970 fostered a domestic uranium industry, chiefly in the western states, through incentive programmes for exploration, development, and production. The AEC also negotiated uranium concentrate procurements contracts, pursuant to the Atomic Energy Act of 1946 and 1954, with guaranteed prices for source materials delivered within specified times. A total of 32 conventional mills and several pilot plants, concentrators, up graders, heap-leach, and solution-mining facilities were operated at various times. As the sole government purchasing agent, the AEC provided the only US market for uranium. By late 1957, domestic ore reserves and milling capacity were sufficient to meet the government's projected requirements. In 1958, the AEC 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 government's uranium procurement programme was ended at year-end 1970, and the industry became a private sector, commercial enterprise with no additional government purchases.

A peak in US production occurred in 1980 (16 810 tU) and subsequently the industry experienced generally declining annual production from 1981-2003. Beginning in 2004, production began increasing once again in response to higher uranium prices. Since 1991, production from ISL and other non-conventional production methods has dominated US annual production. In 2004, 2005 and 2006, concentrate production was obtained from facilities in the states of Colorado, Nebraska, Texas, and Wyoming.

Uranium mine production from all sources in 2010 amounted to 1 630 tU, a 2% increase from 2009 production (1 595 tU). Four underground mines produced uranium-bearing ore in 2010, ten less than in 2009. Four ISL operations produced uranium in 2010. Overall, eight mines produced uranium for processing uranium concentrate.

In 2010, uranium concentrate production (yellowcake) was obtained from facilities in Nebraska, Texas, Utah and Wyoming. Yellowcake was produced at the White Mesa Mill and four ISL plants (Alta Mesa, Crow Butte, Smith Ranch-Highland and La Palangana). All but one was in production for the entire year. In 2010, 1 976 tU were shipped from these facilities, 42% above the 2009 level (1 393 tU).

Two new ISL operations La Palangana in Texas and Christensen Ranch in Wyoming started production during the 4th quarter of 2010. Material produced at La Palangana is processed at the Hobson ISR Plant. Total production of uranium concentrate in the US amounted to 1 627 tU in 2010, a 12% increase from 2009 (1 426 tU).

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

As of the end of 2010, one uranium mill was operating at a capacity of 1 538 tU per day and three were in standby status (a combined capacity of 3 255 t per day) and one mill was under development.

At the end of 2010, seven ISL plants with a combined annual capacity of 4 539 tU were operating or operational. Three other ISL plants with a combined annual capacity of 962 tU were on standby or permitted and licensed. Another eight ISL projects were under development.

Several uranium companies are in pre-licensing negotiations with state and federal regulatory agencies for both conventional and ISL mining in Wyoming, Colorado, Utah, New Mexico and Texas. Existing and new ISL properties are most likely to be the largest contributors to expanded production in the near term. New ISL operations have relatively short lead times due to simpler regulatory requirements, lower capital costs and shorter construction schedules than new conventional mines and mills.

### *Ownership structure of the uranium industry*

Five facilities produced uranium in 2010. Ownership of these facilities included public and privately held firms with both foreign and domestic participation.

### *Employment in the uranium industry*

Employment in the raw materials sector (exploration, mining, milling and processing) generally declined each year during the period 1998-2003, then steadily increased from 2004-2008. Employment levels in 2009 showed the first significant decrease over the preceding six years. In 2010, total employment in the US uranium production industry was 1 073 person-years, a 2% decrease from the 2009 total, while reclamation employment decreased by 23%. Uranium mining, milling and processing employment decreased 3%, while exploration employment rose 21% from 2009 to 2010. Eight states (Arizona, Colorado, Nebraska, New Mexico, Texas, Utah, Washington and Wyoming) accounted for 98% of total industry employment in 2010.

### *Future production centres*

There are a number of production centres that are either in the process of permitting and licensing or under development. One is a conventional uranium mill (Piñon Ridge) and six are ISL plants (Church Rock, Crown Point, Lost Creek, Nichols, Goliad and Jab and Antelope).

## Uranium production centre technical details

(as of 1 January 2011)

| | Centre #1 | Centre #2 | Centre #3 | Centre #4 | Centre #5 | Centre #6 | Centre #7 | Centre #8 |
|---|---|---|---|---|---|---|---|---|
| Name of production centre[1] | Crow Butte | Smith Ranch Highland | White Mesa Mill | Hobson Mill | Alta Mesa | Church Rock | Crownpoint | Irigaray Ranch |
| Production centre classification | Existing | Existing | Existing | Existing | Existing | Existing | Existing | Existing |
| Start-up date | 1991 | 1988 | 1980 | 1979 | 2005 | 1967 | NA | NA |
| Source of ore: | | | | | | | | |
| Deposit name(s) | Crow Butte & North Trend | Smith Ranch Highland | Various | Palangana | Alta Mesa | Church Rock | Crownpoint | Irigaray |
| Deposit type(s) | Sandstone | Sandstone | Sandstone | Sandstone | Sandstone | Sandstone | Sandstone | Sandstone |
| Resources (tU) | W | W | W | W | W | W | W | NA |
| Grade (% U) | W | W | W | W | W | W | W | NA |
| Mining operation: | | | | | | | | |
| Type (OP/UG/ISL) | ISL | ISL | UG | ISL | ISL | ISL | ISL | ISL |
| Size (tonnes ore/day) | NA | NA | NA | NA | NA | NA | NA | NA |
| Average mining recovery (%) | NA | NA | NA | NA | NA | NA | NA | NA |
| Processing plant: | | | | | | | | |
| Acid/alkaline | | | Acid | | | | | |
| Type (IX/SX) | IX | IX | SX | IX | IX | IX | IX | IX |
| Size (tonnes ore/day); for ISL (mega or kilolitre/day or litre/hour, specify) | NA | NA | 1 538 TPD | NA | NA | NA | NA | NA |
| Average process recovery (%) | NA | NA | NA | NA | NA | NA | NA | NA |
| Nominal production capacity (tU/year)[1] | 385 | 2 116 | NA | 385 | 385 | 385 | 385 | 500 |
| Plans for expansion | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| Other remarks[1] | Operating | Operating | Operating | Operational | Producing | Partially permitted and licensed | Partially permitted and licensed | Operational |

1. Source: US Energy Information Administration, Domestic Uranium Production Report, 2010, Tables 4 and 5.

W = Data withheld to avoid disclosure of individual company data.

## Uranium production centre technical details (*continued*)

(as of 1 January 2011)

| | Centre #9 | Centre #10 | Centre #11 | Centre #12 | Centre #13 | Centre #14 | Centre #15 | Centre #16 |
|---|---|---|---|---|---|---|---|---|
| Name of production centre[1] | Christensen Ranch | Lost Creek | Nichols Ranch ISL Project | Goliad Uranium Project | Jab and Antelope | Moore Ranch | La Palangana | Pinon Ridge Mill |
| Production centre classification | Existing | Development | Development | Development | Development | Development | Existing | Development |
| Start-up date | NA | NA | NA | NA | NA | NA | 2010 | NA |
| Source of ore: | | | | | | | | |
| Deposit name(s) | Christensen | Lost Creek | Nichols Ranch and Hank | Various | Various | Various | Various | Pinon Ridge Mill |
| Deposit type(s) | Sandstone | Sandstone | Sandstone | Sandstone | Sandstone | Sandstone | Sandstone | Sandstone |
| Resources (tU) | NA | NA | NA | NA | NA | NA | NA | NA |
| Grade (% U) | NA | NA | NA | NA | NA | NA | NA | NA |
| Mining operation: | | | | | | | | |
| Type (OP/UG/ISL) | ISL | ISL | ISL | ISL | ISL | ISL | ISL | UG |
| Size (tonnes ore/day) | NA | NA | NA | NA | NA | NA | NA | NA |
| Average mining recovery (%) | NA | NA | NA | NA | NA | NA | NA | NA |
| Processing plant: | | | | | | | | |
| Acid/alkaline | | | | | | | | Acid and alkaline |
| Type (IX/SX) | IX | IX | IX | IX | IX | IX | IX | SX |
| Size (tonnes ore/day); for ISL (mega or kilolitre/day or litre/hour, specify) | NA | NA | NA | NA | NA | NA | NA | 385 TPD |
| Average process recovery (%) | NA | NA | NA | NA | NA | NA | NA | NA |
| Nominal production capacity (tU/year)[1] | 385 | 769 | NA | 385 | 769 | 192 | 385 | NA |
| Plans for expansion | Unknown | Development | Development | Development | Development | Development | Development | Development |
| Other remarks[1] | Operating | Developing | Partially permitted and licensed | Partially permitted and licensed | Developing | Permitted and licensed | Operating | Developing |

1. Source: US Energy Information Administration, Domestic Uranium Production Report, 2010, Tables 4 and 5.

## Secondary sources of uranium

### *Production and/or use of mixed oxide fuels*

Mixed oxide (MOX) fuel will be fabricated at the Department of Energy's Savannah River site in South Carolina; beginning in 2016, using surplus military plutonium to fabricate fuel for commercial reactors. The Tennessee Valley Authority (TVA) is evaluating the use of MOX at its Sequoyah and Browns Ferry plants.

### *Production and/or use of re-enriched tails*

The DOE and the Bonneville Power Administration initiated a pilot project to re-enrich 8 500 t of the DOE's enrichment tails inventory. This project is expected to produce approximately 1 939 t of uranium equivalent for use by the Columbia Generating Station between 2007 and 2015.

### *Production and/or use of reprocessed uranium*

In March 2010, the Blue Ribbon Commission on America's Nuclear Future was formed to conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle. The commission will provide advice and make recommendations on issues including alternatives for the storage, processing and disposal of civilian and military spent nuclear fuel and high-level radioactive waste. The commission will produce an interim report in 2011 and a final report in 2012. It is expected to address reprocessing in its interim report. In the meantime, reprocessed uranium use and production is zero.

## Environmental activities and socio-cultural issues

### *Legislation*

*Federal*

Beginning in 2009 and continuing through 2010 and 2011, Congress is seeking to reform the 1872 Mining Law. Bills were introduced in both houses of Congress that would move the uranium mining industry towards competitive leasing of federal lands and away from the traditional claim and patent system. It would also treat uranium as a leasable mineral rather than a locatable mineral. In essence, uranium would be treated as an energy source just as oil, coal and natural gas. The most recent proposed legislation, the Uranium Resources Stewardship Act of 2010, would impose a 12.5% royalty for uranium mining on federal land. Under current law, uranium miners do not pay royalties for minerals removed from federal land. Tension exists as a result of the need to clean-up such sites and some of the royalties imposed via the proposed legislation would be applied to the clean-up of abandoned mines.

*State*

In April 2010, the Colorado legislature authorised the imposition of new, more stringent state regulations for uranium mine and mill cleanup and in June that year the legislation was signed by the governor. In essence, companies proposing to apply for expansion permits would be required to clean up existing hazardous waste prior to applying for such permits. Prior to the enactment of this legislation, mine and mill operators were allowed to postpone cleanup activities until production activities were complete. Provisions for groundwater monitoring of uranium contamination are also included in the legislation. The legislation was triggered by Cotter Corp.'s efforts to reopen its Canon City, Colorado uranium mill and open a new mill in Montrose County, Colorado. Canon City began operations in 1958 and was designated a Superfund site in 1984. Remediation of the Canon site began in 1988, and the EPA cleared the site in 2002. However, the EPA has yet to make a final groundwater cleanup determination. Cotter proposes to reopen the Canon mill to process ore from a New Mexico mine as early as 2014.

### *Regulation*

Uranium recovery is regulated by both the NRC and the EPA. The NRC has initiated an effort to update its guidance for uranium recovery facilities. These updates are related to technical and environmental regulations for conventional, heap and ISL facilities; licence application formats; restoration action plans; and pre-licence exploration vs. post-licence operations. During 2010, several noteworthy licensing activities occurred:

- Pinon Ridge, Colorado received the first new conventional mill licence in over 30 years.
- Moore Ranch, Wyoming received the first new ISL operating licence in nearly 15 years.
- The Final Supplemental Environmental Impact Statement was issued for the Nichols Ranch ISL (ISR) Project in Wyoming. As of October 2011, the Nichols Ranch ISR Project is under construction.
- The Bureau of Land Management (BLM) became a co-operating agency for the new Ross, Wyoming ISL licence application.

The EPA announced in May 2010 that it is reviewing and potentially revising its standards for uranium and thorium milling facilities that were last updated nearly 15 years ago. The regulations apply to by-product material from conventional mills, ISL (ISR) facilities and heap leach facilities, but not to conventional open-pit or underground mines. Any revisions are expected to address such issues as groundwater protection and significant changes in uranium industry technology, judicial decisions relevant to the regulation and the need for new risk assessments to account for unanticipated risks to the public and the environment. EPA expects to issue a notice of proposed rulemaking in early 2012.

### *Litigation*

The Pinon Ridge Mill (Colorado) is the first new mill in the US in 30 years. Commencing in 2007, the Sheep Mountain Alliance challenged Toronto-based Energy Fuel's Inc.'s development of the new mill. After a licence was issued, the Sheep Mountain Alliance filed suit, alleging that the EPA violated the Atomic Energy Act by issuing the licence without providing the public with an opportunity to engage in an open hearing on the matter. In addition, concerns were raised about escrowing monies to cover waste cleanup costs. In April 2011, the Sheep Mountain Alliance and Citizens Against Toxic Waste requested that the EPA delay granting Clean Air Act approval for the mill until such time as the EPA finalises its review of existing air quality regulations. In September 2011, a settlement agreement was reached in this case, and the Colorado District Court issued an order to implement the agreement, thereby settling the dispute between Energy Fuels, Inc. and the Sheep Mountain Alliance *et al*. The settlement agreement is based on Energy Fuels implementation of specific environmental and water supply protections. In October 2011, the EPA issued a construction approval to Energy Fuels for the construction of a tailings impoundment area and evaporation ponds.

In 2005, the US government sued Newmont USA and Dawn Mining Company, LLC in federal court in Washington State for damages under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). The suit was based on pollution produced from 1955 to 1981 by the Midnite mine Superfund site in the Selkirk Mountains of Washington. In 2007, the court determined that Dawn Mining Co., LLC was liable under CERCLA and in 2008 ruled that collectively, Newmont and Dawn were responsible for USD 15.8 million in cleanup costs. In March 2010, Newmont USA filed a complaint against seventeen insurance companies for breach of their policies over the costs of cleaning up hazardous material at the former uranium mine. As of December 2010, only a few insurance companies had settled their claims with Newmont. Settlements with other insurance companies are expected to continue into 2011.

In July 2010, three environmental groups filed suit in the US District Court for the District of Utah against the US Forest Service to prevent Denison Mines Corp. from conducting exploratory drilling for uranium in the Manti-Sal National Forest, Utah. The environmental groups have charged that the Forest Service violated the National Environmental Protection Act by not fully reviewing the environmental impacts of Denison's two new projects, particularly those involving the release of radon gas from vent holes. In September 2010, the request for an injunction was denied since the environmental groups could not prove irreparable harm. Nevertheless, the suit continued to be prosecuted. In early 2011, a settlement was reached under which the Forest Service will verify that proper markings and equipment are installed at mine vent holes.

## Uranium requirements

Annual US uranium requirements for the period 2010 to 2035 are projected to increase by roughly 25% from 19 138 tU in 2010 to 24 158 tU (high case) in 2020 and to 28 069 tU (high case) in 2035. This increase is based on the expected 60-year extended life cycle of existing NPPs as well as the assumption that nearly 80% of existing NPPs will receive a second 20-year licence renewal thereby extending their operating lives to 80 years and the anticipated addition of new NPPs by 2035.

### *Supply and procurement strategy*

The US allows supply and procurement of uranium production 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

The Russian Federation and the US signed a 20-year, government-to-government agreement in February 1993 for the conversion of 500 t of Russian highly enriched uranium (HEU) from nuclear warheads to low-enriched uranium (LEU). Through 31 December 2010, the US Enrichment Corporation (USEC), the US executive agent for the HEU Agreement, announced that it had recycled 412 t of HEU into 11 905 t LEU, eliminating the equivalent of 16 494 warheads. As of 31 December 2010, this programme (also known as the Megatons to Megawatts program), set to expire in 2013, had not been extended. However, in March 2011, USEC signed a ten-year contract with TENEX to supply commercial origin Russian LEU, commencing in 2011 and continuing through 2022.

In December 2008, DOE released a plan to manage its excess uranium inventory. This plan includes the sale or transfer of 22 700 t of natural uranium equivalent over ten years (2008-2017). Designed partly to minimise adverse impacts on the domestic uranium industry, the plan specifies that transfers cannot exceed 10% of the US commercial uranium requirements in any given year. On 1 March 2011, the Secretary of Energy authorised the additional transfer of 1 605 t of natural uranium equivalent per year for 2011, 2012 and 2013. The sale of this additional uranium from the DOE excess inventory will fund accelerated cleanup work at the Portsmouth Gaseous Diffusion Plant from 2011 through 2013. Based on a market impact analysis performed by Energy Resources International, Inc., the Secretary of Energy determined there would be no adverse material impacts to the domestic uranium industries from uranium transfers to fund the Portsmouth cleanup.

### *Uranium stocks*

As of 2010, the total inventories (including government, producer and utility stocks) amounted to 94 548 tU. Of this total, government stocks totalled 56 031 tU which includes 17 596 tU of uranium concentrates, 12 485 tU of enriched uranium, and 25 950 tU in depleted uranium.

Total commercial inventories (producer and utility stocks) in 2010 were 38 517 tU, a 10% decline from the 42 901 tU in 2009. Commercial inventories in 2009 increased 1% from the 2008 level of 42 304 tU. In 2010, over 85% of the commercial inventories, or 33 283 tU, were stocks held by owners and operators of commercial reactors. This was a 2% increase from the 32 602 tU owned by this group at the end of 2009. Commercial inventories held in 2009 by utilities also increased by 2% from 2008 (31 915 tU).

Enriched uranium inventories held by utilities increased by 56% overall from 2008 (9 294 tU) to 2010 (14 497 tU); 30% from 2008 to 2009 (12 001 tU) and 21% from 2009 to 2010. In contrast, natural uranium inventories held by utilities decreased by 17% overall from 2008 (22 621 tU) to 2010 (18 785 tU); 9% from 2008 to 2009 (20 600 tU) and 9% from 2009 to 2010.

Utility stocks held at year-end 2010 (33 283 tU) were 2% more than year-end 2009 (32 602 tU). The utility stocks in 2009 had also increased by 2% from the 31 915 tU held in 2008.

### *Uranium prices*

Owners and operators of US civilian nuclear power reactors purchase uranium under spot contracts and long-term contracts. A spot contract is defined as a one-time delivery of the entire contract to occur within one year of contract execution. A long-term contract is defined as one or more deliveries to occur after a year following contract execution.

In 2009, purchases under spot contracts amounted to 3 133 tU, a 2% decrease from the 3 354 tU purchased under spot contracts in 2008. In 2010 purchases under spot prices increased less than 1% from 2009 to 3 141 tU.

The weighted-average spot price decreased 30% from USD 174/kgU (USD 66.95/lb $U_3O_8$) in 2008 to USD 121/kgU (USD 46.45/lb $U_3O_8$) in 2009. In 2010, the weighted-average spot price decreased 6% from 2009 to USD 114/kgU (USD 43.99/lb $U_3O_8$).

The uranium purchased under long-term contracts in 2009 amounted to 15 777 tU which is a 4% decrease from the 16 457 tU purchased in 2008. In 2010, amounts purchased under long-term contracts decreased 7% to 14 575 tU. The weighted-average price under long-term contracts in 2009 was USD 119/kgU (USD 45.74/lb $U_3O_8$), a 10% increase from the USD 108/kgU (USD 41.59/lb $U_3O_8$) price in 2008. In 2010 the weighted-average price also increased 10% to USD 131/kgU (USD 50.43/lb $U_3O_8$).

**Average US uranium prices, 2000-2010**

(USD per kilogram U equivalent)

| Year | Spot contracts | Long-term contracts |
|---|---|---|
| 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 |
| 2001 | 20.59 | 28.49 |
| 2000 | 22.2 | 30.42 |

Source: US Energy Information Administration, Uranium Marketing Annual Report, 2010, Table 7.

## Uranium exploration and development expenditures and drilling effort – domestic

(USD millions)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures[1] | 50.2 | 24.2 | 34.5 | NA |
| Government exploration expenditures | 0 | 0 | 0 | NA |
| Industry* development expenditures[2] | 196.2 | 115.1 | 109.5 | NA |
| Government development expenditures | 0 | 0 | 0 | NA |
| Total expenditures | 246.4 | 139.3 | 144 | NA |
| Industry* exploration drilling (m)[3] | 775 109 | 320 346 | 445 009 | NA |
| Industry* exploration holes drilled[4] | 5 198 | 1 790 | 2 439 | NA |
| Government exploration drilling (m) | 0 | 0 | 0 | NA |
| Government exploration holes drilled | 0 | 0 | 0 | NA |
| Industry* development drilling (m)[5] | 777 547 | 820 219 | 1 049 735 | NA |
| Industry* development holes drilled[5] | 4 157 | 3 889 | 4 770 | NA |
| Government development drilling (m) | 0 | 0 | 0 | NA |
| Government development holes drilled | 0 | 0 | 0 | NA |
| Subtotal exploration drilling (m) | 775 109 | 320 346 | 445 009 | NA |
| Subtotal exploration holes drilled | 5 198 | 1 790 | 2 439 | NA |
| Subtotal development drilling (m) | 777 547 | 820 219 | 1 049 735 | NA |
| Subtotal development holes drilled | 4 157 | 3 889 | 4 770 | NA |
| Total drilling (m) | 1 552 656 | 1 140 565 | 1 494 744 | NA |
| Total number of holes drilled | 9 355 | 5 679 | 7 209 | NA |

* Non-government.

1. US Energy Information Administration, Domestic Uranium Production Report, 2010, Table 8 – Exploration.

2. US Energy Information Administration, Domestic Uranium Production Report, 2010, Table 8 – Drilling + land + reclamation.

3. US Energy Information Administration, Domestic Uranium Production Report, 2010, Table 1 – Exploration, feet (converted into meters using EIA Uranium Industry Annual Appendix D Uranium Conversion Guide).

4. US Energy Information Administration, Domestic Uranium Production Report, 2010, Table 1 – Exploration, number of holes.

5. US Energy Information Administration, Domestic Uranium Production Report, 2010, Table 1 – Development drilling.

## Uranium exploration and development expenditures – non-domestic

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry* exploration expenditures | NA | NA | NA | NA |
| Government exploration expenditures | 0 | 0 | 0 | NA |
| Industry* development expenditures | NA | NA | NA | NA |
| Government development expenditures | 0 | 0 | 0 | NA |
| Total expenditures | NA | NA | NA | NA |

* Non-government.

### Reasonably assured conventional resources by deposit type[1]

(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 | 39 064 | 191 953 | 401 149 | NA |
| Hematite breccia complex | 0 | 0 | 0 | 0 | NA |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 | NA |
| Vein | 0 | 0 | 0 | 0 | NA |
| Intrusive | 0 | 0 | W | W | NA |
| Volcanic and caldera-related | 0 | 0 | W | W | NA |
| Metasomatite | 0 | 0 | 0 | 0 | NA |
| Other* | 0 | 0 | W | W | NA |
| Total | 0 | 39 064 | 207 435 | 472 056 | NA |

1. EIA Uranium Reserves Data; same information as 2009 Red Book.

* 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.

### Reasonably assured conventional resources by production method[1]

(tonnes U)

| Production method | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU | Recovery factor |
|---|---|---|---|---|---|
| Underground mining (UG) | 0 | 0 | 82 863 | 233 960 | NA |
| Open-pit mining (OP) | 0 | 2 472 | 35 847 | 125 025 | NA |
| *In situ* leaching acid | 0 | 0 | 0 | 0 | NA |
| *In situ* leaching alkaline | 0 | 36 592 | 88 530 | 110 991 | NA |
| Co-product and by-product | 0 | 0 | 0 | 0 | NA |
| Unspecified | 0 | 0 | 195 | 2 080 | NA |
| Total | 0 | 39 064 | 207 435 | 472 056 | NA |

1. EIA Uranium Reserves Data; same information as 2009 Red Book.

### Reasonably assured conventional resources by processing method[1]

(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 | 39 064 | 207 435 | 472 056 | NA |

1. EIA Uranium Reserves Data.

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity-related | NA | NA | NA | NA | NA |
| Sandstone | NA | NA | NA | NA | NA |
| Hematite breccia complex | NA | NA | NA | NA | NA |
| Quartz-pebble conglomerate | NA | NA | NA | NA | NA |
| Vein | NA | NA | NA | NA | NA |
| Intrusive | NA | NA | NA | NA | NA |
| Volcanic and caldera-related | NA | NA | NA | NA | NA |
| Metasomatite | NA | NA | NA | NA | NA |
| Other* | NA | NA | NA | NA | NA |
| Total | 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.

### 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) | NA | NA | NA | NA | NA |
| Open-pit mining (OP) | 0 | NA | NA | NA | NA |
| *In situ* leaching acid | 0 | NA | NA | NA | NA |
| *In situ* leaching alkaline | 0 | NA | NA | NA | NA |
| Co-product and by-product | 0 | NA | NA | NA | NA |
| Unspecified | 0 | NA | NA | NA | NA |
| Total | 0 | NA | NA | NA | NA |

### 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 | NA | NA | NA | NA | NA |
| Conventional from OP | NA | NA | NA | NA | NA |
| *In situ* leaching acid | NA | NA | NA | NA | NA |
| *In situ* leaching alkaline | NA | NA | NA | NA | NA |
| In-place leaching* | NA | NA | NA | NA | NA |
| Heap leaching** from UG | NA | NA | NA | NA | NA |
| Heap leaching** from OP | NA | NA | NA | NA | NA |
| Unspecified | NA | NA | NA | NA | NA |
| Total | NA | NA | NA | NA | 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.

### 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 80/kgU | <USD 130/kgU | <USD 260/kgU |
| NA | NA | NA |

### Historical uranium production by deposit type

(tonnes U in concentrates)

| Deposit type | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (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.

### Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining[1] | 0 | 0 | 0 | 0 | 0 | 0 |
| Underground mining[1] | 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 | 362 148 | 1 492 | 1 594 | 1 630 | 366 864 | NA |

1. Pre-2008 totals may include uranium recovered by heap and in-place leaching.

W = Data withheld to avoid disclosure of individual company data.

Source: US Energy Information Administration, Domestic Uranium Production Report, 2010, Table 2 (mine production).

## Historical uranium production by processing method

(tonnes U in concentrates)

| Processing method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Conventional | NA | W | W | W | NA | NA |
| In-place leaching* | NA | W | W | W | NA | NA |
| Heap 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 | 361 714 | 1 501 | 1 426 | 1 626 | 366 267 | NA |

W = Data withheld to avoid disclosure of individual company data.

* 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, 2010, Table 3 (concentrate production and shipments).

## Ownership of uranium production in 2010

| Domestic | | | | Foreign | | | | Totals | |
|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | | |
| (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) | (tU) | (%) |
| 0 | 0 | W | W | 0 | 0 | W | W | 1 630 | 100 |

W = Data withheld to avoid disclosure of individual company data.

Source: US Energy Information Administration, Domestic Uranium Production Report, 2010, Table 2.

## Uranium industry employment at existing production centres

(person-years)

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Total employment related to existing production centres[1] | 1 409 | 934 | 948 | NA |
| Employment directly related to uranium production[2] | 952 | 759 | 737 | NA |

1. US Energy Information Administration, Domestic Uranium Production Report, 2010, Table 6, all sectors except reclamation.

2. US Energy Information Administration, Domestic Uranium Production Report, 2010, Table 6, all sectors except exploration and reclamation.

## Short-term production capability

(tonnes U/year)

| 2011 | | | | 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 |
| 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 |

### Mixed oxide fuel production and use[1]

(tonnes natural U equivalent)

| Mixed oxide (MOX) fuel | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (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. *Nuclear Energy Data*, OECD, Paris, 2011.

### Re-enriched tails production and use[1]

(tonnes natural U equivalent)

| Re-enriched tails | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Production | 1 939.8 | 0 | 0 | 0 | 1 939.8 | 0 |
| Use | 682 | 0 | 694 | 0 | 1 376 | 191 |

1. *Nuclear Energy Data*, OECD, Paris, 2011.

### Reprocessed uranium use[1]

(tonnes natural U equivalent)

| Reprocessed uranium | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Production | 0 | 0 | 0 | 0 | 0 | 0 |
| Use | 0 | 0 | 0 | 0 | 0 | 0 |

1. *Nuclear Energy Data*, OECD, Paris, 2011.

### Net nuclear electricity generation[1]

| | 2009 | 2010 |
|---|---|---|
| Nuclear electricity generated (TWh net) | 799 | 803p |

1. *Nuclear Energy Data*, OECD, Paris, 2011.

p = provisional data.

### Installed nuclear generating capacity to 2035[1]

(MWe net)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 101.0 | 101.1p | 101.2 | 101.2 | 105.7 | 105.7 | 110.5 | 110.5 | 110.5 | 111.3 | 110.5 | 118.5 | 110.5 | 129.1 |

1. *Nuclear Energy Data*, OECD, Paris, 2011.

p = provisional data.

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

(tonnes U)

| 2009 | 2010 | 2011 | | 2015 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Low | High | Low | High | Low | High | Low | High | Low | High |
| 19 001 | 19 138p | 19 996 | 19 996 | 20 930 | 20 930 | 24 158 | 24 158 | 24 158 | 24 295 | 24 158 | 25 839 | 24 075 | 28 069 |

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] | 17 596 | 12 485 | 25 950 | NA | 56 031 |
| Producer[2] | NA | NA | NA | NA | 5 234p |
| Utility[2] | 18 785p | 14 497p | NA | NA | 33 283p |
| Total | NA | NA | NA | NA | 94 548p |

1. US Department of Energy, Excess Uranium Inventory Management Plan, December 2008.

2. US Energy Information Administration, Uranium Marketing Annual Report, 2010, Tables 22 and 23.

p = provisional data.



# Uzbekistan

## Uranium exploration

### *Historical review*

Prospecting and exploration of uranium deposits in the Central Kyzylkum province, where all the deposits exploited by the Navoi Mining and Metallurgical Complex (NMMC) are concentrated, was started in 1952 by prospecting and exploration party No. 25 of the Krasnokholmsk Expedition of the USSR Ministry of Geology. In 1953, the unique Uchkuduk deposit was discovered, exploration of which was completed in 1959 and the deposit was transferred to NMMC for industrial development.

During exploration of the Uchkuduk deposit, the occurrence patterns of the Uchkuduk type mineralisations were identified, subsequently allowing prospecting for new deposits to be conducted in a goal-oriented manner. As a result of this prospecting, a number of new major deposits were discovered such as Sabyrsay, Sugraly, Shimoliy Bukinai, Janubiy Bukinai, Ketmenchi, Beshkak, Lyavlyakan, North Kanimekh and others, which, after exploration, were transferred to the former Ministry of Medium-Scale Engineering for industrial development.

The mining complexes and mining directorates established around these deposits carried out their own geological exploration work on the sites and flanks of the deposits to be developed, and the Krasnokholmsk Expedition prospected and explored new deposits.

After the disintegration of the USSR, uranium prospecting and geological exploration began to be carried out with NMMC resources, both by mining enterprises on the flanks of the deposits, and by the state enterprise Scientific Production Centre "Urangeologiya" (formerly "Krasnokholmskaya") on new sites.

The northern mining directorate of NMMC prospected the sites of the Altyntau ore field, where significant uranium resources were found and estimated in 1986 in Paleozoic metamorphic carbonaceous-argillaceous shales.

### *Recent and ongoing uranium exploration*

Exploration of new deposits and additional exploration of their flanks is done by drilling vertical boreholes with and without extraction of cores. The research accompanying the drilling allows the uranium resources at new sites to be determined with confidence, and the mining conditions for working them to be determined.

## Uranium resources

### *Identified conventional resources (reasonably assured and inferred resources)*

The changes in the resources counted towards the balance of the Navoi Mining and Metallurgical Complex (NMMC) over 2008–2010 were due to the combined effects of mining depletion and growth from geological exploration work.

Taking into account the above changes, the NMMC balance as of 1 January 2011 was 137 400 tU (*in situ*), of which 101 400 tU are located in water-permeable sand and gravel

deposits from the Upper Cretaceous and 36 000 tU are associated with a complex of carbonaceous-siliceous Palaeozoic rocks.

Of 101 400 tU counted towards the NMMC balance located in sand and gravel beds, 65 800 tU are to be extracted *in situ* leaching (ISL) at a cost of not more than USD 40/kgU, whereas 35 600 tU would cost significantly more (up to USD 130/kgU) because of difficult mining conditions. The uranium mineralisation in the sandstone type ores occurs as pitchblende, sometimes mixed with coffinite. Besides uranium, the ores contain selenium, rhenium, scandium, molybdenum and rare and dispersed elements.

The 36 000 tU (*in situ*) associated with the carbonaceous-siliceous formation counting towards the NMMC's balance can be extracted by open-pit mining with subsequent heap leaching at costs not exceeding USD 40/kgU. The mineralisation of the black shale type ores occurs, to depths of 30 m, as phosphates and vanadates of hexavalent uranium and at greater depths, as pitchblende-coffinite with sulfides. Besides uranium, these ores contain vanadium in industrial concentrations, and rhenium, scandium and molybdenum in elevated quantities.

All the explored resources lie at depths of up to 500 m. The uranium content of the ores varies between 0.026 and 0.180% U.

#### *Undiscovered conventional resources (prognosticated and speculative resources)*

NMMC's undiscovered resources (prognosticated and speculative resources) as of 1 January 2011 stood at 24 800 tU, of which 19 100 tU have been estimated to lie in sand and gravel beds and 5 700 tU in carbonaceous-siliceous shales in the Altyntau ore field. Of the 19 100 tU in sandstone type ores, 13 100 tU have been estimated to lie along the south-western beds of the Sugraly deposit, and 6 000 tU in the Shark, Yogdu and Jarkuduk deposits.

### Uranium production

#### *Historical review*

Uranium mining was launched in the Republic of Uzbekistan in 1964 by the NMMC at the Uchkuduk deposit using open-pit and underground mining methods. Since 1963, experimental work has been conducted at the same location on uranium mining using *in situ* leaching. As early as 1965, industrial mining of uranium using *in situ* leaching had begun.

In 1966, underground mining of uranium began at the Sabyrsay deposit and in 1977 at the Sugraly deposit. In 1978, ISL was initiated at the Ketmenchi deposit. As of 1975, resources were being extracted at the Sabyrsay deposit by ISL. In 1983, all mining operations ceased.

In 1994, as a result of instructions to reduce extraction, the resources that could be extracted by open-pit mining at the Uchkuduk deposit were conserved, as were the resources that could be extracted by underground mining and by ISL at the Sugraly deposit.

#### *Status of production capability*

Uranium is mined in the Republic of Uzbekistan by the NMMC. As of 1 January 2011, three mining directorates were extracting uranium via ISL at the Sabyrsay, Ketmenchi, Shimoliy Bukinai, Janubiy Bukinai, Beshkak, Lyavlyakan, Kendyktjube, Sugraly, North Kanimekh, Kokhnur and Istiklol deposits, and experimental work is being conducted at the Yogdu deposit.

The uranium concentrate is subjected to further processing at the hydrometallurgical plant in Navoi. Currently, as of 1 January 2011, NMMC is producing uranium only via ISL.

The annual figure for extraction of uranium using ISL in 2010 was 2 874 tU and the projected figure for 2011 is 3 350 tU.

**Uranium production centre technical details**

(as of 1 January 2011)

| | Centre #1 | Centre #2 | Centre #3 |
|---|---|---|---|
| Name of production centre | North Mining Directorate | South Mining Directorate | Mining Directorate 5 |
| Classification | Existing | Existing | Existing |
| Date of first production | 1964 | 1966 | 1968 |
| Source of ore: | | | |
| Deposit name | Kendyktjube, Sugraly, Uchkuduk, Meylysai | Sabyrsay, Ketmenchi, Jarkuduk, Yogdu | Shimoliy Bukinai, Janubiy Bukinai, Beshkak, Lyavlyakan Istiklol, Kokhnur, Janubiy Sugraly |
| Deposit type | Sandstone | Sandstone | Sandstone |
| Mining operation: | | | |
| Type | ISL | ISL | ISL |
| Mining recovery | 70% | 70% | 70% |
| Annual productivity (tU) | 800 | 800 | 2 100 |
| Processing plant: | | | |
| Type | Hydrometallurgical plant | | |
| Productivity (ore per day) | - | - | - |
| Average recovery | 99.5% | | |
| Nominal capacity (tU/year) | 2 350 | | |
| Plans for expansion | Expansion of production planned | | |
| Other remarks | - | - | - |

### *Environmental aspects*

There are some environmental issues relating to uranium resources. Prior to exploitation there is a high level of mineralisation (3–8 g/L) in groundwater and high concentrations of sulphate, chlorine, strontium, selenium, iron and manganese and the radionuclide content in confined groundwater is 5-10 times higher than the maximum permissible concentration.

Several steps are being taken to reduce the environmental impact of uranium mining. One example is NMMC's uranium mining operations that are moving from using airlift pumps to submersible pumps to raise pregnant solutions, which reduces discharges of pregnant solutions and steam from these solutions into the atmosphere and soil. The boreholes are equipped with devices which prevent spilling of solutions.

In addition, to reduce pollution of groundwater in ore-bearing beds, mini-reagent technology is being employed wherever possible.

Promotion of good environmental practise in decommissioning of mining and processing facilities includes:

- studies for subsequent planning of clean-up work;
- planning clean up of work after the facility closes, including re-cultivation of the land;
- approval of the plan by the State Committee of the Republic of Uzbekistan for Environmental Protection;

- carrying out of work to clean up after the facility and re-cultivate the land, in line with the plan developed while mining is underway; and
- handover of the re-cultivated land to the authorities.

### *Uranium requirements*

Uzbekistan has no uranium requirements.

### *Re-enrichment of depleted uranium*

The Republic of Uzbekistan has not been re-enriching depleted uranium either at home or abroad.

## Uranium policies, uranium stocks and uranium prices

### *National policies relating to uranium*

The Republic of Uzbekistan adheres to and complies with all points of the agreement between the Republic of Uzbekistan and the International Atomic Energy Agency for the application of safeguards in connection with the Treaty on the Non-Proliferation of Nuclear Weapons and the protocol additional thereto.

### *Uranium stocks*

There were no uranium stocks as of 1 January 2011.

### *Uranium prices*

Uranium prices are set in long-term contracts.

**Uranium exploration and development expenditures and drilling effort – domestic***

(UZS thousands [Uzbek soums])

| | 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|---|
| Industry exploration expenditures | 3 439 900.0 | 4 768 100.0 | NA | NA |
| Government exploration expenditures | 0 | 0 | 0 | 0 |
| Total exploration expenditures | 3 439 900.0 | 4 768 100.0 | NA | NA |
| Total development expenditures | 27 664 500.0 | 33 197 400.0 | NA | NA |
| Total expenditures | 31 104 400.0 | 37 965 500.0 | NA | NA |
| Industry exploration drilling (m) | 92 198 | 69 886 | 155 364 | 578 600 |
| Industry exploration holes drilled | 246 | 186 | 414 | 1 543 |
| Government exploration drilling (m) | 0 | 0 | 0 | 0 |
| Government exploration holes drilled | 0 | 0 | 0 | 0 |
| Total exploration drilling (m) | 92 198 | 69 886 | 155 364 | 578 600 |
| Total exploration holes drilled | 246 | 186 | 414 | 1 543 |
| Total exploitation drilling (m) | 503 500 | 603 700 | 685 100 | 822 000 |
| Number of development holes drilled | 1 968 | 2 214 | 2 963 | 3 132 |
| Total drilling (m) | 595 698 | 673 586 | 840 464 | 140 600 |
| Total number of holes drilled | 2 214 | 2 400 | 3 377 | 4 675 |

* Excluding “Urangeologiya”.

### Reasonably assured conventional resources by deposit type*

(tonnes U)

| Deposit type | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU |
|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 |
| Sandstone | 46 580 | 46 580 | 64 286 | 64 286 |
| Hematite breccia complex | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 |
| Other** | 0 | 0 | 0 | 0 |
| Total | 46 580 | 46 580 | 64 286 | 64 286 |

* 30% deducted for mining and processing losses.

** 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.

### Inferred conventional resources by deposit type*

(tonnes U)

| Deposit type | <USD 40/kgU | <USD 80/kgU | <USD 130/kgU | <USD 260/kgU |
|---|---|---|---|---|
| Unconformity-related | 0 | 0 | 0 | 0 |
| Sandstone | 24 716 | 24 716 | 31 916 | 31 916 |
| Hematite breccia complex | 0 | 0 | 0 | 0 |
| Quartz-pebble conglomerate | 0 | 0 | 0 | 0 |
| Vein | 0 | 0 | 0 | 0 |
| Intrusive | 0 | 0 | 0 | 0 |
| Volcanic and caldera-related | 0 | 0 | 0 | 0 |
| Metasomatite | 0 | 0 | 0 | 0 |
| Other** | 0 | 0 | 0 | 0 |
| Total | 24 716 | 24 716 | 31 916 | 31 916 |

* 30% deducted for mining and processing losses.

** 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.

### Prognosticated conventional resources

(tonnes U)

| Enterprise | Cost category | | |
|---|---|---|---|
| | <USD 40/kg U | <USD 80/kg U | <USD 130/kg U |
| NMMC | 24 800 | 24 800 | 24 800 |

### Speculative conventional resources

| Enterprise | Cost category | | |
|---|---|---|---|
| | <USD 40/kg U | <USD 80/kg U | <USD 130/kg U |
| NMMC | 0 | 0 | 0 |

## Historical uranium production by production method

(tonnes U in concentrates)

| Production method | Total through end of 2007 | 2008 | 2009 | 2010 | Total through end of 2010 | 2011 (expected) |
|---|---|---|---|---|---|---|
| Open-pit mining (OP)[1] | 36 249 | 0 | 0 | 0 | 36 249 | 0 |
| Underground mining (UG)[1] | 19 719 | 0 | 0 | 0 | 19 719 | 0 |
| *In situ* leaching | 54 109 | 2 283 | 2 657 | 2 874 | 61 923 | 3 350 |
| Co-product/by-product | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 110 077 | 2 283 | 2 657 | 2 874 | 117 891 | 3 350 |

1. Pre-2008 totals may include uranium recovered by heap and in-place leaching.

## Ownership of uranium production in 2010

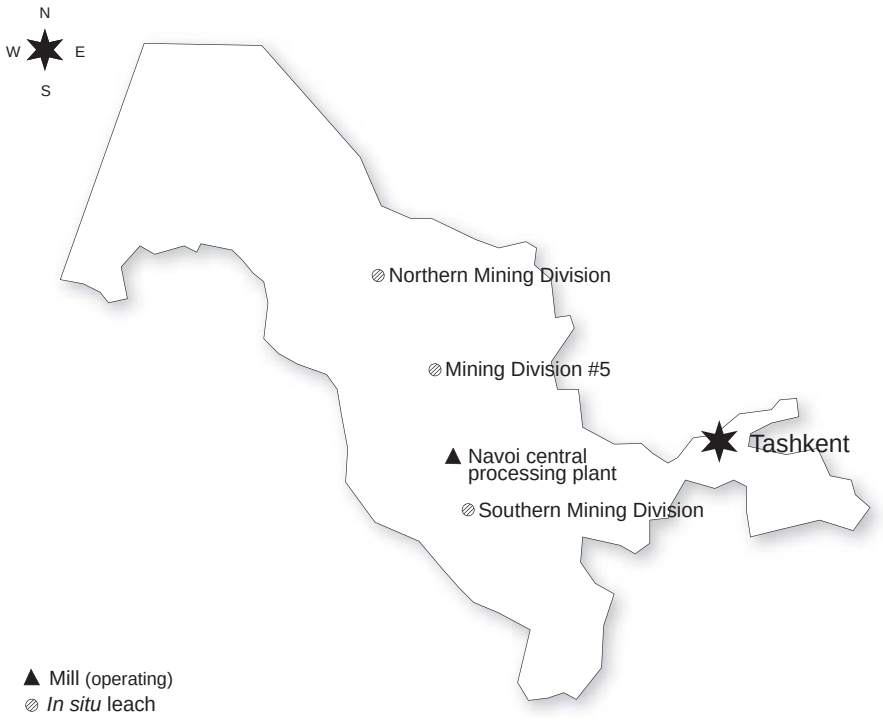
| Domestic | | | | Foreign | | | | Totals | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Government | | Private | | Government | | Private | | Government | | Private | |
| tU | % | tU | % | tU | % | tU | % | tU | % | tU | % |
| 2 874 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 2 874 | 100 | 0 | 0 |

## Employment at existing production centres

| 2008 | 2009 | 2010 | 2011 (expected) |
|---|---|---|---|
| 8 750 | 8 800 | 8 860 | 9 020 |

## Short-term production capability

| 2010 | | | | 2011 | | | | 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 | A-I | B-I | A-II | B-II | A-I | B-I | A-II | B-II |
| 2 350 | 2 350 | 2 350 | 2 350 | 3 350 | 3 350 | 3 350 | 3 350 | 4 150 | 4 150 | 4 150 | 4 150 | 4 500 | 4 500 | 4 500 | 4 500 | 5 000 | 5 000 | 5 000 | 5 000 |



# 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 t $U_3O_8$ (86 tU) was produced. Although no uranium has been produced from that mine or from Zambia as a whole 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 focussed 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 fundamental change in 1969. Prior to 1969 all mineral rights were in private hands, but in 1969 these rights reverted to the state. In 1969, the state 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, and 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*

Denison Mines commenced exploration activities in 2007, concentrating on the Mutanga Project in the south-east of the country near the Zimbabwe border that the company acquired that year through the acquisition of Omega Corp. Initial airborne geophysics detected a number of anomalous areas that were followed up by ground investigations. Prospective targets were further investigated by drilling which identified sandstone hosted uranium ore bodies. Metallurgical test work and environmental studies resulted in the preparation and submission of an environmental impact statement (EIS) and applications for an ionising radiation licence and a mineral processing licence. The EIS was accepted late in 2009 and both licences were granted in 2010. The mining licence is valid for 25 years. Initial plans were for production to commence in 2012 but the company has since decided that further studies, drilling and a better uranium price are needed before a decision to proceed can be made.

African Energy is also undertaking extensive exploration activities on a variety of projects along strike extensions of Denison's Mutanga Project as well as the northern Luangwa Valley Project. All are aimed at identifying Karoo sandstone-hosted deposits. The most advanced is the Chirundu Project (adjacent to Mutanga), where JORC compliant resources have been identified. A mining licence valid for 25 years was granted in 2009 and metallurgical test work and base-line environmental studies are being carried out to update an EIS.

* Prepared by Secretariat based on company reports, open source information and information provided by the government.

African Energy is also conducting work on the Kariba Valley Project, 50 km south of Chirundu. Although this project is at an early stage of drilling, Luangwa and Chirundu are at a preliminary field investigation stage.

Aldershot Resources holds prospecting licences for the Kariba Project in partnership with African Energy. The agreement is such that African Energy can earn up to 70% beneficial interest in the properties by completing a pre-feasibility study to an inferred resource level.

Zambezi Resources has four uranium prospects where previous work has identified uranium mineralisation. An independent geological consultant has reviewed this work in order to plan future activities. However, these activities are on hold while the company is developing its Kangaluwi copper mine.

The Lumwana copper mine in the Zambian Copperbelt also hosts significant uranium resources. The uranium occurs in the immediate footwall and hanging wall of the copper mineralisation and is mined concurrently. Plans were developed to establish a standalone uranium processing plant but the plans have been put on hold as market conditions were not considered sufficiently favourable. The uraniferous ore is being stockpiled separately for possible future processing. At the end of 2010 a total of 4.2 Mt at a grade of 0.118% $U_3O_8$ was stockpiled. This stockpile may be processed at a later date, if the company decides to build a uranium mill for an estimated cost of USD 200 to 230 million. Lumwana was discovered and developed by Equinox Minerals but the company was taken over by Barrick Gold Corporation in 2011.

## Uranium resources

Only three properties in Zambia have reached the stage of development where NI 43-101 or JORC compliant resources have been published. Denison's Mutanga Project is the closest to actual production and has a total of 35.7 Mt of measured, indicated and inferred ore at a grade of 0.021% U containing 7 436 tU.

African Energy's Chirundu Project, adjacent to the Mutanga Project, has total measured, indicated and inferred resources of 18.7 Mt at a grade of 0.023% containing 4 270 tU.

The only other reported JORC compliant resources are those of the Lumwana copper mine. These resources are hosted by mica-quartz-kyanite schists of the Katangan Supergroup. Measured resources are the 4.2 Mt of stockpiled ore and the total resources are 11.2 Mt of ore containing 7 746 tU.

Considerable potential for the discovery of additional resources exist in various parts of the country which has been poorly explored. Of particular interest would be the Copperbelt where many copper orebodies have known associated uranium mineralisation. The Copperbelt extends into the Democratic Republic of the Congo to the Shinkolobwe mine that supplied uranium for military purposes during the early stage of uranium mining.

## Uranium production

Uranium was produced from the Mindola mine in Kitwe during the late 1950s. A total of 102 t $U_3O_8$ (86 tU) was produced. Production ceased in 1960 and no other uranium has been produced since.

### 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 aspects of 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 purposes.

Public participation is an essential part of any mining project. 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.

The Christian Council of Zambia is strongly opposed to uranium mining, citing the lack of any stringent safety policy regarding uranium mining. The state is in the process of developing safety strategies to control the safety of workers and local inhabitants.

### Uranium requirements

Zambia has no nuclear generating capacity and no formal plans to develop any. It thus has no current or future uranium requirements.

### National policies relating to uranium

Concerns regarding the exploitation of recently discovered uranium mineralisation prompted the Council of Churches of Zambia to commission a review of uranium mining policy in Zambia. The study found that Zambia has no specific policy framework on uranium. Mining activities in general are regulated by the Mines and Minerals Act (1995) but until recently there was no legislation specifically relating to exploration for and mining of uranium.

This changed in 2008 when the state promulgated the Mines and Minerals Development (Prospecting, Mining and Milling of Uranium Ores and Other Radioactive Mineral Ores) and Regulations of 2008. These regulations 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 to the country. Applicants for export licences will also have to prove the authenticity of the importers in terms of IAEA guidelines.

The Council of Churches study concluded that current legislation and enforcement was inadequate. They recommended that current regulations should 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 in reviewing 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity related | | | | | |
| Sandstone | | | | 4 647 | 80 |
| Haematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera related | | | | | |
| Metasomatite | | | | 5 209 | NA |
| Surficial/calcrete | | | | | |
| Other* | | | | | |
| Total | | | | 9 856 | |

* 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.

### 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) | | | | | |
| Open-pit mining (OP) | | | | 9 856 | 80 |
| *In* situ leaching acid | | | | | |
| *In* situ leaching alkaline | | | | | |
| Co-product and by-product | | | | | |
| Unspecified | | | | | |
| Total | | | | 9 856 | |

### 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 | | | | | |
| Conventional from OP | | | | 9 856 | 80 |
| *In* situ leaching acid | | | | | |
| *In* situ leaching alkaline | | | | | |
| In-place leaching* | | | | | |
| Heap leaching** from UG | | | | | |
| Heap leaching** from OP | | | | | |
| Unspecified | | | | | |
| Total | | | | 9 856 | |

* 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 | Recovery factor (%) |
|---|---|---|---|---|---|
| Unconformity related | | | | | |
| Sandstone | | | | 4 718 | 80 |
| Haematite breccia complex | | | | | |
| Quartz-pebble conglomerate | | | | | |
| Vein | | | | | |
| Intrusive | | | | | |
| Volcanic and caldera related | | | | | |
| Metasomatite | | | | 987 | NA |
| Surficial/calcrete | | | | | |
| Other* | | | | | |
| Total | | | | 5 705 | |

* 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.

### 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) | | | | | |
| Open-pit mining (OP) | | | | 5 705 | 80 |
| *In* situ leaching acid | | | | | |
| *In* situ leaching alkaline | | | | | |
| Co-product and by-product | | | | | |
| Unspecified | | | | | |
| Total | | | | 5 705 | |

### 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 | | | | | |
| Conventional from OP | | | | 5 705 | 80 |
| *In* situ leaching acid | | | | | |
| *In* situ leaching alkaline | | | | | |
| In-place leaching* | | | | | |
| Heap leaching** from UG | | | | | |
| Heap leaching** from OP | | | | | |
| Unspecified | | | | | |
| Total | | | | 5 705 | |

* Also known as stope leaching or block leaching.

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

# *Appendix 1.* Members of the Joint NEA-IAEA Uranium Group

| | | |
|---|---|---|
| **Algeria** | Ms. A. Badani<br>Mr. A. Khaldi | Ministère de l'Énergie et des Mines, Alger |
| **Argentina** | Mr. R. Bianchi<br>Mr. R. Grüner | Comisión Nacional de Energía Atómica, Buenos Aires |
| **Armenia** | Mr. A. Galstyan | Ministry of Energy and Natural Resources, Yerevan |
| **Australia** | Mr. I. Lambert **(Vice-chair)**<br>Mr. A. McKay<br>Ms. L. Carson | Geoscience Australia, Canberra |
| **Austria** | Mr. N. Arnold | University of Natural Resources and Life Sciences, Vienna |
| **Belgium** | Ms. F. Renneboog | Fuel Supply Department, Synatom, Brussels |
| **Brazil** | Mr. L. F. Da Silva | Indústrias Nucleares do Brasil INB-S/A, Rio de Janeiro |
| **Canada** | Mr. T. Calvert **(Vice-chair)** | Natural Resources Canada, Ottawa |
| **China** | Mr. W. Chen<br>Mr. D. Zhang | China Nuclear Uranium Corporation, Beijing |
| **Czech Republic** | Mr. J. Trojacek<br>Mr. P. Vostarek | DIAMO s.p., Stráž pod Ralskem |
| **Egypt** | Mr. M. Aly Mohamadin | Nuclear Materials Authority (NMA), Cairo |
| **Finland** | Mr. O. Äikäs<br>Mr. E. Pohjolainen | Geological Survey of Finland, Espoo |
| **France** | Mr. G. Capus **(Chair)** | AREVA NC, Paris |
| | Ms. S. Gabriel | Commissariat à l'énergie atomique, Direction de l'énergie nucléaire, Gif-sur-Yvette |
| | Ms. A. Chauvin | EDF Division Combustible Nucléaire, Saint-Denis |

| | | |
|---|---|---|
| **Germany** | Mr. M. Schauer<br>Mr. U Schwarz-Schampera | Federal Institute for Geoscience and Natural Resources (BGR), Hannover |
| **Hungary** | Mr. G. Németh | Mecsek-Öko Zrt, Pécs |
| **India** | Mr. A. Awati | Department of Atomic Energy, Mumbai |
| | Mr. P. B. Maithani<br>Mr. P. S. Parihar<br>Dr A. Chaki | Atomic Minerals Directorate, Hyderabad |
| **Indonesia** | Mr. J. Baratha<br>Mr. I. Sukadana | National Nuclear Energy Agency, Jakarta |
| **Iran, Islamic Republic of** | Mr. F. Yegani<br>Mr. M. R. Ghaderi | Atomic Energy Organisation of Iran, Tehran |
| **Italy** | Mr. F. Vettraino | ENEA – Nuclear Fission Division, Bologna |
| **Japan** | Mr. H. Miyada<br>Mr. M. Sowanaka<br>Mr. K. Hisatani | Japan Oil, Gas and Metals National Corporation, Tokyo |
| **Jordan** | Mr. K. El-Kaysi | Jordan Energy Resources Incorporation (JERI) |
| **Kazakhstan** | Ms. O. Gorbatenko<br>Mr. Y. Demekhov | National Atomic Company "KAZATOMPROM", Almaty |
| **Mauritania** | Mr. A. Taleb Mohamed | Ministère de l'Industrie et des Mines, Nouakchott |
| **Mexico** | Mr. F. C. Torres Alvarez | Laguna Verde Nuclear Power Plant (CFE), Veracruz |
| **Mongolia** | Mr. M. Batbold<br>Mr. T. Bayarbayasgalan<br>Mr. T. Nyambayar | Nuclear Energy Agency, Ulaanbaatar |
| **Morocco** | Mr. M. Benmansour | Centre National de l'Énergie, Rabat |
| | Mr. D. Dhiba | OCP – Pôle Commercial, Casablanca |
| | Mr. A. Zerdane | Office National des Hydrocarbures et des Mines, Rabat |
| **Namibia** | Ms. H. Itamba | Ministry of Mines and Energy, Windhoek |

| | | |
|---|---|---|
| **Russian Federation** | Mr. A. Boytsov **(Vice-chair)** | JSC Atomredmetzoloto (ARMZ), Moscow |
| | Mr. A. Tarkhanov | State Atomic Energy Corp. (Rosatom), Moscow |
| **South Africa** | Ms. M. Makhado<br>Ms. N. Mayekiso<br>Ms. T. Nngigideni | Council for Geoscience, Pretoria |
| | Mr. L. Ainslee<br>Mr. A. Logue | Nuclear Energy Corp. of South Africa, Pretoria |
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| | |
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# *Appendix 3*. Glossary of definitions and terminology

## Units

Metric units are used in all tabulations and statements. Resources and production quantities are expressed in terms of tonnes (t) contained uranium (U) rather than uranium oxide ($U_3O_8$).

| | | |
|---|---|---|
| 1 short ton $U_3O_8$ | = | 0.769 tU |
| 1% $U_3O_8$ | = | 0.848% U |
| 1 USD/lb $U_3O_8$ | = | USD 2.6/kg U |
| 1 tonne | = | 1 metric ton |

## Resource terminology

Resource estimates are divided into separate categories reflecting different levels of confidence in the quantities reported. The resources are further separated into categories based on the cost of production.

### *Definitions of resource categories*

Uranium resources are broadly classified as either conventional or unconventional. Conventional resources are those that have an established history of production where uranium is a primary product, co-product or an important by-product (e.g. from the mining of copper and gold). Very low-grade resources or those from which uranium is only recoverable as a minor by-product are considered unconventional resources.

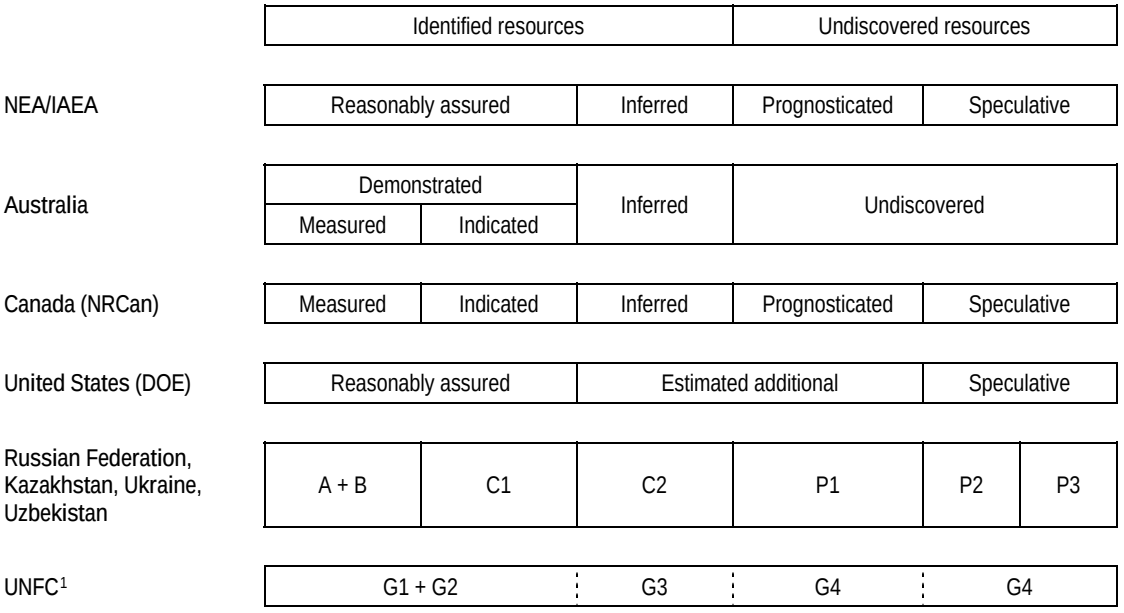
Conventional resources are further divided, according to different confidence levels of occurrence, into four categories. The correlation between these resource categories and those used in selected national resource classification systems is shown in Figure A3.1.

*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**




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.

*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.

1. United Nations Framework Classification correlation with NEA/IAEA and national classification systems is still under consideration.

*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, which uses the exchange rate of 1 January 2009 (Appendix 7).

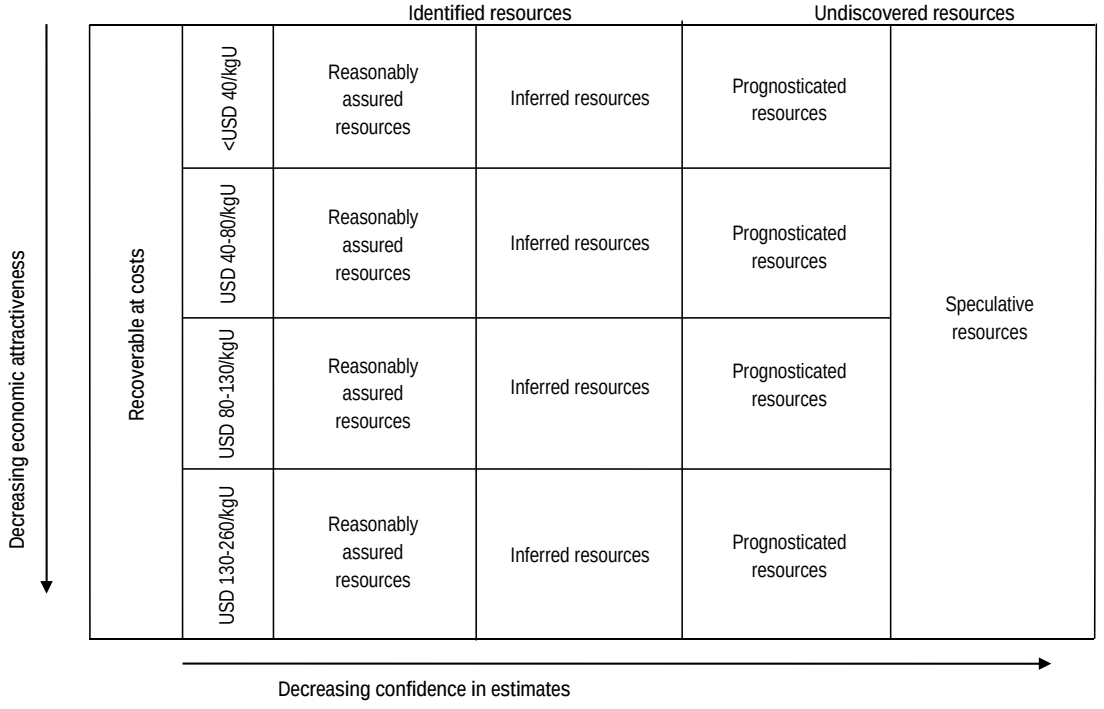
When estimating the cost of production for assigning resources within these cost categories, account has been taken of the following costs:

- the direct costs of mining, transporting and processing the uranium ore;
- the costs of associated environmental and waste management during and after mining;
- the costs of maintaining non-operating production units where applicable;
- in the case of ongoing projects, those capital costs that remain non-amortised;
- the capital cost of providing new production units where applicable, including the cost of financing;
- indirect costs such as office overheads, taxes and royalties where applicable;
- future exploration and development costs wherever required for further ore delineation to the stage where it is ready to be mined;
- sunk costs are not normally taken into consideration.

### *Relationship between resource categories*

Figure A3.2 illustrates the inter-relationship between the different resource categories. The horizontal axis expresses the level of assurance about the actual existence of a given tonnage based on varying degrees of geologic knowledge while the vertical axis expresses the economic feasibility of exploitation by the division into cost categories.

**Figure A3.2. NEA/IAEA classification scheme for uranium resources**



### *Recoverable resources*

RAR and IR estimates are expressed in terms of recoverable tonnes of uranium, i.e. quantities of uranium recoverable from mineable ore, as opposed to quantities contained in mineable ore, or quantities *in situ*, i.e. not taking into account mining and milling losses. Therefore both expected mining and ore processing losses have been deducted in most cases. If a country reports its resources as *in situ* and the country does not provide a recovery factor, the Secretariat 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 |
| ISL (acid) | 75 |
| ISL (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[2]

### *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 and include those plants which are closed down but which could be readily brought back into operation.
- *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 either completed or under way, but for which construction commitments have not yet

2. IAEA (1984), *Manual on the Projection of Uranium Production Capability,* General Guidelines, Technical Report Series No. 238, Vienna, Austria.

been made. This class also includes those plants that are closed which would require substantial expenditures to bring them back into operation.

- *Prospective* production centres are those that could be supported by tributary RAR and inferred, i.e. "identified resources", but for which construction plans have not yet been made.

### *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[3]

*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.

3. Definitions based on those published in OECD (2002), *Environmental Remediation of Uranium Production Facilities*, Paris.

*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.

*Geologic types of uranium deposits*[4]*:* Uranium resources can be assigned on the basis of their geological setting to the following categories of uranium ore deposit types (arranged according to their approximate economic significance):

1. Sandstone deposits.
2. Unconformity-related deposits.
3. Hematite breccia complex deposits.
4. Quartz-pebble conglomerate deposits.
5. Vein deposits.
6. Intrusive deposits.
7. Volcanic and caldera-related deposits.
8. Metasomatite deposits.
9. Surficial deposits.
10. Collapse breccia pipe deposits.
11. Phosphorite deposits.
12. Other types of deposits.
13. Rock types with elevated uranium contents.

1. *Sandstone deposits:* Sandstone 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, for example, carbonaceous material, sulphides (pyrite), hydrocarbons and ferro-magnesium minerals (chlorite), etc. Sandstone uranium deposits can be divided into four main sub-types:

- *Roll-front deposits:* The mineralised zones are convex 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 tonnes to several thousands of tonnes of uranium, at grades averaging 0.05-0.25%. Examples are Moynkum, Inkay and Mynkuduk (Kazakhstan); Crow Butte and Smith Ranch (United States) and Bukinay, Sugraly and Uchkuduk (Uzbekistan).
- *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 hundreds of tonnes up to 150 000 tonnes of uranium, at average grades ranging from 0.05-0.5%, occasionally up to 1%. Examples of deposits include Westmoreland (Australia), Nuhetting (China), Hamr-Stráz (Czech Republic), Akouta, Arlit, Imouraren (Niger) and Colorado Plateau (United States).
- *Basal channel deposits:* Paleodrainage systems consist of several hundred metres wide channels filled with thick permeable alluvial-fluvial sediments. Here, the uranium is predominantly associated with detrital plant debris in ore bodies 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

4. This classification of the geological types of uranium deposits was developed by the IAEA in 1988-89 and updated for use in the Red Book.

range from several hundreds to 20 000 tonnes uranium, at grades ranging from 0.01-3%. Examples are the deposits of Dalmatovskoye (Transural Region), Malinovskoye (West Siberia), Khiagdinskoye (Vitim district) in Russia and Beverley in Australia.

- *Tectonic/lithologic deposits* occur in sandstone related to a permeable zone. Uranium is precipitated in open zones related to tectonic extension. Individual deposits contain a few hundred tonnes up to 5 000 tonnes of uranium at average grades ranging from 0.1-0.5%. Examples include the deposits of Mas Laveyre (France) and Mikouloungou (Gabon).

2. *Unconformity-related deposits:* Unconformity-related deposits are associated with and occur immediately below and above an unconformable contact that separates a crystalline basement intensively altered from overlying clastic sediments of either Proterozoic or Phanerozoic age.

The unconformity-related deposits include the following sub-types:

- Unconformity contact:
  - Fracture bound deposits occur in metasediments immediately below the unconformity. Mineralisation is monometallic and of medium grade. Examples include Rabbit Lake and Dominique Peter in the Athabasca Basin, Canada.
  - Clay-bound deposits occur associated with clay at the base of the sedimentary cover directly above the unconformity. Mineralisation is commonly polymetallic and of high to very high grade. An example is Cigar Lake in the Athabasca Basin, Canada.
- Sub-unconformity-post-metamorphic deposits: Deposits are strata-structure bound in metasediments below the unconformity on which clastic sediments rest. These deposits can have large resources, at low to medium grade. Examples are Jabiluka and Ranger in Australia.

3. *Hematite breccia complex deposits:* Deposits of this group occur in hematite-rich breccias and contain uranium in association with copper, gold, silver and rare earths. The main representative of this type of deposit is the Olympic Dam deposit in South Australia. Significant deposits and prospects of this type occur in the same region, including Prominent Hill, Wirrda Well, Acropolis and Oak Dam as well as some younger breccia-hosted deposits in the Mount Painter area.

4. *Quartz-pebble conglomerate deposits:* Detrital uranium oxide ores are found in quartz-pebble conglomerates deposited as basal units in fluvial to lacustrine braided stream systems older than 2.3-2.4 Ga. The conglomerate matrix is pyritiferous, and gold, as well as other oxide and sulphide detrital minerals are often present in minor amounts. Examples include deposits found in the Witwatersrand Basin where uranium is mined as a by-product of gold. Uranium deposits of this type were mined in the Blind River/Elliot Lake area of Canada.

5. *Vein deposits:* In vein deposits, the major part of the mineralisation fills fractures with highly variable thickness, but generally important extension along strike. The veins consist mainly of gangue material (e.g. carbonates, quartz) and ore material, mainly pitchblende. Typical examples range from the thick and massive pitchblende veins of Pribram (Czech Republic), Schlema-Alberoda (Germany) and Shinkolobwe (Democratic Republic of Congo), to the stockworks and episyenite columns of Bernardan (France) and Gunnar (Canada), to the narrow cracks in granite or metamorphic rocks, also filled with pitchblende of Mina Fe (Spain) and Singhbhum (India).

6. *Intrusive deposits:* Deposits included in this type are those associated with intrusive or anatectic rocks of different chemical composition (alaskite, granite, monzonite, peralkaline syenite, carbonatite and pegmatite). Examples include the Rossing and Husab

deposits (Namibia), the uranium occurrences in the porphyry copper deposits such as Bingham Canyon and Twin Butte (United States), the Ilimaussaq deposit (Greenland), Palabora (South Africa), as well as the deposits in the Bancroft area (Canada).

*7. Volcanic and caldera-related deposits:* Uranium deposits of this type are located within and nearby volcanic caldera filled by mafic to felsic volcanic complexes and intercalated clastic sediments. Mineralisation is largely controlled by structures (minor stratabound), occurs at several stratigraphic levels of the volcanic and sedimentary units and extends into the basement where it is found in fractured granite and in metamorphites. Uranium minerals are commonly associated with molybdenum, other sulphides, violet fluorine and quartz. Most significant commercial deposits are located within Streltsovsk caldera in the Russian Federation. Examples are known in China, Mongolia (Dornot deposit), Canada (Michelin deposit) and Mexico (Nopal deposit).

*8. Metasomatite deposits:* Deposits of this type are confined to the areas of tectono-magmatic activity of the Precambrian shields and are related to near-fault alkali metasomatites, developed upon different basement rocks: granites, migmatites, gneisses and ferruginous quartzites with production of albitites, aegirinites, alkali-amphibolic and carbonaceous-ferruginous rocks. Ore lenses and stocks are a few metres to tens of metres thick and a few hundred metres long. Vertical extent of ore mineralisation can be up to 1.5 km. Ores are uraninite-brannerite by composition and belong to ordinary grade. The reserves are usually medium scale or large. Examples include Michurinskoye, Vatutinskoye, Severinskoye, Zheltorechenskoye and Pervomayskoye deposits (Ukraine), Lagoa Real, Itataia and Espinharas (Brazil), the Valhalla deposit (Australia) and deposits of the Arjeplog region in the north of Sweden.

*9. Surficial deposits:* Surficial uranium 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), and they have been found in Australia (Yeelirrie deposit), Namibia (Langer Heinrich deposit) and Somalia. These calcrete-hosted deposits are associated with deeply weathered uranium-rich granites. They also can occur in valley-fill sediments along Tertiary drainage channels and in playa lake sediments (e.g. Lake Maitland, Australia). Surficial deposits also can occur in peat bogs and soils.

*10. Collapse breccia pipe deposits:* Deposits in this group occur in circular, vertical pipes filled with down-dropped fragments. The uranium is concentrated as primary uranium ore, generally uraninite, in the permeable breccia matrix, and in the arcuate, ring-fracture zone surrounding the pipe. 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.

*11. Phosphorite deposits:* Phosphorite deposits consist of marine phosphorite of continental-shelf origin containing syn-sedimentary stratiform, disseminated uranium in fine-grained apatite. Phosphorite deposits constitute large uranium resources, but at a very low grade. Uranium can be recovered as a by-product of phosphate production. Examples include New Wales Florida (pebble phosphate) and Uncle Sam (United States), Gantour (Morocco) and Al-Abiad (Jordan). Other type of phosphorite deposits consists of organic phosphate, including argillaceous marine sediments enriched in fish remains that are uraniferous (Melovoe deposit, Kazakhstan).

*12. Other deposits*

- *Metamorphic deposits:* In metamorphic uranium deposits, the uranium concentration directly results from metamorphic processes. The temperature and pressure conditions, and age of the uranium deposition have to be similar to those of the metamorphism of the enclosing rocks. Examples include the Forstau deposit (Austria) and Mary Kathleen (Australia).

- *Limestone deposits:* This includes uranium mineralisation in the Jurassic Todilto Limestone in the Grants district (United States). Uraninite occurs in intra-formational folds and fractures as introduced mineralisation.
- *Uranium coal deposits:* Elevated uranium contents occur in lignite/coal, and in clay and sandstone immediately adjacent to lignite. Examples are uranium in the Serres basin (Greece), in North and South Dakota (United States), Koldjat and Nizhne Iliyskoe (Kazakhstan) and Freital (Germany). Uranium grades are very low and average less than 50 ppm U.
- *Rock types with elevated uranium contents:* Elevated uranium contents have been observed in different rock types such as pegmatite, granites and black shale. In the past no economic deposits have been mined commercially in these types of rocks. Their grades are very low, and it is unlikely that they will be economic in the foreseeable future.
- *Rare metal pegmatites:* These pegmatites contain Sn, Ta, Nb and Li mineralisation. They have variable U, Th and rare earth elements contents. Examples include Greenbushes and Wodgina pegmatites (Western Australia). The Greenbushes pegmatites commonly have 6-20 ppm U and 3-25 ppm Th.
- *Granites:* A small proportion of un-mineralised granitic rocks have elevated uranium contents. These "high heat producing" granites are potassium feldspar-rich. Roughly 1% of the total number of granitic rocks analysed in Australia have uranium-contents above 50 ppm.
- *Black shale:* Black shale-related uranium mineralisation consists of marine organic-rich shale or coal-rich pyritic shale, containing syn-sedimentary disseminated uranium adsorbed onto organic material. Examples include the uraniferous alum shale in Sweden and Estonia, the Chatanooga shale (United States), the Chanziping deposit (China) and the Gera-Ronneburg deposit (Germany).

13. *Rock types with elevated uranium contents:* Elevated uranium contents have been observed in different rock types such as pegmatite, granites and black shale. In the past no economic deposits have been mined commercially in these types of rocks. Their grades are very low, and it is unlikely that they will be economic in the foreseeable future.

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# *Appendix* 4. Acronym list

| | |
|---|---|
| AGR | Advanced gas-cooled reactor |
| AL | Acid leaching |
| ALKAL | Alkaline atmospheric leaching |
| BWR | Boiling water reactor |
| CANDU | *Ca*nadian *d*euterium *u*ranium |
| CEC | Commission of the European Communities |
| CWG | Crush-wet grind |
| DIP | Decision-in-principle |
| DOE | Department of Energy (United States) |
| EIA | US Energy Information Administration |
| EIA | Environmental impact assessment |
| EIS | Environmental impact statement |
| EPR | European pressurised water reactor |
| EU | European Union |
| EUP | Enriched uranium product |
| FLOT | Flotation |
| Ga | Giga-years |
| GDR | German Democratic Republic |
| GIF | Generation IV International Forum |
| GNSS | Global Nuclear Services and Supply |
| GWe | Gigawatt electric |
| HEU | Highly enriched uranium |
| HL | Heap leaching |
| IAEA | International Atomic Energy Agency |
| IEA | International Energy Agency |
| INPRO | International Project on Innovative Nuclear Reactors and Fuel Cycles |
| IPL | In-place leaching |
| IR | Inferred resources |
| ISL | *In situ* leaching |
| IX | Ion exchange |

| | |
|---|---|
| kg | Kilogram |
| km | Kilometre |
| LEU | Low enriched uranium |
| LWR | Light water reactor |
| MAGNOX | Magnesium alloy graphite moderated gas cooled reactor |
| MOX | Mixed oxide fuel |
| MWe | Megawatt electric |
| NEA | Nuclear Energy Agency |
| NPP | Nuclear power plant |
| OECD | Organisation for Economic Co-operation and Development |
| OP | Open-pit |
| PHWR | Pressurised heavy-water reactor |
| ppm | Part per million |
| PR | Prognosticated resources |
| Pu | Plutonium |
| PWR | Pressurised water reactor |
| RAR | Reasonably assured resources |
| RBMK | Water-cooled, graphite-moderated reactor (Russian acronym) |
| SR | Speculative resources |
| SWU | Separative work unit |
| SX | Solvent extraction |
| t | Tonnes (metric tons) |
| Th | Thorium |
| tHM | Tonnes heavy metal |
| tNatU | Tonnes natural uranium equivalent |
| TOE | Tonnes oil equivalent |
| tU | Tonnes uranium |
| TVA | Tennessee Valley Administration |
| TWh | Terawatt-hour |
| U | Uranium |
| UG | Underground mining |
| USSR | Union of Soviet Socialist Republics |
| VVER | Water-cooled, water-moderated reactor (Russian acronym) |

# *Appendix* 5. Energy conversion factors

The need to establish a set of factors to convert quantities of uranium into common units of energy appeared during recent years with the increasing frequency of requests for such factors applying to the various reactor types.

**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, 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 | = | 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 | = | 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.

## Table 5A.1. Energy values for uranium used in various rector types[1]

| Country | Canada | France | Germany | | Japan | | Russian Federation | | Sweden | | United Kingdom | | United States | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reactor type | CANDU | N4 PWR | BWR | PWR | BWR | PWR | VVER-1000 | RBMK-1000 | BWR | PWR | MAGNOX | AGR | BWR | PWR |
| Burn-up [Mw/day/tU] | | | | | | | | | | | | | | |
| a) Natural uranium or natural uranium equivalent | 7 770 | 5 848 | 5 665 | 5 230 | 5 532 | 4 694 | 4 855 | 4 707 | 6 250 | 5 780 | 5 900 | NA | 4 996 | 4 888 |
| b) Enriched uranium | – | 42 500 | 40 000 | 42 000 | 33 000 | 43 400 | 42 000 | 22 000 | 40 000 | 42 000 | – | 24 000 | 33 000 | 40 000 |
| Uranium enrichment [% $^{235}$U] | – | 3.60 | 3.20 | 3.60 | 3.00 | 4.10 | 4.23 | 2.40 | 3.20 | 3.60 | – | 2.90 | 3.02 | 3.66 |
| Tails assay [% $^{235}$U] | – | 0.25 | 0.30 | 0.30 | 0.25 | 0.30 | 0.25 | 0.25 | 0.25 | 0.25 | – | 0.30 | 0.30 | 0.30 |
| Efficiency of converting thermal energy into electricity | 30% | 34.60% | 33.50% | 34.20% | 33% | 34% | 33.30% | 31.20% | 34.00% | 34.50% | 26% | 40% | 32% | 32% |
| Thermal energy equivalent of 1 t natural uranium [in $10^{15}$ joules][2] | 0.671 | 0.505 | 0.49 | 0.452 | 0.478 | 0.406 | 0.419 | 0.406 | 0.540 | 0.500 | 0.512 | 0.360 | 0.432 | 0.422 |
| Electrical energy equivalent of 1 t natural uranium [in $10^{15}$ joules][2] | 0.201 | 0.175 | 0.164 | 0.155 | 0.158 | 0.140 | 0.139 | 0.127 | 0.184 | 0.173 | 0.133 | 0.144 | 0.138 | 0.135 |

1. Does not include Pu and U recycled. Does not take into account the requirement of an initial core load, which would reduce the equivalence by about 6%, if based on a plant life of about 30 years with a 70% capacity factor.

2. Does not take into account the energy consumed for $^{235}$U enrichment in LWR and AGR fuel. The factor to be applied to the energy equivalent under the condition of 3% $^{235}$U enrichment and 0.2% tails assay should be multiplied by 0.957.

NA – Not available.

# *Appendix 6.* Listing of all Red Book editions (1965-2012) and national reports

## Listing of Red Book editions (1965-2012)

| | |
|---|---|
| OECD/ENEA | World Uranium and Thorium Resources, Paris, 1965 |
| OECD/ENEA | Uranium Resources, Revised Estimates, Paris, 1967 |
| OECD/ENEA-IAEA | Uranium Production and Short-Term Demand, Paris, 1969 |
| OECD/ENEA-IAEA | Uranium Resources, Production and Demand, Paris, 1970 |
| OECD/NEA-IAEA | Uranium Resources, Production and Demand, Paris, 1973 |
| OECD/NEA-IAEA | Uranium Resources, Production and Demand, Paris, 1976 |
| OECD/NEA-IAEA | Uranium Resources, Production and Demand, Paris, 1977 |
| OECD/NEA-IAEA | Uranium Resources, Production and Demand, Paris, 1979 |
| OECD/NEA-IAEA | Uranium Resources, Production and Demand, Paris, 1982 |
| OECD/NEA-IAEA | Uranium Resources, Production and Demand, Paris, 1983 |
| OECD/NEA-IAEA | Uranium Resources, Production and Demand, Paris, 1986 |
| OECD/NEA-IAEA | Uranium Resources, Production and Demand, Paris, 1988 |
| OECD/NEA-IAEA | Uranium Resources, Production and Demand, Paris, 1990 |
| OECD/NEA-IAEA | Uranium 1991: Resources, Production and Demand, Paris, 1992 |
| OECD/NEA-IAEA | Uranium 1993: Resources, Production and Demand, Paris, 1994 |
| OECD/NEA-IAEA | Uranium 1995: Resources, Production and Demand, Paris, 1996 |
| OECD/NEA-IAEA | Uranium 1997: Resources, Production and Demand, Paris, 1998 |
| OECD/NEA-IAEA | Uranium 1999: Resources, Production and Demand, Paris, 2000 |
| OECD/NEA-IAEA | Uranium 2001: Resources, Production and Demand, Paris, 2002 |
| OECD/NEA-IAEA | Uranium 2003: Resources, Production and Demand, Paris, 2004 |
| OECD/NEA-IAEA | Uranium 2005: Resources, Production and Demand, Paris, 2006 |
| OECD/NEA-IAEA | Uranium 2007: Resources, Production and Demand, Paris, 2008 |
| OECD/NEA-IAEA | Uranium 2009: Resources, Production and Demand, Paris, 2010 |
| OECD/NEA-IAEA | Uranium 2011: Resources, Production and Demand, Paris, 2012 |

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Algeria | | | | | | 1976 | 1977 | 1979 | 1982 | | | |
| Argentina | | 1967 | 1969 | 1970 | 1973 | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| Armenia | | | | | | | | | | | | |
| Australia | | 1967 | 1969 | 1970 | 1973 | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| Austria | | | | | | | 1977 | | | | | |
| Bangladesh | | | | | | | | | | | 1986 | 1988 |
| Belgium | | | | | | | | | 1982 | 1983 | 1986 | 1988 |
| Benin | | | | | | | | | | | | |
| Bolivia | | | | | | | 1977 | 1979 | 1982 | 1983 | 1986 | |
| Botswana | | | | | | | | 1979 | | 1983 | 1986 | 1988 |
| Brazil | | | | 1970 | 1973 | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | |
| Bulgaria | | | | | | | | | | | | |
| Cameroon | | | | | | | 1977 | | 1982 | 1983 | | |
| Canada | 1965 | 1967 | 1969 | 1970 | 1973 | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| Central African Republic | | | | 1970 | 1973 | | 1977 | 1979 | | | 1986 | |
| Chile | | | | | | | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| China, People's Rep. of | | | | | | | | | | | | |
| Colombia | | | | | | | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| Costa Rica | | | | | | | | | 1982 | 1983 | 1986 | 1988 |
| Côte d'Ivoire | | | | | | | | | 1982 | | | |
| Cuba | | | | | | | | | | | | 1988 |
| Czech Republic | | | | | | | | | | | | |
| Czech and Slovak Rep. | | | | | | | | | | | | |
| Denmark (Greenland) | 1965 | 1967 | 1969 | 1970 | 1973 | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | |
| Dominican Republic | | | | | | | | | 1982 | | | |
| Ecuador | | | | | | | 1977 | | 1982 | 1983 | 1986 | 1988 |
| Egypt | | | | | | | 1977 | 1979 | | | 1986 | 1988 |
| El Salvador | | | | | | | | | | 1983 | 1986 | |
| Estonia | | | | | | | | | | | | |
| Ethiopia | | | | | | | | 1979 | | 1983 | 1986 | |
| Finland | | | | | 1973 | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| France | 1965 | 1967 | 1969 | 1970 | 1973 | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| Gabon | | 1967 | | 1970 | 1973 | | | | 1982 | 1983 | 1986 | |
| Germany | | | | 1970 | | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| Ghana | | | | | | | 1977 | | | 1983 | | |
| Greece | | | | | | | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| Guatemala | | | | | | | | | | | 1986 | 1988 |


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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2002 | 2004 | 2006 | 2008 | | 2012 | Algeria |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Argentina |
| | | | | | 2000 | 2002 | 2004 | 2006 | | 2010 | 2012 | Armenia |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Australia |
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| | | | | | | | | | | | | Bangladesh |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | | | Belgium |
| 1990 | | | | | | | | | | | | Benin |
| | | | | | | | | | | | | Bolivia |
| | | | | | | | | | | 2010 | 2012 | Botswana |
| | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Brazil |
| 1990 | 1992 | 1994 | 1996 | 1998 | | | | | 2008 | 2010 | | Bulgaria |
| | | | | | | | | | | | | Cameroon |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Canada |
| | | | | | | | | | | | | Central African Republic |
| | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | | 2012 | Chile |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | China, People's Rep. of |
| 1990 | | | 1996 | 1998 | | | | | 2008 | | | Colombia |
| 1990 | | | | | | | | | | | | Costa Rica |
| | | | | | | | | | | | | Côte d'Ivoire |
| | 1992 | | 1996 | 1998 | | | | | | | | Cuba |
| | | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Czech Republic |
| 1990 | | | | | | | | | | | | Czech and Slovak Rep. |
| 1990 | 1992 | | 1996 | 1998 | | | 2004 | | | 2010 | 2012 | Denmark (Greenland) |
| | | | | | | | | | | | | Dominican Republic |
| | | | | | | | | | | | | Ecuador |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | | 2004 | 2006 | 2008 | 2010 | | Egypt |
| | | | | | | | | | | | | El Salvador |
| | | | | 1998 | | | 2004 | | | | | Estonia |
| | | | | | | | | | | | 2012 | Ethiopia |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Finland |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | France |
| | | | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | | | | Gabon |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | | 2006 | 2008 | 2010 | 2012 | Germany |
| | | | | | | | | | | | | Ghana |
| 1990 | 1992 | 1994 | 1996 | 1998 | | | | | | | | Greece |
| | | | | | | | | | | | | Guatemala |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Guyana | | | | | | | | 1979 | 1982 | 1983 | 1986 | |
| Hungary | | | | | | | | | | | | |
| India | 1965 | 1967 | | 1970 | 1973 | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | |
| Indonesia | | | | | | | 1977 | | | | 1986 | 1988 |
| Iran, Islamic Republic of | | | | | | | 1977 | | | | | |
| 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 |
| Jordan | | | | | | | 1977 | | | | 1986 | 1988 |
| Kazakhstan | | | | | | | | | | | | |
| Korea, Republic of | | | | | | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| Kyrgyzstan | | | | | | | | | | | | |
| Lesotho | | | | | | | | | | | | 1988 |
| Liberia | | | | | | | 1977 | | | 1983 | | |
| Libyan Arab Jamahiriya | | | | | | | | | | 1983 | | |
| Lithuania | | | | | | | | | | | | |
| Madagascar | | | | | | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| Malawi | | | | | | | | | | | | |
| Malaysia | | | | | | | | | | 1983 | 1986 | 1988 |
| Mali | | | | | | | | | | | 1986 | 1988 |
| Mauritania | | | | | | | | | | | | |
| Mexico | | | | 1970 | 1973 | 1976 | 1977 | 1979 | 1982 | | 1986 | |
| Mongolia | | | | | | | | | | | | |
| Morocco | 1965 | 1967 | | | | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| Namibia | | | | | | | | 1979 | 1982 | 1983 | 1986 | 1988 |
| Netherlands | | | | | | | | | 1982 | 1983 | 1986 | |
| New Zealand | | 1967 | | | | | 1977 | 1979 | | | | |
| Niger | | 1967 | | 1970 | 1973 | | 1977 | | | | 1986 | 1988 |
| Nigeria | | | | | | | | 1979 | | | | |
| Norway | | | | | | | | 1979 | 1982 | 1983 | | |
| Pakistan | | 1967 | | | | | | | | | | |
| Panama | | | | | | | | | | 1983 | | 1988 |
| Paraguay | | | | | | | | | | 1983 | 1986 | |
| Peru | | | | | | | 1977 | 1979 | | 1983 | 1986 | 1988 |
| Philippines | | | | | | | 1977 | | 1982 | 1983 | 1986 | |
| Poland | | | | | | | | | | | | |
| Portugal | 1965 | 1967 | 1969 | 1970 | 1973 | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| Romania | | | | | | | | | | | | |
| Russian Federation | | | | | | | | | | | | |


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| | | | | | | | | | | | | Guyana |
| | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Hungary |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | India |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | | 2010 | 2012 | Indonesia |
| | | | | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Iran, Islamic Republic of |
| | 1992 | | | 1998 | | | | | | | | Ireland |
| | 1992 | 1994 | 1996 | 1998 | 2000 | | | | | | 2012 | Italy |
| | | | | | | | | | | | | Jamaica |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Japan |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Jordan |
| | | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Kazakhstan |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | | Korea, Republic of |
| | | | 1996 | | | 2002 | | | | | | Kyrgyzstan |
| | | | | | | | | | | | | Lesotho |
| | | | | | | | | | | | | Liberia |
| | | | | | | | | | | | | Libyan Arab Jamahiriya |
| | | 1994 | 1996 | 1988 | 2000 | 2002 | 2004 | 2006 | 2008 | | | Lithuania |
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| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | | | | | | Malaysia |
| | | | | | | | | | | | | Mali |
| 1990 | | | | | | | | | | | | Mauritania |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | | | | | | 2012 | Mexico |
| | | 1994 | 1996 | 1998 | | | | | | | 2012 | Mongolia |
| 1990 | | | | 1998 | | | | | | 2010 | | Morocco |
| 1990 | | | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Namibia |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | | | | | | Netherlands |
| | | | | | | | | | | | | New Zealand |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Niger |
| | | | | | | | | | | | | Nigeria |
| | 1992 | | 1996 | 1998 | | | | | | | | Norway |
| | | | | 1998 | 2000 | 2002 | | | | | | Pakistan |
| | | | | | | | | | | | | Panama |
| | | | | | | | | | | | | Paraguay |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | | 2004 | 2006 | 2008 | 2010 | 2012 | Peru |
| 1990 | | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | | | | Philippines |
| | | | | | 2000 | 2002 | | | 2008 | 2010 | 2012 | Poland |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Portugal |
| | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | | | | | | Romania |
| | | 1994 | | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Russian Federation |

**Index of national reports in Red Books** *(continued)*

| | 1965 | 1967 | 1969 | 1970 | 1973 | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| 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 |
| Switzerland | | | | | | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| Syrian Arab Republic | | | | | | | | | 1982 | 1983 | 1986 | 1988 |
| Tajikistan | | | | | | | | | | | | |
| Tanzania | | | | | | | | | | | | |
| Thailand | | | | | | | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| Togo | | | | | | | | 1979 | | | | |
| Turkey | | | | | 1973 | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| Turkmenistan | | | | | | | | | | | | |
| Ukraine | | | | | | | | | | | | |
| United Kingdom | | | | | | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| United States | 1965 | 1967 | 1969 | 1970 | 1973 | 1976 | 1977 | 1979 | 1982 | 1983 | 1986 | 1988 |
| Uruguay | | | | | | | 1977 | | 1982 | 1983 | 1986 | 1988 |
| USSR | | | | | | | | | | | | |
| Uzbekistan | | | | | | | | | | | | |
| Venezuela | | | | | | | | | | | 1986 | 1988 |
| Vietnam | | | | | | | | | | | | |
| Yugoslavia | | | | | 1973 | 1976 | 1977 | | 1982 | | | |
| Zaire | | 1967 | | | 1973 | | 1977 | | | | | 1988 |
| Zambia | | | | | | | | | | | 1986 | 1988 |
| Zimbabwe | | | | | | | | | 1982 | | | 1988 |


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**Index of national reports in Red Books** *(continued)*

| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Rwanda |
| | | | | | | | | | | | | Senegal |
| | | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Slovak Republic |
| | | 1994 | 1996 | 1998 | | 2002 | 2004 | 2006 | 2008 | 2010 | | Slovenia |
| | | | | | | | | | | | | Somalia |
| | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | South Africa |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Spain |
| | | | | | | | | | | | | Sri Lanka |
| | | | | | | | | | | | | Sudan |
| | | | | | | | | | | | | Surinam |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Sweden |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | | | Switzerland |
| 1990 | | 1994 | | | | | | | | | | Syrian Arab Republic |
| | | | | | | 2002 | | | | | | Tajikistan |
| 1990 | | | | | | | | | | 2010 | 2012 | Tanzania |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | | 2006 | | | | Thailand |
| | | | | | | | | | | | | Togo |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Turkey |
| | | | | | | | 2004 | | | | | Turkmenistan |
| | | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | Ukraine |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | | United Kingdom |
| 1990 | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | United States |
| 1990 | | | | | | | | | | | | Uruguay |
| | 1992 | | | | | | | | | | | USSR |
| | | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | | | 2012 | Uzbekistan |
| | | | | | | | | | | | | Venezuela |
| | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | | | Vietnam |
| 1990 | 1992 | | | | | | | | | | | Yugoslavia |
| | | | | | | | | | | | | Zaire |
| 1990 | 1992 | 1994 | 1996 | 1998 | | | | | | | 2012 | Zambia |
| | 1992 | 1994 | 1996 | 1998 | | | | | | | | Zimbabwe |

# *Appendix 7.* Currency exchange rates

| Country (currency abbreviation) | June 2008 | June 2009 | June 2010 | January 2011 |
|---|---|---|---|---|
| Algeria (DZD) | 63.26 | 73.045 | 75.52 | 74.29 |
| Argentina (ARS) | 3.12 | 3.77 | 3.93 | 3.98 |
| Armenia (AMD) | 308.83 | 362 | 369 | 360.5 |
| Australia (AUD) | 1.042 | 1.242 | 1.144 | 0.986 |
| Austria (EUR) | 0.643 | 0.711 | 0.811 | 0.761 |
| Belgium (EUR) | 0.643 | 0.711 | 0.811 | 0.761 |
| Botswana (BWP) | 6.32 | 6.91 | 6.92 | 6.47 |
| Brazil (BRL) | 1.648 | 1.98 | 1.79 | 1.69 |
| Bulgaria (BGL) | 1.258 | 1.391 | 1.586 | 1.488 |
| Canada (CAD) | 0.983 | 1.153 | 1.034 | 1 |
| Chile (CLP) | 470 | 525 | 535 | 465 |
| China (CNY) | 6.95 | 6.81 | 6.8 | 6.63 |
| Colombia (COP) | 1 772 | 2 108 | 1 900 | 1 950 |
| Cuba (CUP) | 1 | 1 | 1 | 1 |
| Czech Republic (CZK) | 16.1 | 18.48 | 20.78 | 19.31 |
| Denmark (DKK) | 4.74 | 5.293 | 6.035 | 5.675 |
| Egypt (EGP) | 5.34 | 5.59 | 5.66 | 5.74 |
| Ethiopia (ETB) | 9.59 | 11.277 | 13.52 | 16.53 |
| Finland (EUR) | 0.643 | 0.711 | 0.811 | 0.761 |
| France (EUR) | 0.643 | 0.711 | 0.811 | 0.761 |
| Gabon (XAF) | 421.78 | 466.385 | 531.981 | 499.183 |
| Germany (EUR) | 0.643 | 0.711 | 0.811 | 0.761 |
| Greece (EUR) | 0.643 | 0.711 | 0.811 | 0.761 |
| Greenland (DKK) | 4.74 | 5.293 | 6.035 | 5.675 |
| Hungary (HUF) | 155 | 195 | 231 | 212.9 |
| India (INR) | 42.82 | 48.5 | 46.28 | 45.3 |
| Indonesia (IDR) | 9 310 | 10 350 | 8 955 | 8 965 |
| Iran, Islamic Republic of (IRR) | 9 155 | 9 900 | 10 347.5 | 10 338 |
| Italy (EUR) | 0.643 | 0.711 | 0.811 | 0.761 |
| Japan (JPY) | 105 | 95.2 | 89.4 | 82 |
| Jordan (JOD) | 0.708 | 0.708 | 0.708 | 0.708 |
| Kazakhstan (KZT) | 120.3 | 150 | 146.5 | 147.5 |
| Korea, Republic of (KRW) | 1 039 | 1 272 | 1 209 | 1 146 |
| Kyrgyzstan (KGS) | 36.05 | 43 | 46 | 47 |

| Country (currency abbreviation) | June 2008 | June 2009 | June 2010 | January 2011 |
|---|---|---|---|---|
| Lithuania (LTL) | 2.218 | 2.454 | 2.798 | 2.628 |
| Malawi (MWK) | 140.51 | 163 | 151.545 | 150.8 |
| Malaysia (MYR) | 3.2 | 3.52 | 3.2 | 3.1 |
| Mauritania (MRO) | 238.18 | 265.4 | 275 | 283 |
| Mexico (MXN) | 10.3 | 13.17 | 12.83 | 12.31 |
| Mongolia (MNT) | 1 163 | 1 428 | 1 374 | 1 237 |
| Morocco (MAD) | 7.265 | 8.07 | 8.92 | 8.45 |
| Namibia (NAD) | 7.65 | 7.91 | 7.6 | 6.66 |
| Netherlands (EUR) | 0.643 | 0.711 | 0.811 | 0.761 |
| Niger (XOF) | 421.78 | 466.385 | 531.981 | 499.183 |
| Norway (NOK) | 5.06 | 6.425 | 6.406 | 5.956 |
| Peru (PEN) | 2.8 | 3.02 | 2.83 | 2.81 |
| Philippines (PHP) | 43.69 | 48.57 | 46 | 43.92 |
| Poland (PLN) | 2.14 | 3.18 | 3.348 | 3.02 |
| Portugal (EUR) | 0.643 | 0.711 | 0.811 | 0.761 |
| Romania (ROL) | 2.31 | 3.04 | 3.44 | 3.26 |
| Russian Federation (RUB) | 23.56 | 31.14 | 30.6 | 30.35 |
| Serbia and Montenegro (RSD) | 51.1 | 66.26 | 84 | 80.4 |
| Slovak Republic (EUR) | 19.65 | 0.711 | 0.811 | 0.761 |
| Slovenia (EUR) | 0.643 | 0.711 | 0.811 | 0.761 |
| South Africa (ZAR) | 7.65 | 7.91 | 7.6 | 6.66 |
| Spain (EUR) | 0.643 | 0.711 | 0.811 | 0.761 |
| Sweden (SEK) | 6 | 7.77 | 7.714 | 6.852 |
| Switzerland (CHF) | 1.045 | 1.084 | 1.0874 | 0.951 |
| Syrian Arab Republic (SYP) | 45.6 | 46.9 | 46.9 | 46.58 |
| Tajikistan (TJS) | 3.425 | 4.4 | 4.43 | 4.45 |
| Tanzania (TZS) | 1 172.5 | 1 317 | 1 467 | 1 460 |
| Thailand (THB) | 32.26 | 34.07 | 32.36 | 30.17 |
| Turkey (TRL) | 1.24 | 1.55 | 1.55 | 1.55 |
| Ukraine (UAH) | 4.69 | 7.675 | 7.89 | 7.93 |
| United Kingdom (GBP) | 0.505 | 0.607 | 0.663 | 0.648 |
| United States (USD) | 1 | 1 | 1 | 1 |
| Uruguay (UYU) | 19.45 | 23.45 | 20.89 | 19.9 |
| Uzbekistan (UZS) | 1 307 | 1 480 | 1 595 | 1 640 |
| Vietnam (VND) | 16 190 | 17 792 | 18 965 | 19 500 |
| Zambia (ZMK) | 3 432 | 5 145 | 5 050 | 4 703 |
| Zimbabwe (ZWR) | 680 000 000 | | | |

Note: In national currency units per USD.

Source: United Nations Operational Rates of Exchange, United Nations Treasury.

# *Appendix 8.* Grouping of countries and areas with uranium-related activities

The countries and geographical areas referenced in this report are listed below. Countries followed by "*" are OECD members.

### North America

| | | |
|---|---|---|
| Canada* | Mexico* | United States* |

### Central and South America

| | | |
|---|---|---|
| Argentina | Bolivia | Brazil |
| Chile* | Colombia | Costa Rica |
| Cuba | Ecuador | El Salvador |
| Guatemala | Jamaica | Paraguay |
| Peru | Uruguay | Venezuela |

### Western Europe

| | | |
|---|---|---|
| Austria* | Belgium* | Denmark* |
| Finland* | France* | Germany* |
| Ireland* | Italy* | Netherlands* |
| Norway* | Portugal* | Spain* |
| Sweden* | Switzerland* | United Kingdom* |

### Central, Eastern and Southeastern Europe

| | | |
|---|---|---|
| Armenia | Bulgaria | Croatia |
| Czech Republic* | Estonia* | Greece* |
| Hungary* | Lithuania | Poland* |
| Romania | Russian Federation | Slovak Republic* |
| Slovenia* | Turkey* | Ukraine |

### Africa

| | | |
|---|---|---|
| Algeria | Botswana | Central African Rep. |
| Congo, Democratic Rep. | Egypt | Gabon |
| Ghana | Lesotho | Libya |
| Madagascar | Malawi | Mali |
| Morocco | Namibia | Niger |
| Nigeria | Somalia | South Africa |
| Zambia | Zimbabwe | |

### Middle East, Central and Southern Asia

| | | |
|---|---|---|
| Bangladesh | India | Iran, Islamic Rep. of |
| Israel* | Jordan | Kazakhstan |
| Kyrgyzstan | Pakistan | Sri Lanka |
| Syria | Tajikistan | Turkmenistan |
| Uzbekistan | | |

### Southeastern Asia

| | | |
|---|---|---|
| Indonesia | Malaysia | Philippines |
| Thailand | Vietnam | |

### Pacific

| | |
|---|---|
| Australia* | New Zealand* |

### East Asia[1]

| | | |
|---|---|---|
| China | Japan* | Korea, Democratic People's Rep. of |
| Korea, Republic of* | Mongolia | |

The countries associated with other groupings of nations used in this report are listed below.

### Commonwealth of Independent States (CIS) or Newly Independent States (NIS)

| | | |
|---|---|---|
| Armenia | Azerbaijan | Belarus |
| Georgia | Kazakhstan | Kyrgyzstan |
| Tajikistan | Turkmenistan | Moldavia |
| Russian Federation | Ukraine | Uzbekistan |

### European Union

| | | |
|---|---|---|
| Austria* | Belgium* | Bulgaria |
| Cyprus | Czech Republic* | Denmark* |
| Estonia* | Finland* | France* |
| Germany* | Greece* | Hungary* |
| Ireland* | Italy* | Latvia |
| Lithuania | Luxembourg* | Malta |
| Netherlands* | Poland* | Portugal* |
| Romania | Slovak Republic* | Slovenia* |
| Spain* | Sweden* | United Kingdom* |

1. Includes Chinese Taipei.

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# 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.

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