Appendix 1

MEMBERS OF THE JOINT NEA-IAEA URANIUM GROUP

Algeria	Mr. M.T. BOUARROUDJ	Commissariat à l'énergie atomique (COMENA), Alger
Argentina	Mr. A. CASTILLO **(Vice-Chair)**	Comisión Nacional de Energía Atómica Unidad de Proyectos Especiales de Suministros Nucleares, Buenos Aires
Australia	Mr. I. LAMBERT **(Vice-Chair)** Mr. A. McKAY Ms. L. CARSON	Geoscience Australia, Canberra
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
Bulgaria	Ms. K. KOSTADINOVA	Nuclear Energy and Safety Unit, Ministry of Economy and Energy, Sofia
	Mr. P. PETROV	Ministry of Economy and Energy, Sofia
Canada	Mr. T. CALVERT	Uranium and Radioactive Waste Division, Natural Resources Canada, Ottawa
China	Mr. X. PENG	Bureau of Geology, China National Nuclear Corporation (CNNC), Beijing
	Mr. B. XIU	Division of Nuclear Fuel, China Atomic Energy Authority, Beijing
Czech Republic	Mr. P. VOSTAREK	DIAMO s.p. Stráz pod Ralskem
Egypt	Mr. H.S.E.N.S. ABOU KHOZAYEM Mr. E.M.I. ELKATTAN Mr. A.E.M. ELSIRAFY	Nuclear Materials Authority (NMA) El-Maadi, Cairo
Finland	Mr. O. ÄIKÄS	Department of Economic Geology Geological Survey of Finland, Espoo
France	Mr. G. CAPUS **(Chair)**	AREVA NC, Vélizy
	Mr. F.-L. LINET	Commissariat à l'énergie atomique Direction de l'énergie nucléaire, Gif-sur-Yvette
Germany	Mr. U. SCHWARZ-SCHAMPERA	Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover

Hungary	Mr. G. Németh	Paks Nuclear Power Plant, Paks
India	Mr. A. CHAKI Mr. S.A. PANDIT	Atomic Minerals Directorate for Exploration and Research (AMD), Dept. of Atomic Energy, Hyderabad
Iran, Islamic Republic of	Mr. F. YEGANI Mr. A. REZA	Atomic Energy Organisation of Iran, Tehran
Japan	Mr. T. KOBAYASHI	Office of Strategy Research, Japan Atomic Energy Agency (JAEA), Tokai-mura
	Mr. H. MIYADA	Japan Atomic Energy Agency (JAEA), Toki-shi
	Mr. K. SAWADA	Japan Oil, Gas and Metals National Corporation, Kawasaki
Jordan	Mr. A.M. SAYMEH	Geophysics Division, Natural Resources Authority, Amman
Kazakhstan	Mr. A. KUTZHAN	National Atomic Company "KAZATOMPROM", Almaty
Pakistan	Mr. Kahlid BIN SATTAR	Pakistan Atomic Energy Commission, Atomic Energy Minerals Centre, Lahore
Romania	Mr. D.-A. STIOPOL	Commission for Nuclear Activities Control, Bucharest
Russian Federation	Mr. A.V. BOITSOV **(Vice-Chair)**	TENEX, Moscow
	Mr. A.V. TARKHANOV Mr. O. KNJAZEV	All-Russian Institute of Chemical Technology, Ministry of Atomic Energy, Moscow
Slovak Republic	Mr. M. LASCEK	Slovenské elecktrárne, a.s., Bratislava
South Africa	Mr. S. PHETO	National Nuclear Regulator (NNR), Centurion
Spain	Mr. F. T. GARCIA	Enusa Industrias Avanzadas, S.A.
Switzerland	Mr. G. KLAIBER	Nordostschweizerische (NOK) Kraftwerke AG, Baden
Ukraine	Mr. A. BAKARZHIYEV Mr. Y. BAKARZHIYEV	The State Geological Enterprise "Kirovgeology", Kiev
United Kingdom	Mr. K. WELHAM	Rio Tinto plc, London
	Mr. Craig JONES	UK Delegation to the OECD
United States	Mr. S. SITZER **(Vice-Chair)**	Energy Information Administration US Department of Energy, Washington
	Mr. J. OTTON	US Geological Survey, Denver

Uzbekistan	Mr. H. HALMURZAEV	State Geological Enterprise “Kyzyltepageologia”, Tashkent
Venezuela	Mr. T. TOSIANI	Ministerio del Poder Popular para la Energía y Petróleo, Caracas
Vietnam	Mr. Le BA THUAN	Vietnam Atomic Energy Commission (VAEC), Hanoi
European Commission	Mr. Z. PATAKI	Euratom Supply Agency, Luxembourg
IAEA	Mr. J. SLEZÁK **(Scientific Secretary)**	Division of Nuclear Fuel Cycle and Waste Technology, Vienna
OECD/NEA	Mr. R. VANCE **(Scientific Secretary)**	Nuclear Development Division, Paris

Appendix 2

LIST OF REPORTING ORGANISATIONS AND CONTACT PERSONS

Algeria	Commissariat à l'énergie atomique (COMENA), 02, Boulevard Franz Fanon, BP 399, Alger-Gare, 16000, Alger Contact person: Mr. Allaoua Khaldi
Argentina	Comisión Nacional de Energía Atómica, Unidad de Proyectos Especiales de Suministros Nucleares, Avenida del Libertador 8250, 1429 Buenos Aires Contact person: Mr. Alberto Castillo
Australia	Geoscience Australia, GPO Box 378, Canberra, ACT 2601 Contact person: Mr. Aden D McKay
Belgium	Ministère des Affaires économiques, Administration de l'énergie, Division des applications nucléaires, 16 Boulevard du Roi Albert II, B-1000 Bruxelles Contact person: Ms. Françoise Renneboog (SYNATOM)
Brazil	Indústrias Nucleares do Brasil S/A, INB, Rua Mena Barreto, 161, 4^{o} andar, Botafogo, CEP 22271-100, Rio de Janeiro – RJ, Brasil Contact person: Mr. Luiz Filipe da Silva
Bulgaria	Ministry of Economy and Energy, 8 Slavianska Str., Sofia Contact person: Ms. Katerina Kostadinova
Canada	Natural Resources Canada, Uranium and Radioactive Waste Division, 580 Booth Street, Ottawa, Ontario K1A OE4 Contact person: Mr. Tom Calvert
Chile	Comisión Chilena de Energía Nuclear, Departamento de Materiales Nucleares, Unidad de Geologia Y Mineria, Centro Nuclear Lo Aguirre, Ruta 68, km 28 Region Metropolitana Contact person: Mr. Loreto Villanueva Zamora
China	China Atomic Energy Authority, Division of Nuclear Affairs and International Organisations, A8, Fuchenglu, Haidian District, Beijing 100037 Contact person: Mr. Xiu Binglin
Colombia	Ingeominas, Dirección Servicio Geológico, Diagonal 53 N^{o} 34-53, Bogota, D.C. Contact person: Ms. Silvia Alvarez Quintero
Czech Republic	DIAMO s.p., Máchova 201, 471 27 Stráz pod Ralskem. CĚZ, a.s., Nuclear Fuel Cycle Section Duhová 2/1911, 14053 Praha 4 Contact person: Pavel Vostarek
Denmark	Danish Energy Authority, Ministry of Transport and Energy, Energy Efficiency and Economics, Amaliegade 44, DK-1256 Copenhagen K Contact person: Mr. Ali Zarnaghi
Egypt	Nuclear Materials Authority, Maadi-Kattamya Road, P.O. Box 530, Elmaadi, Cairo Contact person: Mr. El Sayed M. Elkattan

Finland
Ministry of Trade and Industry, Energy Department, P.O. Box 32,
FIN-00023 Helsinki
Contact person: Mr. Olli Äikas

France
Commissariat à l'énergie atomique, CEA Saclay, Bât. 125
F-91191 Gif sur Yvette
Contact person: Mr. F.-L. Linet

Germany
Bundesanstalt für Geowissenschaften und Rohstoffe, Stilleweg 2,
D-30657 Hannover
Contact person: Mr. Ulrich Schwarz-Schampera

Hungary
Paks Nuclear Power Plant, H-7031 Paks, P.O.Box 71
Contact person: Mr. Gabor Németh

India
Atomic Minerals Directorate for Exploration and Research, Department of Atomic Energy, 1-10-153-156, Begumpet, Hyderabad 500 016, Andhra Pradesh
Contact person: Mr. Anjan Chaki

Iran, Islamic Rep. of
Atomic Energy Organisation of Iran, Nuclear Fuel Production Deputy,
North Karegar Ave., P.O. Box 14155-1339, Tehran
Contact person: Mr. Farrokhshad Yegani

Japan
Ministry of Economy, Trade and Industry, 3-1 Kasumigaseki, 1-chome, Chiyoda-ku, Tokyo 100
Contact person: Mr. Hatsuho Miyada

Jordan
Natural Resources Authority, P.O. Box 7, Amman
Contact person: Mr. Allam Saymeh

Kazakhstan
National Atomic Company "Kazatoprom", 168 Bogenbai batyr Street,
Almaty, 480012
Contact person: Mr. Aidos Kutzhan

Korea, Rep. of
Ministry of Science and Technology, Atomic Energy Co-operation Division, Government Complex, Gwacheon, Kyunggi-Do 427-715
Contact person: Ms. Ji-Hyuan Ahn

Lithuania
Ministry of Economy, Nuclear Energy Division, Gedimino pr.38/2,
LT-01104 Vilnius
Contact person: Ms. Renata Karaliute

Namibia
Ministry of Mines and Energy, Directorate of Mines, P/Bag 13297, Windhoek
Contact person: Ms. Helena Itamba

Niger
Ministère des Mines et de l'Énergie, B.P. 11700, Niamey
Contact person: Mr. Massalabi Oumarou

Peru
Instituto Peruano de Energia Nuclear, Dirección de Servicios y Dirección de Aplicaciones, Av. Canada 1470, San Borja, Lima 41
Contact person: Mr. Jacinto Valencia Herrera

Poland
Ministry of the Environment, Department of Geology and Geological Concessions, ul. Wawelska 52/54, 00-922 Warsaw
Contact person: Mr. Maciej Jadezak

Portugal
Ministério da Economia, Instituto Geológico e Mineiro, 38 Rua Almirante Barroso, P-1000 Lisbon
Contact person: Mr. Luis Rodrigues Costa

Russian Federation
SC Atomredmetzoloto, Ziatoustinsky per. 5, blg. 3, Moscow
Contact person: Mr. Alexander Boitsov

Slovak Republic
Slovenské Electrárne, Hranicna 12,827 36 Bratislava
Contact person: Mr. Milos Lacsek

Slovenia
GEN energija, d.o.o., Cesta 4.julija 42, SI-8270 Krško
Contact person: Mr. Tomaž Žagar

South Africa
Council for Geoscience, 280 Pretoria Road, Silverton, Pretoria
Private Bag X112, Pretoria 001
Contact person: Ms. Ria Putter

Spain
ENUSA Industrias Avanzadas, S. A., Santiago Rusiñol, 12, E-28040 Madrid
Contact person: Mr. Francisco Tarin Garcia

Sweden
Vattenfall Fuel Supply, Jamtlandsgatan 99, SE-162 87 Stockholm
Contact person: Mr. Ali Etemad

Switzerland
Nordostschweizerische Kraftwerke (NOK), Parkstrasse 23, CH-5401 Baden
Contact person: Mr. Guido Klaiber

Turkey
Turkish Atomic Energy Authority, Eskişehir Yolu 9 km,, 06530 Ankara
Contact person: Mr. Serpil Aktürk

Ukraine
SGE Kirovgeology, 8/9 Kikvidze str., Kiev 01103, Ukraine.
Contact person: Mr. Yuri A. Bakarzhiyev

United Kingdom
Department of Trade and Industry, 1 Victoria Street, London SW1H OET
Contact person: Mr. John Lownds

Department for Business, Enterprise and Regulatory Reform, Nuclear
Consultations and Liabilities Unit, 1 Victoria Street, London SW1H 0ET
Contact Person: Mr. Andrew Wooldridge

United States
Energy Information Administration, Coal, Nuclear, Electric and Alternate Fuels
(EI-50), US Department of Energy, 1000 Independence Avenue,
SW, Washington, D.C. 20585
Contact person: Scott Sitzer

Vietnam
Vietnam Atomic Energy Commission, Hanoi
Contact person: Mr. Le Ba Thuan

Appendix 3

THE URANIUM MINING REMEDIATION EXCHANGE GROUP (UMREG)

> *"The time is ripe to launch an international initiative*
> *for consolidation of a good remediation practice*
> *for the old uranium mining sites and to*
> *limit the environmental impact of the*
> *new uranium mines worldwide."*

Origins

In 1993 and 1994, the first bilateral US/German meetings were held on remediation of uranium mining and milling legacy sites (that is, sites at which mining practices of the past, no longer licensed today, led to environmental impacts that were left to governments to remediate). These meetings facilitated a useful exchange of ideas on remedial strategies and resulted in the introduction of cost-efficient solutions and pragmatic administrative procedures based on sound scientific principles and proven technology.

The first multilateral meeting (with the participation of Canada and South Africa) followed in 1995. Later meetings in 1995, 1997, 1998, 2000 and 2001 included participation by representatives from Australia and France. In more recent meetings (2002, 2003, 2005 and 2007), participation progressively increased to include representatives from uranium producing countries in Africa, Latin America, Central and Eastern Europe and Central Asia. Proceedings were published after each UMREG Meeting.

With the aim of promoting "economically and environmentally balanced uranium mining and remediation practices," UMREG provides a non-commercial exchange platform for all members. Shared experiences in UMREG clearly demonstrate that low-impact mining practices both minimise environmental impacts and enhance life-cycle economics of projects.

The present revival of the uranium mining

According to many sources, world energy demand is expected to increase significantly by 2030 and beyond. The majority of base-load electricity is presently generated by power plants using fossil fuels or uranium. The use of uranium as a fuel is a plausible solution to the dilemma of a simultaneously increasing energy demand and reducing greenhouse gas emissions. Hence, uranium demand and prices for the commodity are increasing, as are global exploration and mine development activities.

The need to achieve stakeholder support for uranium mining was underestimated in the past and this, combined with practices that led to environmental impacts in the past, have undermined the credibility of today's uranium miners. Past experience shows that societal concerns must be on the "critical path" of any new uranium mine development project. The revival of the uranium market today also presents an opportunity to governments to remediate uranium mining legacy sites not yet dealt with. Although needs differ between countries, the commitment to remediation is universally seen as an environmentally responsible approach to mining.

Increasing uranium production today typically requires a lengthy review and approval process. While the time required from discovery to the opening of a mine took approximately 3-5 years in the 1950 and 1960s, it had increased to as much as twenty years in the 1990s. This represents a serious hindrance to the economic development of the industry. Accordingly, challenges for governments, industry and regulatory authorities today include:

- Improving credibility with stakeholders;
- Establishing global mine development practices that minimise environmental impacts;
- Continuing to repair environmental damages resulting from past practices no longer licensed today.

Mission of UMREG

To overcome these challenges, UMREG advocates adoption of policies that will minimise environmental impacts from efficient mining operations and promote remediation of the remaining legacy sites. These policies should be developed with full stakeholder consultations to achieve broad consensus and should include:

- Consideration of the utilisation of mining sites following remediation, driven by stakeholder interest;
- Promotion of efficient, environmentally sound mining, production and full life cycle use of uranium, a non-renewable resource;
- Distribution of information on past experiences to relevant parties in countries where these approaches have not yet been adopted.

UMREG helps implement these general policy goals by providing an international forum for the exchange of experience on low environmental impact uranium mining and value added remediation, harmonisation of "good environmental practices" and positive involvement of stakeholders in the remediation of uranium mines. UMREG promotes education and implementation of desired policies by linking with institutions, companies and projects involved in the transfer of technology and know-how and by maintaining a worldwide network of experts and a data and information management system that makes the cumulative experience available to the co-operating parties.

Conclusion

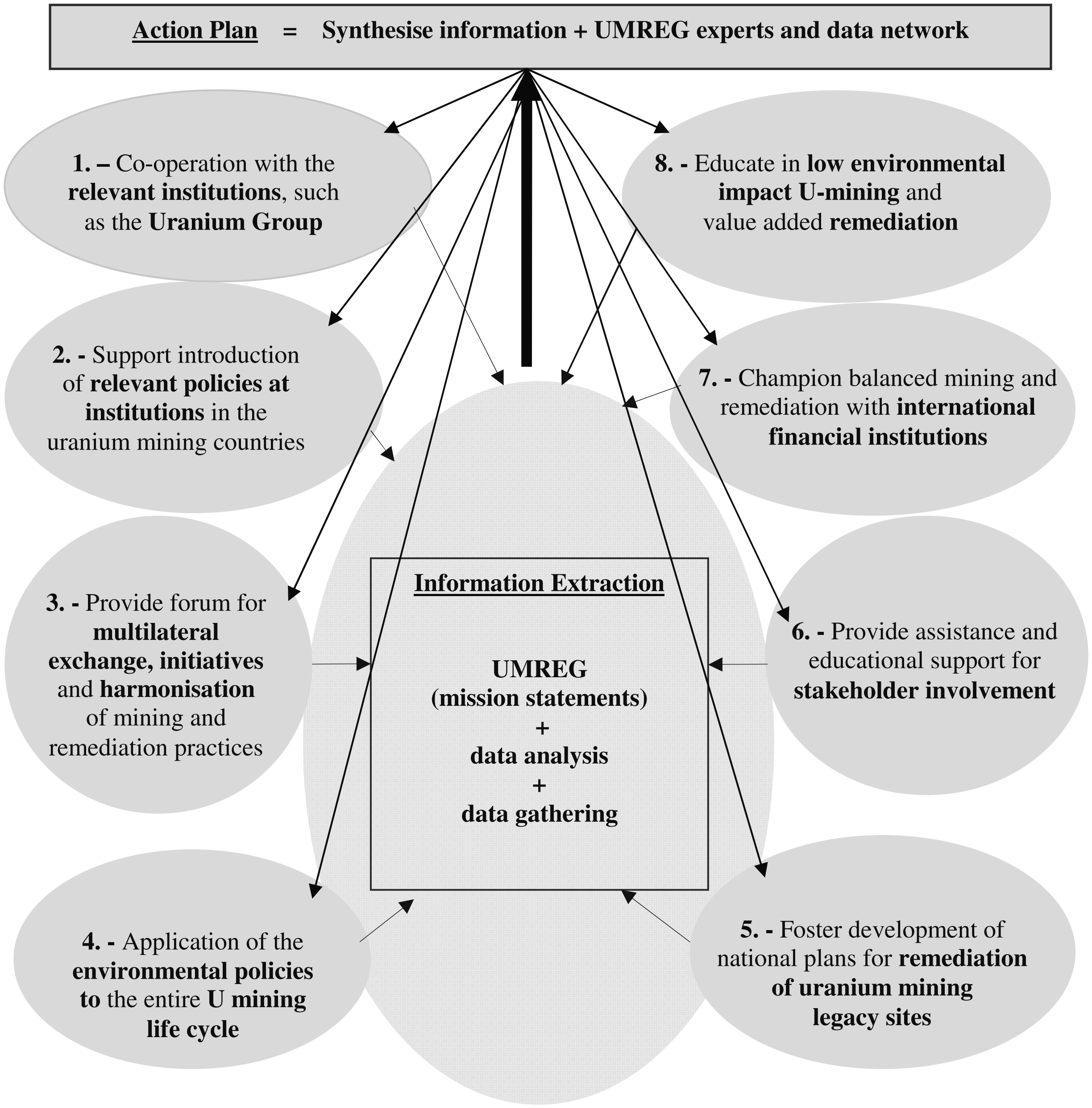
The remediation of the remaining uranium mining legacy sites is an important step toward enhancing future stakeholder support of the industry and hence the stability of future uranium mining projects. The present revival of the uranium mining industry is an ideal setting for governments to advance the cause of remediation of the remaining legacy sites.

New uranium mine developments should follow a complete life-cycle approach to environmental and waste management to keep environmental impacts as low as reasonably achievable to improve stakeholder confidence and minimise the risk of inflated remediation costs.

Beyond compliance with the health, safety and environmental standards, the remediation of the remaining legacy sites should be considered as an investment in the creation of conditions needed for value-added economic development of these regions.

"The true goal of mine remediation has been achieved if the health and environmental hazards have been contained <u>*and*</u> *conditions created that facilitate future utilisation of the site, thus triggering economic development and revitalisation in the post-mining region."*

IMPLEMENTATION OF THE POLICIES RECOMMENDED BY UMREG AND CONSIDERATION OF PROJECT FEEDBACK



Appendix 4

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 percent U_3O_8 = 0.848 percent 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.

a) 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 A.

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 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 A. **Approximate Correlation of Terms used in Major Resources Classification Systems**

<table>
<tr><td></td><td colspan="3">IDENTIFIED RESOURCES</td><td colspan="3">UNDISCOVERED RESOURCES</td></tr>
<tr><td>NEA/IAEA</td><td colspan="2">REASONABLY ASSURED</td><td>INFERRED</td><td>PROGNOSTICATED</td><td colspan="2">SPECULATIVE</td></tr>
<tr><td rowspan="2">Australia</td><td colspan="2">DEMONSTRATED</td><td rowspan="2">INFERRED</td><td colspan="3" rowspan="2">UNDISCOVERED</td></tr>
<tr><td>MEASURED</td><td>INDICATED</td></tr>
<tr><td>Canada (NRCan)</td><td>MEASURED</td><td>INDICATED</td><td>INFERRED</td><td>PROGNOSTICATED</td><td colspan="2">SPECULATIVE</td></tr>
<tr><td>United States (DOE)</td><td colspan="2">REASONABLY ASSURED</td><td colspan="2">ESTIMATED ADDITIONAL</td><td colspan="2">SPECULATIVE</td></tr>
<tr><td>Russian Federation, Kazakhstan, Ukraine, Uzbekistan</td><td>A + B</td><td>C 1</td><td>C 2</td><td>P1</td><td>P2</td><td>P3</td></tr>
<tr><td>UNFC*</td><td colspan="2">G1 + G2</td><td>G3</td><td>G4</td><td colspan="2">G4</td></tr>
</table>

* United Nations Framework Classification correlation with NEA/IAEA and national classification systems is still under consideration.

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 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.

b) Cost categories

The cost categories, in United States dollars (USD), used in this report are defined as: <USD 40/kgU, <USD 80/kgU, and <USD 130/kgU. All resource categories are defined in terms of costs of uranium recovered at the ore processing plant

NOTE: It is not intended that the cost categories should follow fluctuations in market conditions.

Conversion of costs from other currencies into USD is done using an average exchange rate for the month of June in that year except for the projected costs for the year of the report, which uses the exchange rate of 1 January 2007 (Appendix 8).

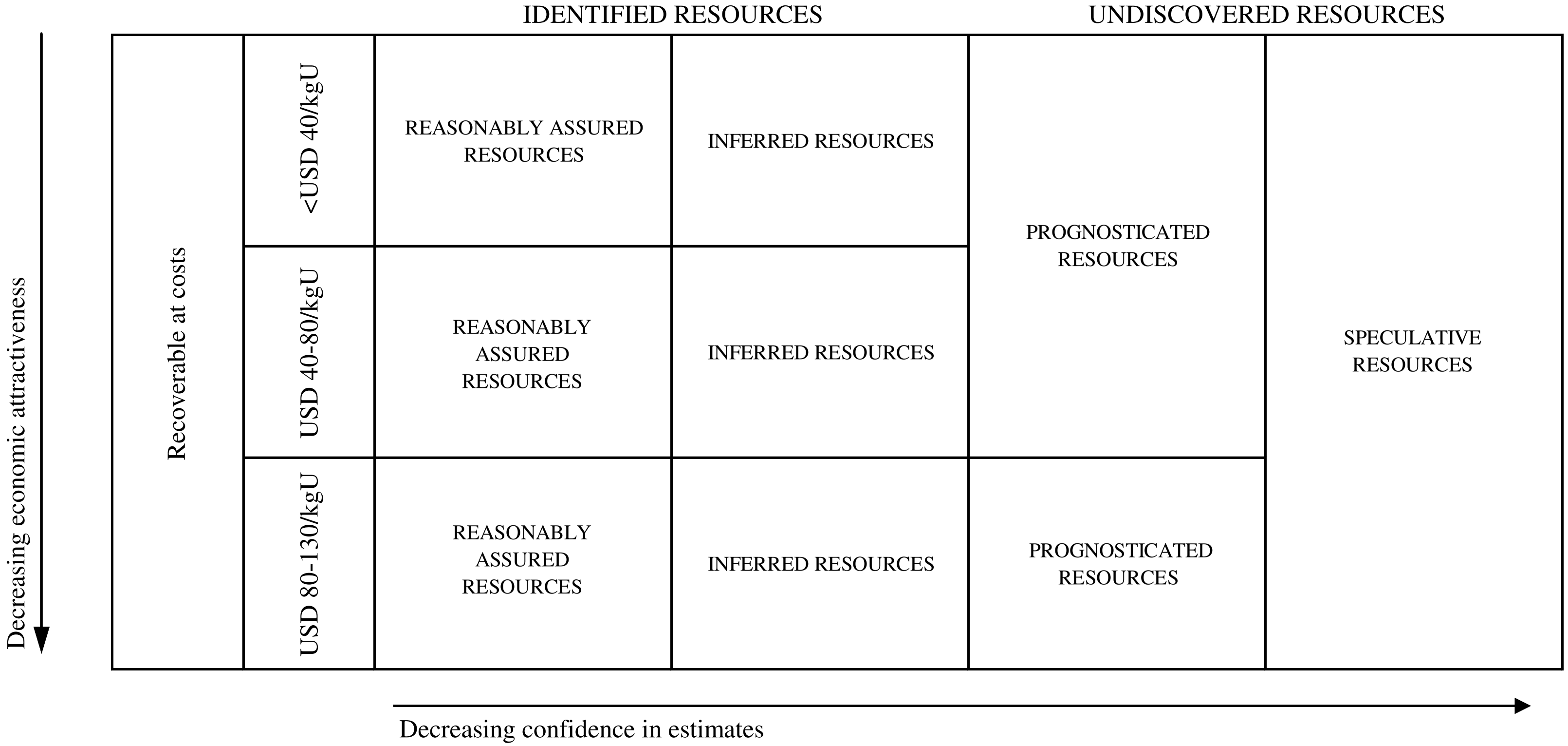
When estimating the cost of production for assigning resources within these cost categories, account has been taken of the following costs:

- 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.

c) Relationship between resource categories

Figure B 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 B. **NEA/IAEA Classification Scheme for Uranium Resources**



		IDENTIFIED RESOURCES		UNDISCOVERED RESOURCES	
Recoverable at costs	<USD 40/kgU	REASONABLY ASSURED RESOURCES	INFERRED RESOURCES	PROGNOSTICATED RESOURCES	SPECULATIVE RESOURCES
	USD 40-80/kgU	REASONABLY ASSURED RESOURCES	INFERRED RESOURCES		
	USD 80-130/kgU	REASONABLY ASSURED RESOURCES	INFERRED RESOURCES	PROGNOSTICATED RESOURCES	

d) Recoverable resources

RAR and Inferred Resource 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	80
ISL (acid)	75
ISL (alkaline)	70
Heap leaching	70
Block and stope leaching	75
Co-product or by-product	70
Unspecified method	75

SECONDARY SOURCES OF URANIUM TERMINOLOGY

a) 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.

b) Depleted uranium: Uranium where the ^{235}U assay is below the naturally occurring 0.7110%. (Natural uranium is a mixture of three isotopes, ^{238}U – accounting for 99.2836%, ^{235}U – 0.7110%, and ^{234}U – 0.0054%). Depleted uranium is a by-product of the enrichment process, where enriched uranium is produced from initial natural uranium feed material.

PRODUCTION TERMINOLOGY[1]

a) 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:

---

[1] IAEA (1984), *Manual on the Projection of Uranium Production Capability,* General Guidelines, Technical Report Series No. 238, Vienna, Austria.

i) **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.

ii) **Committed** production centres are those that are either under construction or are firmly committed for construction.

iii) **Planned** production centres are those for which feasibility studies are either completed or under way, but for which construction commitments have not yet been made. This class also includes those plants that are closed which would require substantial expenditures to bring them back into operation.

iv) **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.

b) 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 EAR-I. The projection is presented based on those resources recoverable at costs <USD 80/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).

c) 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.

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 phosphates: 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

a) Reactor-related requirements: Refers to natural uranium acquisitions *not* necessarily consumption during a calendar year.

ENVIRONMENTAL TERMINOLOGY[2]

a) 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.

b) 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.

c) Decontamination: The removal or reduction of radioactive or toxic chemical contamination using physical, chemical, or biological processes.

d) 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.

---

2. Definitions based on those published in OECD (2002), *Environmental Remediation of Uranium Production Facilities*, Paris.

e) Environmental restoration: Cleanup and restoration, according to predefined criteria, of sites contaminated with radioactive and/or hazardous substances during past uranium production activities.

f) 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.

g) Groundwater restoration: The process of returning affected groundwater to acceptable quality and quantity levels for future use.

h) Reclamation: The process of restoring a site to predefined conditions, which allows new uses.

i) 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.

j) 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.

k) Tailings impoundment: A structure in which the tailings are deposited to prevent their release into the environment.

l) 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

a) Uranium occurrence: A naturally occurring, anomalous concentration of uranium.

b) Uranium deposit: A mass of naturally occurring mineral from which uranium could be exploited at present or in the future.

c) Geologic types of uranium deposits[3]

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. Unconformity-related deposits.
2. Sandstone 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 content.

---

[3] 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.

1. **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*
     1. 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.
     2. 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.

2. **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 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).

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 Trekkopje 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.

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.

    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).

Appendix 5

ACRONYM LIST

AGR	Advanced gas-cooled reactor
AL	Acid leaching
ALKAL	Alkaline atmospheric leaching
BWR	Boiling water reactor
CANDU	***Can***adian ***d***euterium ***u***ranium
CWG	Crush-wet grind
DOE	Department of Energy (United States)
EC	European Commission
EIA	U.S. Energy Information Administration
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
ISL	*In situ* leaching
IX	Ion exchange
kg	Kilograms
km	Kilometre
LEU	Low enriched uranium
LWR	Light water reactor
MAGNOX	Magnesium oxide
MOX	Mixed oxide fuel
MWe	Megawatt electric

NEA	Nuclear Energy Agency
OECD	Organisation for Economic Co-operation and Development
OP	Open-pit
ppm	Part per million
Pu	Plutonium
PHWR	Pressurised heavy-water reactor
PWR	Pressurised water reactor
RAR	Reasonably assured resources
RBMK	Water-cooled, graphite-moderated reactor (Russian acronym)
SWU	Separative work unit
SX	Solvent extraction
t	Tonnes (metric tons)
Th	Thorium
tHM	Tonnes heavy metal
TOE	Tonnes oil equivalent
tU	Tonnes uranium
TVA	Tennessee Valley Administration
TWh	Terrawatt-hour
U	Uranium
UG	Underground mining
USSR	Union of Soviet Socialist Republics
VVER	Water-cooled, water-moderated reactor (Russian acronym)

Appendix 6

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.

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	3.2	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	0.490	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.

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 000kWh (final consumption) = 860 Mcal as WEC conversion factor.

Appendix 7

LISTING OF ALL RED BOOK EDITIONS (1965-2008) AND NATIONAL REPORTS

Listing of Red Book editions (1965-2008)

1.	OECD/ENEA	World Uranium and Thorium Resources, Paris, 1965
2.	OECD/ENEA	Uranium Resources, Revised Estimates, Paris, 1967
3.	OECD/ENEA-IAEA	Uranium Production and Short-Term Demand, Paris, 1969
4.	OECD/ENEA-IAEA	Uranium Resources, Production and Demand, Paris, 1970
5.	OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1973
6.	OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1975
7.	OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1977
8.	OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1979
9.	OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1982
10.	OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1983
11.	OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1986
12.	OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1988
13.	OECD/NEA-IAEA	Uranium Resources, Production and Demand, Paris, 1990
14.	OECD/NEA-IAEA	Uranium 1991: Resources, Production and Demand, Paris, 1992
15.	OECD/NEA-IAEA	Uranium 1993: Resources, Production and Demand, Paris, 1994
16.	OECD/NEA-IAEA	Uranium 1995: Resources, Production and Demand, Paris, 1996
17.	OECD/NEA-IAEA	Uranium 1997: Resources, Production and Demand, Paris, 1998
18.	OECD/NEA-IAEA	Uranium 1999: Resources, Production and Demand, Paris, 2000
19.	OECD/NEA-IAEA	Uranium 2001: Resources, Production and Demand, Paris, 2002
20.	OECD/NEA-IAEA	Uranium 2003: Resources, Production and Demand, Paris, 2004
21.	OECD/NEA-IAEA	Uranium 2005: Resources, Production and Demand, Paris, 2006
22.	OECD/NEA-IAEA	Uranium 2007: Resources, Production and Demand, Paris, 2008

INDEX OF NATIONAL REPORTS

	1965	**1967**	**1969**	**1970**	**1973**	**1975**	**1977**	**1979**	**1982**	**1983**	**1986**
Algeria						1975	1977	1979	1982		
Argentina		1967	1969	1970	1973	1975	1977	1979	1982	1983	1986
Armenia											
Australia		1967	1969	1970	1973	1975	1977	1979	1982	1983	1986
Austria							1977				
Bangladesh											1986
Belgium									1982	1983	1986
Benin											
Bolivia							1977	1979	1982	1983	1986
Botswana								1979		1983	1986
Brazil				1970	1973	1975	1977	1979	1982	1983	1986
Bulgaria											
Cameroon							1977		1982	1983	
Canada	1965	1967	1969	1970	1973	1975	1977	1979	1982	1983	1986
Central African Rep.				1970	1973		1977	1979			1986
Chile							1977	1979	1982	1983	1986
China											
Colombia							1977	1979	1982	1983	1986
Costa Rica									1982	1983	1986
Côte d'Ivoire									1982		
Cuba											
Czech Rep.											
Czech and Slovak Rep.											
Denmark (Greenland)	1965	1967	1969	1970	1973	1975	1977	1979	1982	1983	1986
Dominican Republic									1982		
Ecuador							1977		1982	1983	1986
Egypt							1977	1979			1986
El Salvador										1983	1986
Estonia											
Ethiopia								1979		1983	1986
Finland					1973	1975	1977	1979	1982	1983	1986
France	1965	1967	1969	1970	1973	1975	1977	1979	1982	1983	1986
Gabon		1967		1970	1973				1982	1983	1986
Germany				1970		1975	1977	1979	1982	1983	1986
Ghana							1977			1983	
Greece							1977	1979	1982	1983	1986
Guatemala											1986
Guyana								1979	1982	1983	1986

INDEX OF NATIONAL REPORTS (contd.)

1988	**1990**	**1992**	**1994**	**1996**	**1998**	**2000**	**2002**	**2004**	**2006**	**2008**	
							2002	2004	2006	2008	Algeria
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	Argentina
						2000	2002	2004	2006		Armenia
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	Australia
											Austria
1988											Bangladesh
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	Belgium
	1990										Benin
											Bolivia
1988											Botswana
		1992	1994	1996	1998	2000	2002	2004	2006	2008	Brazil
	1990	1992	1994	1996	1998					2008	Bulgaria
											Cameroon
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	Canada
											Central African Rep.
1988		1992	1994	1996	1998	2000	2002	2004	2006	2008	Chile
	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	China
1988	1990			1996	1998					2008	Colombia
1988	1990										Costa Rica
											Côte d'Ivoire
1988		1992		1996	1998						Cuba
			1994	1996	1998	2000	2002	2004	2006	2008	Czech Rep.
	1990										Czech and Slovak Rep.
	1990	1992		1996	1998			2004			Denmark (Greenland)
											Dominican Republic
1988											Ecuador
1988	1990	1992	1994	1996	1998	2000		2004	2006	2008	Egypt
											El Salvador
					1998			2004			Estonia
											Ethiopia
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	Finland
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	France
				1996	1998	2000	2002	2004	2006		Gabon
1988	1990	1992	1994	1996	1998	2000	2002		2006	2008	Germany
											Ghana
1988	1990	1992	1994	1996	1998						Greece
1988											Guatemala
											Guyana

INDEX OF NATIONAL REPORTS (contd.)

	1965	**1967**	**1969**	**1970**	**1973**	**1975**	**1977**	**1979**	**1982**	**1983**	**1986**
Hungary											
India	1965	1967		1970	1973	1975	1977	1979	1982	1983	1986
Indonesia							1977				1986
Iran, Islamic Rep. of							1977				
Ireland								1979	1982	1983	1986
Italy		1967		1970	1973	1975	1977	1979	1982	1983	1986
Jamaica									1982	1983	
Japan	1965	1967		1970	1973	1975	1977	1979	1982	1983	1986
Jordan							1977				1986
Kazakhstan											
Korea, Rep. of						1975	1977	1979	1982	1983	1986
Kyrgyzstan											
Lesotho											
Liberia							1977			1983	
Libyan Arab Jamahirya										1983	
Lithuania											
Madagascar						1975	1977	1979	1982	1983	1986
Malawi											
Malaysia										1983	1986
Mali											1986
Mauritania											
Mexico				1970	1973	1975	1977	1979	1982		1986
Mongolia											
Morocco	1965	1967				1975	1977	1979	1982	1983	1986
Namibia								1979	1982	1983	1986
Netherlands									1982	1983	1986
New Zealand		1967					1977	1979			
Niger		1967		1970	1973		1977				1986
Nigeria								1979			
Norway								1979	1982	1983	
Pakistan		1967									
Panama										1983	
Paraguay										1983	1986
Peru							1977	1979		1983	1986
Philippines							1977		1982	1983	1986

INDEX OF NATIONAL REPORTS (contd.)

1988	**1990**	**1992**	**1994**	**1996**	**1998**	**2000**	**2002**	**2004**	**2006**	**2008**	
		1992	1994	1996	1998	2000	2002	2004	2006	2008	Hungary
	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	India
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006		Indonesia
					1998	2000	2002	2004	2006	2008	Iran, Islamic Rep. of
		1992			1998						Ireland
1988		1992	1994	1996	1998	2000					Italy
											Jamaica
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	Japan
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	Jordan
			1994	1996	1998	2000	2002	2004	2006	2008	Kazakhstan
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	Korea, Rep. of
				1996			2002				Kyrgyzstan
1988											Lesotho
											Liberia
											Libyan Arab Jamahirya
			1994	1996	1998	2000	2002	2004	2006	2008	Lithuania
1988											Madagascar
						2000				2008	Malawi
1988	1990	1992	1994	1996	1998	2000	2002				Malaysia
1988											Mali
	1990										Mauritania
	1990	1992	1994	1996	1998	2000					Mexico
			1994	1996	1998						Mongolia
1988	1990				1998						Morocco
1988	1990			1996	1998	2000	2002	2004	2006	2008	Namibia
	1990	1992	1994	1996	1998	2000	2002				Netherlands
											New Zealand
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	Niger
											Nigeria
		1992		1996	1998						Norway
					1998	2000	2002				Pakistan
1988											Panama
											Paraguay
1988	1990	1992	1994	1996	1998	2000		2004	2006	2008	Peru
	1990		1994	1996	1998	2000	2002	2004	2006		Philippines

INDEX OF NATIONAL REPORTS (contd.)

	1965	**1967**	**1969**	**1970**	**1973**	**1975**	**1977**	**1979**	**1982**	**1983**	**1986**
Poland											
Portugal	1965	1967	1969	1970	1973	1975	1977	1979	1982	1983	1986
Romania											
Russian Fed.											
Rwanda											1986
Senegal									1982		
Slovak Rep.											
Slovenia											
Somalia							1977	1979			
South Africa	1965	1967	1969	1970	1973	1975	1977	1979	1982	1983	1986
Spain	1965	1967	1969	1970	1973	1975	1977	1979	1982	1983	1986
Sri Lanka							1977		1982	1983	1986
Sudan							1977				
Surinam									1982	1983	
Sweden	1965	1967	1969	1970	1973	1975	1977	1979	1982	1983	1986
Switzerland						1975	1977	1979	1982	1983	1986
Syrian Arab Rep.									1982	1983	1986
Tajikistan											
Tanzania											
Thailand							1977	1979	1982	1983	1986
Togo								1979			
Turkey					1973	1975	1977	1979	1982	1983	1986
Turkmenistan											
Ukraine											
United Kingdom						1975	1977	1979	1982	1983	1986
United States	1965	1967	1969	1970	1973	1975	1977	1979	1982	1983	1986
Uruguay							1977		1982	1983	1986
USSR											
Uzbekistan											
Venezuela											1986
Vietnam											
Yugoslavia											
Zaire		1967			1973		1977				
Zambia											1986
Zimbabwe									1982		

INDEX OF NATIONAL REPORTS (contd.)

1988	**1990**	**1992**	**1994**	**1996**	**1998**	**2000**	**2002**	**2004**	**2006**	**2008**	
						2000	2002			2008	Poland
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	Portugal
		1992	1994	1996	1998	2000	2002				Romania
			1994		1998	2000	2002	2004	2006	2008	Russian Fed.
											Rwanda
											Senegal
			1994	1996	1998	2000	2002	2004	2006	2008	Slovak Rep.
			1994	1996	1998		2002	2004	2006	2008	Slovenia
											Somalia
		1992	1994	1996	1998	2000	2002	2004	2006	2008	South Africa
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	Spain
1988											Sri Lanka
											Sudan
											Surinam
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	Sweden
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	Switzerland
1988	1990		1994								Syrian Arab Rep.
							2002				Tajikistan
	1990										Tanzania
1988	1990	1992	1994	1996	1998	2000	2002		2006		Thailand
											Togo
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	Turkey
								2004			Turkmenistan
			1994	1996	1998	2000	2002	2004	2006	2008	Ukraine
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	United Kingdom
1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	United States
1988	1990										Uruguay
		1992									USSR
			1994	1996	1998	2000	2002	2004	2006		Uzbekistan
1988											Venezuela
		1992	1994	1996	1998	2000	2002	2004	2006	2008	Vietnam
		1992									Yugoslavia
1988											Zaire
1988	1990	1992	1994	1996	1998						Zambia
1988		1992	1994	1996	1998						Zimbabwe

Appendix 8

CURRENCY EXCHANGE RATES*

(in national currency units per USD)

COUNTRY (currency abbreviation)	**June 2004**	**June 2005**	**June 2006**	**January 2007**
Afghanistan (AFA)	49.37	49.68	49.57	49.76
Algeria (DZD)	70.450	72.51	70.32	69
Argentina (ARS)	2.940	2.9	3.08	3.05
Armenia (AMD)	557.000	436	440	362
Australia (AUD)	1.400	1.31	1.31	1.27
Austria (EURO)	0.816	0.797	0.778	0.76
Belgium (EURO)	0.816	0.797	0.778	0.76
Brazil (BRL)	3.120	2.43	2.19	2.16
Bulgaria (BGN)	1.610	1.54	1.51	1.48
Canada (CAD)	1.360	1.26	1.1	1.16
Chile (CLP)	630.000	580	524	530
China (CNY)	8.266	8.266	8	7.82
Colombia (COP)	2 700.000	2 335	2 438	2 226
Cuba (CUP)	1.000	1	1	1
Czech Republic (CZK)	26.200	24.3	22	21
Denmark (DKK)	6.070	5.93	5.82	5.67
Egypt (EGP)	6.180	5.78	5.76	5.71
Finland (EURO)	0.816	0.797	0.778	0.76
France (EURO)	0.816	0.797	0.778	0.76
Gabon (XOF) [CFA Franc BEAC]	535.261	522.798	510.335	498.527
Germany (EURO)	0.816	0.797	0.778	0.76
Greece (EURO)	0.816	0.797	0.778	0.76
Hungary (HUF)	205.000	201	204	192
India (INR)	45.050	42.96	45.19	44.55
Indonesia (IDR)	8 800.000	9 400	9 200	9 015
Iran, Islamic Republic of	8 570	8 945	9 155	9 231
Italy (EURO)	0.816	0.797	0.778	0.76
Japan (JPY)	111.000	108	112	118
Jordan (JOD)	0.708	0.708	0.708	0.708
Kazakhstan (KZT)	135.500	130.9	122	127.6
Korea, Republic of (KRW)	1 166.000	990	933	927.55

COUNTRY (currency abbreviation)	**June 2004**	**June 2005**	**June 2006**	**January 2007**
Kyrgyzstan (KGS)	43.470	40.6	40.47	38.2
Lithuania (LTL)	2.817	2.752	2.686	2.624
Malawi (MWK)	106.060	114.84	140.18	137.31
Malaysia (MYR)	3.770	3.77	3.62	3.55
Mauritania (MRO)	264.230	264.5	276	270.61
Mexico (MXN)	11.400	10.94	11.29	10.84
Mongolia (MNT)	1 159.000	1 188	1 175	1 163
Morocco (MAD)	9.120	8.75	8.67	8.38
Namibia (NAD)	6.580	6.63	6.54	7
Netherlands (EURO)	0.816	0.797	0.778	0.76
Niger (XOF) [CFA Franc BCEAO]	535.261	522.798	510.335	498.527
Norway (NOK)	6.700	6.36	6.11	6.27
Peru (PEN)	3.480	3.25	3.27	3.2
Philippines (PHP)	55.670	54.4	52.92	49.28
Poland (PLN)	3.800	3.24	3.01	2.9
Portugal (EURO)	0.816	0.797	0.778	0.76
Romania (RON)	----	----	2.75	2.56
Russian Federation (RUB)	29.000	28	27	26.3
Serbia & Montenegro (CSD)	59.150	65.06	68.65	
Slovak Republic (SKK)	33.120	30.6	29.44	26.11
Slovenia (SIT, EUR)	SIT 195.000	SIT 190	SIT 186	EUR 182
South Africa (ZAR)	6.580	6.63	6.54	7
Spain (EURO)	0.816	0.797	0.778	0.76
Sweden (SEK)	7.420	7.32	7.21	6.87
Switzerland (CHF)	1.250	1.23	1.21	1.22
Syria (SYP)	51.720	53.15	52.2	52.21
Tajikistan (TJS)	3.010	3.1	3.25	3.47
Thailand (THB)	40.710	39.92	38.12	35.52
Turkey (TRY)	----	1.34	1.53	1.43
Ukraine (UAH)	5.330	5.02	5.01	5
United Kingdom (GBP)	0.545	0.548	0.533	0.511
United States (USD)	1.000	1.000	1.000	1.000
Uruguay (UYU)	29.700	24.4	23.9	24.25
Uzbekistan (UZS)	1 010.720	1 099.73	1 221.39	1 239
Viet Nam (VND)	15 680.000	15 765.000	15 935.000	16 061.000
Zambia (ZMK)	4 700.000	192	196.4	198.4
Zimbabwe (ZWD)	5 350.000	4 590	3 370	4 050

* *Source*: The Department of Finance of the United Nations Development Programme, New York.

Appendix 9

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 members of OECD.

1. North America

Canada*
Mexico*
United States of America*

2. Central and South America

Argentina
Bolivia
Brazil
Chile
Colombia
Costa Rica
Cuba
Ecuador
El Salvador
Guatemala
Jamaica
Paraguay
Peru
Uruguay
Venezuela

3. Western Europe

Austria*
Belgium*
Denmark*
Finland*
France*
Germany*
Ireland*
Italy*
Netherlands*
Norway*
Portugal*
Spain*
Sweden*
Switzerland*
United Kingdom*

4. Central, Eastern and South-eastern Europe

Armenia
Bulgaria
Croatia
Czech Republic*
Estonia
Greece*
Hungary*
Lithuania
Poland*
Romania
Russian Federation
Slovak Republic*
Slovenia
Turkey*
Ukraine

5. Africa

Algeria
Botswana
Central African Republic
Congo, Democratic Republic
Egypt
Gabon
Ghana
Lesotho
Libya
Madagascar
Malawi
Mali
Morocco
Namibia
Niger
Nigeria
Somalia
South Africa
Zambia
Zimbabwe

6. Middle East, Central and Southern Asia

Bangladesh
India
Iran, Islamic Republic of
Israel
Jordan
Kazakhstan
Kyrgyzstan
Pakistan
Sri Lanka
Syria
Tajikistan
Turkmenistan
Uzbekistan

7. South-eastern Asia

Indonesia
Malaysia
Philippines
Thailand
Vietnam

8. Pacific

Australia*
New Zealand*

9. East Asia[1]

China
Japan*
Mongolia
Korea, Republic of*
Korea, Democratic People's Republic of

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
Moldavia
Russian Federation
Tajikistan
Turkmenistan
Ukraine
Uzbekistan

European Union

Austria
Belgium
Bulgaria
Cyprus
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Latvia
Lithuania
Luxemburg
Malta
Netherlands
Poland
Portugal
Romania
Slovak Republic
Slovenia
Spain
Sweden
United Kingdom

---

[1] Includes Chinese Taipei.

Appendix 4

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 percent U_3O_8 = 0.848 percent 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.

a) 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 A.

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 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 A. **Approximate Correlation of Terms used in Major Resources Classification Systems**

<table>
<tr><td></td><td colspan="3">IDENTIFIED RESOURCES</td><td colspan="3">UNDISCOVERED RESOURCES</td></tr>
<tr><td>NEA/IAEA</td><td colspan="2">REASONABLY ASSURED</td><td>INFERRED</td><td>PROGNOSTICATED</td><td colspan="2">SPECULATIVE</td></tr>
<tr><td rowspan="2">Australia</td><td colspan="2">DEMONSTRATED</td><td rowspan="2">INFERRED</td><td colspan="3" rowspan="2">UNDISCOVERED</td></tr>
<tr><td>MEASURED</td><td>INDICATED</td></tr>
<tr><td>Canada (NRCan)</td><td>MEASURED</td><td>INDICATED</td><td>INFERRED</td><td>PROGNOSTICATED</td><td colspan="2">SPECULATIVE</td></tr>
<tr><td>United States (DOE)</td><td colspan="2">REASONABLY ASSURED</td><td colspan="2">ESTIMATED ADDITIONAL</td><td colspan="2">SPECULATIVE</td></tr>
<tr><td>Russian Federation, Kazakhstan, Ukraine, Uzbekistan</td><td>A + B</td><td>C 1</td><td>C 2</td><td>P1</td><td>P2</td><td>P3</td></tr>
<tr><td>UNFC*</td><td colspan="2">G1 + G2</td><td>G3</td><td>G4</td><td colspan="2">G4</td></tr>
</table>

* United Nations Framework Classification correlation with NEA/IAEA and national classification systems is still under consideration.

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 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.

b) Cost categories

The cost categories, in United States dollars (USD), used in this report are defined as: <USD 40/kgU, <USD 80/kgU, and <USD 130/kgU. All resource categories are defined in terms of costs of uranium recovered at the ore processing plant

NOTE: It is not intended that the cost categories should follow fluctuations in market conditions.

Conversion of costs from other currencies into USD is done using an average exchange rate for the month of June in that year except for the projected costs for the year of the report, which uses the exchange rate of 1 January 2007 (Appendix 8).

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.

c) Relationship between resource categories

Figure B 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 B. **NEA/IAEA Classification Scheme for Uranium Resources**

		IDENTIFIED RESOURCES		UNDISCOVERED RESOURCES	
Recoverable at costs	<USD 40/kgU	REASONABLY ASSURED RESOURCES	INFERRED RESOURCES	PROGNOSTICATED RESOURCES	SPECULATIVE RESOURCES
	USD 40-80/kgU	REASONABLY ASSURED RESOURCES	INFERRED RESOURCES		
	USD 80-130/kgU	REASONABLY ASSURED RESOURCES	INFERRED RESOURCES	PROGNOSTICATED RESOURCES	

Decreasing economic attractiveness

Decreasing confidence in estimates

d) Recoverable resources

RAR and Inferred Resource 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	80
ISL (acid)	75
ISL (alkaline)	70
Heap leaching	70
Block and stope leaching	75
Co-product or by-product	70
Unspecified method	75

SECONDARY SOURCES OF URANIUM TERMINOLOGY

a) 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.

b) Depleted uranium: Uranium where the ^{235}U assay is below the naturally occurring 0.7110%. (Natural uranium is a mixture of three isotopes, ^{238}U – accounting for 99.2836%, ^{235}U – 0.7110%, and ^{234}U – 0.0054%). Depleted uranium is a by-product of the enrichment process, where enriched uranium is produced from initial natural uranium feed material.

PRODUCTION TERMINOLOGY[1]

a) 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:

---

[1] IAEA (1984), *Manual on the Projection of Uranium Production Capability,* General Guidelines, Technical Report Series No. 238, Vienna, Austria.

i) **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.

ii) **Committed** production centres are those that are either under construction or are firmly committed for construction.

iii) **Planned** production centres are those for which feasibility studies are either completed or under way, but for which construction commitments have not yet been made. This class also includes those plants that are closed which would require substantial expenditures to bring them back into operation.

iv) **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.

b) 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 EAR-I. The projection is presented based on those resources recoverable at costs <USD 80/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).

c) 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.

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 phosphates: 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

a) Reactor-related requirements: Refers to natural uranium acquisitions *not* necessarily consumption during a calendar year.

ENVIRONMENTAL TERMINOLOGY[2]

a) 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.

b) 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.

c) Decontamination: The removal or reduction of radioactive or toxic chemical contamination using physical, chemical, or biological processes.

d) 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.

---

[2] Definitions based on those published in OECD (2002), *Environmental Remediation of Uranium Production Facilities*, Paris.

e) Environmental restoration: Cleanup and restoration, according to predefined criteria, of sites contaminated with radioactive and/or hazardous substances during past uranium production activities.

f) 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.

g) Groundwater restoration: The process of returning affected groundwater to acceptable quality and quantity levels for future use.

h) Reclamation: The process of restoring a site to predefined conditions, which allows new uses.

i) 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.

j) 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.

k) Tailings impoundment: A structure in which the tailings are deposited to prevent their release into the environment.

l) 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

a) Uranium occurrence: A naturally occurring, anomalous concentration of uranium.

b) Uranium deposit: A mass of naturally occurring mineral from which uranium could be exploited at present or in the future.

c) Geologic types of uranium deposits[3]

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. Unconformity-related deposits.
2. Sandstone 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 content.

---

[3] 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.

1. **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*
     1. 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.
     2. 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.

2. **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 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).

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 Trekkopje 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.

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.

    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).

Appendix 5

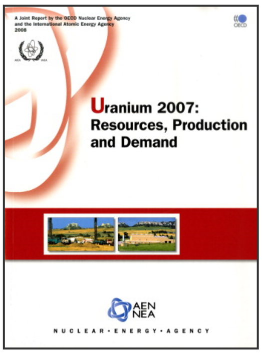
ACRONYM LIST

AGR	Advanced gas-cooled reactor
AL	Acid leaching
ALKAL	Alkaline atmospheric leaching
BWR	Boiling water reactor
CANDU	***Can***adian ***d***euterium ***u***ranium
CWG	Crush-wet grind
DOE	Department of Energy (United States)
EC	European Commission
EIA	U.S. Energy Information Administration
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
ISL	*In situ* leaching
IX	Ion exchange
kg	Kilograms
km	Kilometre
LEU	Low enriched uranium
LWR	Light water reactor
MAGNOX	Magnesium oxide
MOX	Mixed oxide fuel
MWe	Megawatt electric

NEA	Nuclear Energy Agency
OECD	Organisation for Economic Co-operation and Development
OP	Open-pit
ppm	Part per million
Pu	Plutonium
PHWR	Pressurised heavy-water reactor
PWR	Pressurised water reactor
RAR	Reasonably assured resources
RBMK	Water-cooled, graphite-moderated reactor (Russian acronym)
SWU	Separative work unit
SX	Solvent extraction
t	Tonnes (metric tons)
Th	Thorium
tHM	Tonnes heavy metal
TOE	Tonnes oil equivalent
tU	Tonnes uranium
TVA	Tennessee Valley Administration
TWh	Terrawatt-hour
U	Uranium
UG	Underground mining
USSR	Union of Soviet Socialist Republics
VVER	Water-cooled, water-moderated reactor (Russian acronym)

TABLE OF CONTENTS

APPENDICES



Uranium 2007

Resources, Production and Demand

Please cite this chapter as:

OECD/International Atomic Energy Agency (2008), “Appendices”, in *Uranium 2007: Resources, Production and Demand*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/uranium-2007-46-en