I. URANIUM SUPPLY

This chapter summarises the current status of worldwide uranium resources, exploration and production. In addition, production capabilities in reporting countries for the period ending in the year 2030 are presented and discussed.

A. URANIUM RESOURCES

Identified Resources (previously "Known Conventional Resources")

Identified Resources consist of ***Reasonably Assured Resources*** (RAR) and ***Inferred Resources*** (previously EAR-I), recoverable at a cost of less than USD 130/kgU (<USD 130/kgU).[1] Relative changes in different resource and cost categories of Identified Resources between this edition and the 2005 edition of the Red Book are summarised in Table 1. As shown in Table 1, Identified Resources <USD 130/kgU increased significantly between 2005 and 2007. This increase is mainly the result of reported increases by Australia, the Russian Federation, South Africa and Ukraine. The overall increase in Identified Resources recoverable at <USD 130/kgU between 2005 and 2007 (about 726 000 tU) is equivalent to about 11 years of 2006 uranium requirements. The most significant change occurred in the Inferred Resources <USD 40/kgU, which saw an increase of about 405 000 tU. Though some of these reported increases are due to new discoveries resulting from increased exploration, it is important to note that the bulk of the increases are due to re-evaluations reflecting the effects of higher uranium prices on cut-off grades. Current estimates of Identified Resources, RAR and Inferred Resources, on a country-by-country basis, are presented in Tables 2, 3 and 4, respectively.[2]

Distribution of Identified Resources by categories and cost ranges

The most significant changes between 2005 and 2007 in Identified Resources (Table 1) occurred in Australia, Kazakhstan, the Russian Federation, South Africa and Ukraine, and to a lesser extent in Bulgaria, Canada, China, Jordan and Niger. The distribution of Identified Resources, RAR and Inferred Resources, among countries with major resources, is shown in Figures 1, 2 and 3, respectively.

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1. All Identified Resources are reported as recoverable uranium. In cases where resources were reported by countries as *in situ*, resource figures were adjusted to estimate recoverable resources either by using recovery factors provided by the country or applying Secretariat estimates according to expected production method (see ***Recoverable Resources*** in Appendix 4).

2. It should be noted that the United States does not report resources in the Inferred Resource category.

Table 1. **Changes in Identified Resources 2005-2007**
(1 000 tU)

Resource category	2005	2007	Changes*
Identified (Total)			
<USD 130/kgU	4 743	5 469	+ 726
<USD 80/kgU	3 804	> 4 456	+ 652
<USD 40/kgU**	> 2 746	2 970	+ 224
RAR			
<USD 130/kgU	3 297	> 3 338	+ 41
<USD 80/kgU	2 643	2 598	– 45
<USD 40/kgU**	> 1 947	> 1 766	– 181
Inferred Resources			
<USD 130/kgU	1 446	> 2 130	+ 684
<USD 80/kgU	1 161	> 1 858	+ 697
<USD 40/kgU**	> 799	1 204	+ 405

* Changes might not equal differences between 2007 and 2005 because of independent rounding.

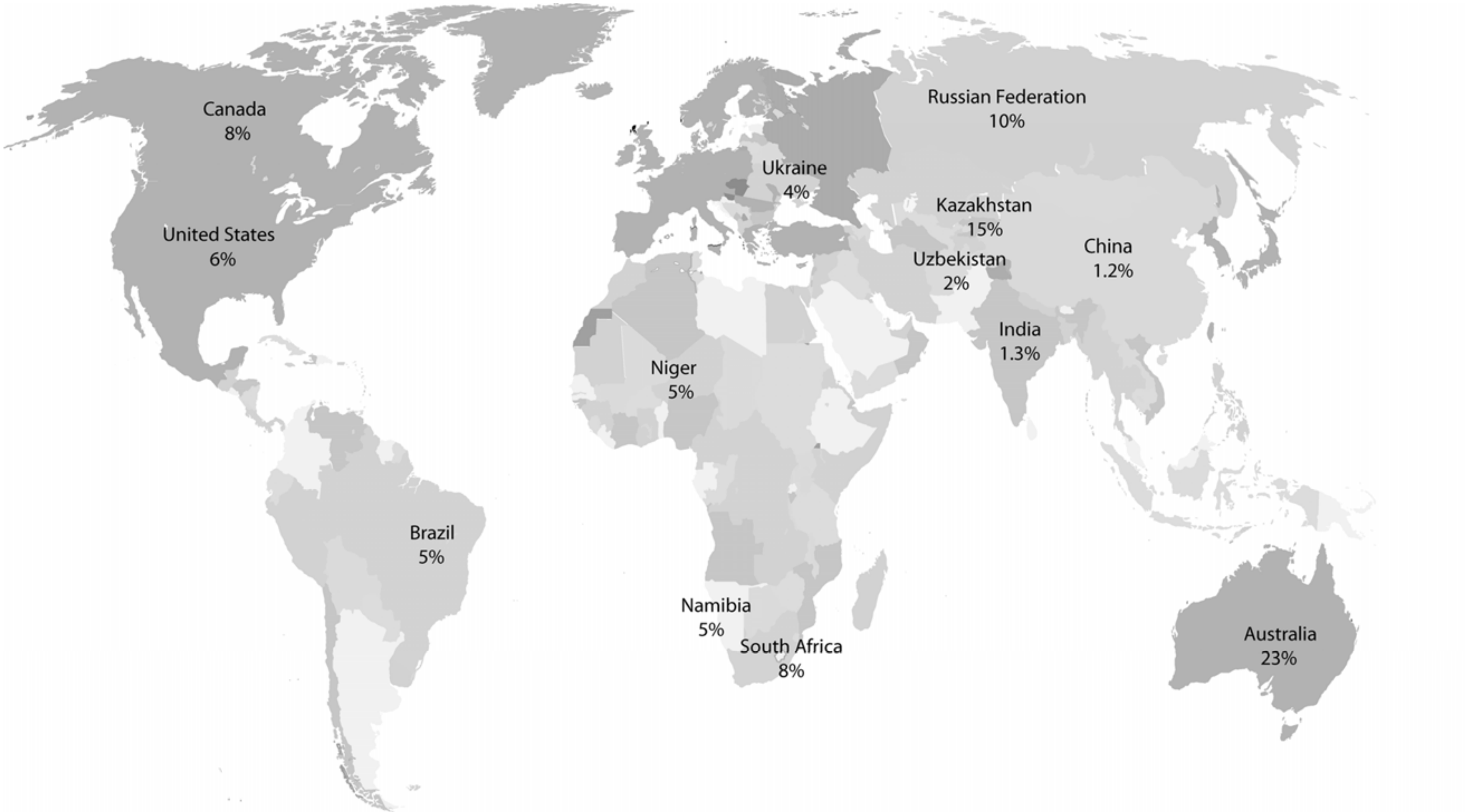
** Resources in the cost categories of <USD 40/kgU are likely higher than reported, because several countries have indicated that either detailed estimates are not available, or the data are confidential.

RAR recoverable at costs <USD 40/kgU, the most economically attractive category, decreased significantly by 181 000 tU since 2005 (about 9%). RAR at <USD 130/kgU increased by about 41 000 tU compared to 2005 (about 1%). Although most of these changes were the result of re-evaluation of known deposits and their transfer to and from other resource categories, additions to resource totals from deposits that had not been previously reported were also important (e.g. the Russian Federation and Ukraine; Table 5). Of particular note are changes reported by Kazakhstan and Niger. In Kazakhstan, RAR available at <USD 130/kgU decreased by almost 136 000 tU and in Niger, total resources available at <USD 130/kgU increased overall by more than 60 000 tU but lower cost resources decreased considerably (over 150 000 tU at <USD 40/kgU and over 135 000 tU at <USD 80/kgU).

Inferred Resources recoverable at <USD 130/kgU increased by about 684 000 tU, compared to 2005 (about 47%). Inferred Resource increases were greatest in Australia, Kazakhstan, the Russian Federation, South Africa and Ukraine. These changes (Table 5) are mainly related to additional resources defined during exploration and development activities (Australia, Niger).

Together, the changes in Identified Resources (i.e. RAR plus Inferred Resources), recoverable at a cost of <USD 40/kgU, significantly increased by about 224 000 tU (about 8% from 2005) and at costs <USD 130/kgU increased by even more (726 000 tU, some 15% greater than in 2005). These changes are mainly the result of increased resources reported in Australia, the Russian Federation and South Africa.

Figure 1. **Global distribution of Identified Resources** (<USD 130/kgU)



The global distribution of Identified Resources amongst 13 countries that are either major uranium producers or have significant plans for growth of nuclear generating capacity illustrates the widespread distribution of these resources. Together, these 13 countries are endowed with about 93% of the identified global resource base in this cost category (the remaining 7% are distributed among another 30 countries). The widespread distribution of uranium resources is an important geographic aspect of nuclear energy in light of security of energy supply.

Table 2. **Identified Resources (RAR + Inferred)**
(recoverable resources as of 1 January 2007, tonnes U, rounded to nearest 100 tonnes)

COUNTRY	Cost ranges		
	< USD 40/kgU	< USD 80/kgU	< USD 130/kgU
Algeria (b, c)	NA	19 500	19 500
Argentina	7 100	11 000	12 000
Australia	1 196 000	1 216 000	1 243 000
Brazil (e)	139 600	231 000	278 400
Canada	352 400	423 200	423 200
Central African Republic (a, b, c)	NA	6 000	12 000
Chile (c)	NA	NA	1 500
China (c)	39 300	61 900	67 900
Congo, Dem. Rep. of (a, b, c)	NA	2 700	2 700
Czech Republic	0	700	700
Denmark (a, b, c)	0	0	32 300
Finland (b, c)	0	0	1 100
France (a)	0	0	11 700
Gabon (a, b)	0	0	5 800
Germany (b)	0	0	7 000
Greece (a, b)	1 000	7 000	7 000
India (c, d)	NA	NA	72 900
Indonesia (a, b, c)	0	300	5 800
Iran, Islamic Republic of (c)	0	0	1 600
Italy (a, b)	NA	4 800	6 100
Japan (b)	0	0	6 600
Jordan (c)	111 800	111 800	111 800
Kazakhstan (c)	517 300	751 600	817 300
Malawi (a, b, c)	NA	9 600	11 600
Mexico (a, b, c)	0	0	1 800
Mongolia (a, b, c)	16 300	62 000	62 000
Namibia * (e)	116 400	230 300	275 000
Niger	34 200	75 200	274 000
Peru (c)	0	2 900	2 900
Portugal	0	5 700	7 200
Romania (a)	0	0	6 700
Russian Federation	83 600	495 400	545 600
Slovenia (b, c)	0	3 300	5 500
Somalia (a, b, c)	0	0	7 600
South Africa (b, f)	234 700	343 200	435 100
Spain (b)	0	2 500	11 300
Sweden (a, b)	0	0	10 000
Turkey (b, c)	0	7 300	7 300
Ukraine (c)	34 100	184 100	199 500
United States (b)	NA	99 000	339 000
Uzbekistan * (a, c)	86 200	86 200	111 000
Vietnam (c)	NA	800	6 400
Zimbabwe (a, b, c)	NA	1 400	1 400
Total (g)	**2 970 000**	**4 456 400**	**5 468 800**

NA Data not available. * Secretariat estimate.
(a) Not reported in 2007 responses, data from previous Red Book.
(b) Assessment not made within the last five years.
(c) *In situ* resources were adjusted by the Secretariat to estimate recoverable resources using recovery factors provided by countries or estimated by the Secretariat according to the expected production method.
(d) Cost data not provided, therefore resources are reported in the < USD 130/kgU category.
(e) Data from previous Red Book, reduced by past production.
(f) Resource estimates do not account for production.
(g) Totals related to cost ranges <USD 40/kgU and <USD 80/kgU are higher than reported in the tables because certain countries do not report resource estimates, mainly for reasons of confidentiality.

Table 3. **Reasonably Assured Resources (RAR)**
(recoverable resources as of 1 January 2007, tonnes U, rounded to nearest 100 tonnes)

COUNTRY	Cost ranges		
	< USD 40/kgU	< USD 80/kgU	< USD 130/kgU
Algeria (b, c)	NA	19 500	19 500
Argentina	5 100	9 000	9 000
Australia	709 000	714 000	725 000
Brazil (e)	139 600	157 400	157 400
Canada	270 100	329 200	329 200
Central African Republic (a, b, c)	NA	6 000	12 000
Chile (c)	NA	NA	800
China (c)	31 800	44 300	48 800
Congo, Dem. Rep. of (a, b, c)	NA	1 400	1 400
Czech Republic	0	600	600
Denmark (a, b, c)	0	0	20 300
Finland (b, c)	0	0	1 100
Gabon (a, b)	0	0	4 800
Germany (b)	0	0	3 000
Greece (a, b)	1 000	1 000	1 000
India (c, d)	NA	NA	48 900
Indonesia (a, b, c)	0	300	4 600
Iran, Islamic Republic of (c)	0	0	500
Italy (a, b)	NA	4 800	4 800
Japan (b)	0	0	6 600
Jordan (c)	44 000	44 000	44 000
Kazakhstan (c)	235 500	344 200	378 100
Malawi (a, b, c)	NA	9 600	11 600
Mexico (a, b, c)	0	0	1 300
Mongolia (a, b, c)	8 000	46 200	46 200
Namibia * (e)	56 000	145 100	176 400
Niger	21 300	44 300	243 100
Peru (c)	0	1 400	1 400
Portugal (a)	0	4 500	6 000
Romania (a)	0	0	3 100
Russian Federation	47 500	172 400	172 400
Slovenia (b, c)	0	1 000	1 000
Somalia (a, b, c)	0	0	5 000
South Africa (b, f)	114 900	205 900	284 400
Spain (b)	0	2 500	4 900
Sweden (a, b)	0	0	4 000
Turkey (b, c)	0	7 300	7 300
Ukraine (c)	27 400	126 500	135 000
United States (b)	NA	99 000	339 000
Uzbekistan * (a, c, e)	55 200	55 200	72 400
Vietnam (c)	NA	NA	1 000
Zimbabwe (a, b, c)	NA	1 400	1 400
Total (g)	**1 766 400**	**2 598 000**	**3 338 300**

NA Data not available. * Secretariat estimate.

(a) Not reported in 2007 responses, data from previous Red Book.

(b) Assessment not made within the last five years.

(c) *In situ* resources were adjusted by the Secretariat to estimate recoverable resources using recovery factors provided by countries or estimated by the Secretariat according to the expected production method.

(d) Cost data not provided, therefore resources are reported in the < USD 130/kgU category.

(e) Data from previous Red Book, reduced by past production.

(f) Resource estimates do not account for production.

(g) Totals related to cost ranges <USD 40/kgU and <USD 80/kgU are higher than reported in the tables because certain countries do not report resource estimates, mainly for reasons of confidentiality.

Table 4. **Inferred Resources**
(recoverable resources as of 1 January 2007, tonnes U, rounded to nearest 100 tonnes)

COUNTRY	Cost ranges		
	< USD 40/kgU	< USD 80/kgU	< USD 130/kgU
Argentina	2 000	2 000	3 000
Australia	487 000	502 000	518 000
Brazil (b)	0	73 600	121 000
Canada	82 300	94 000	94 000
Chile (c)	NA	NA	700
China (c)	7 500	17 600	19 100
Congo, Dem. Rep. of (a, b, c)	NA	1 300	1 300
Czech Republic	0	100	100
Denmark (a, b, c)	0	0	12 000
France (a)	0	0	11 700
Gabon (a, b)	0	0	1 000
Germany (b)	0	0	4 000
Greece (a, b)	NA	6 000	6 000
India (c, d)	NA	NA	24 000
Indonesia (a, b, c)	0	0	1 200
Iran, Islamic Republic of (c)	0	0	1 100
Italy (a, b)	0	0	1 300
Jordan (c)	67 800	67 800	67 800
Kazakhstan (c)	281 800	407 400	439 200
Mexico (a, b, c)	0	0	500
Mongolia (a, b, c)	8 300	15 800	15 800
Namibia (a, c)	60 400	85 200	98 600
Niger	12 900	30 900	30 900
Peru (c)	NA	1 500	1 500
Portugal	0	1 200	1 200
Romania (a, b, c)	0	0	3 600
Russian Federation	36 100	323 000	373 300
Slovenia (b, c)	0	2 300	4 500
Somalia (a, b, c)	0	0	2 600
South Africa (b)	119 800	137 300	150 700
Spain (b)	0	0	6 400
Sweden (a, b)	0	0	6 000
Ukraine (c)	6 700	57 600	64 500
Uzbekistan (a, c)	31 000	31 000	38 600
Vietnam (c)	NA	800	5 400
Total (e)	**1 203 600**	**1 858 400**	**2 130 600**

NA Data not available.
(a) Not reported in 2007 responses, data from previous Red Book using Inferred or EAR-I data.
(b) Assessment not made within the last five years.
(c) *In situ* resources were adjusted to estimate recoverable resources, using recovery factors provided by the countries or estimated by the Secretariat according to the expected production method.
(d) Cost data not provided, therefore resources are reported in the < USD 130/kgU category.
(e) Total related to cost range < USD 40/kgU is higher than reported in the tables because certain countries do not report resource estimates, mainly for reasons of confidentiality.

Distribution of resources by production method

In 2007, countries reported Identified Resources by cost categories and by the expected production method, i.e., ***open-pit*** or ***underground*** mining, ***in situ leaching***, ***heap leaching or in-place leaching***, ***co-product/by-product*** or as unspecified.

Of the low-cost RAR (<USD 40/kgU) reported by mining method, recovery as a co-product/by-product is the most important (mainly in Australia and South Africa), followed closely by underground mining (Table 6). Significant portions of these low-cost resources are also expected to be recovered by *in situ* leaching (ISL), underlining the importance of this method in future production. With respect to RAR recoverable at costs <USD 130/kgU, most are expected to be produced by underground mining (almost 1/3 of the reported resources), followed by open-pit mining then by co-product/by-product and ISL.

Similar observations may be made for the Inferred Resources (Table 7). In the <USD 40/kgU category, uranium that would be recovered as a co-product/by-product represents the most important proposed production method, followed closely by ISL. In the <USD 130/kgU category, underground mining is expected to be the most important production method (about 1/3 of the reported resources with a specified production method), followed by recovery as co-product/by-product, ISL and open-pit mining.

Distribution of resources by deposit type

In 2007, countries reported Identified Resources by cost categories and by geological types of deposits, i.e., unconformity related, sandstone, hematite breccia complex, quartz-pebble conglomerate, vein intrusive, volcanic and caldera-related, metasomatite or as other. Definition of the deposit types can be found in the glossary of definitions in Appendix 4.

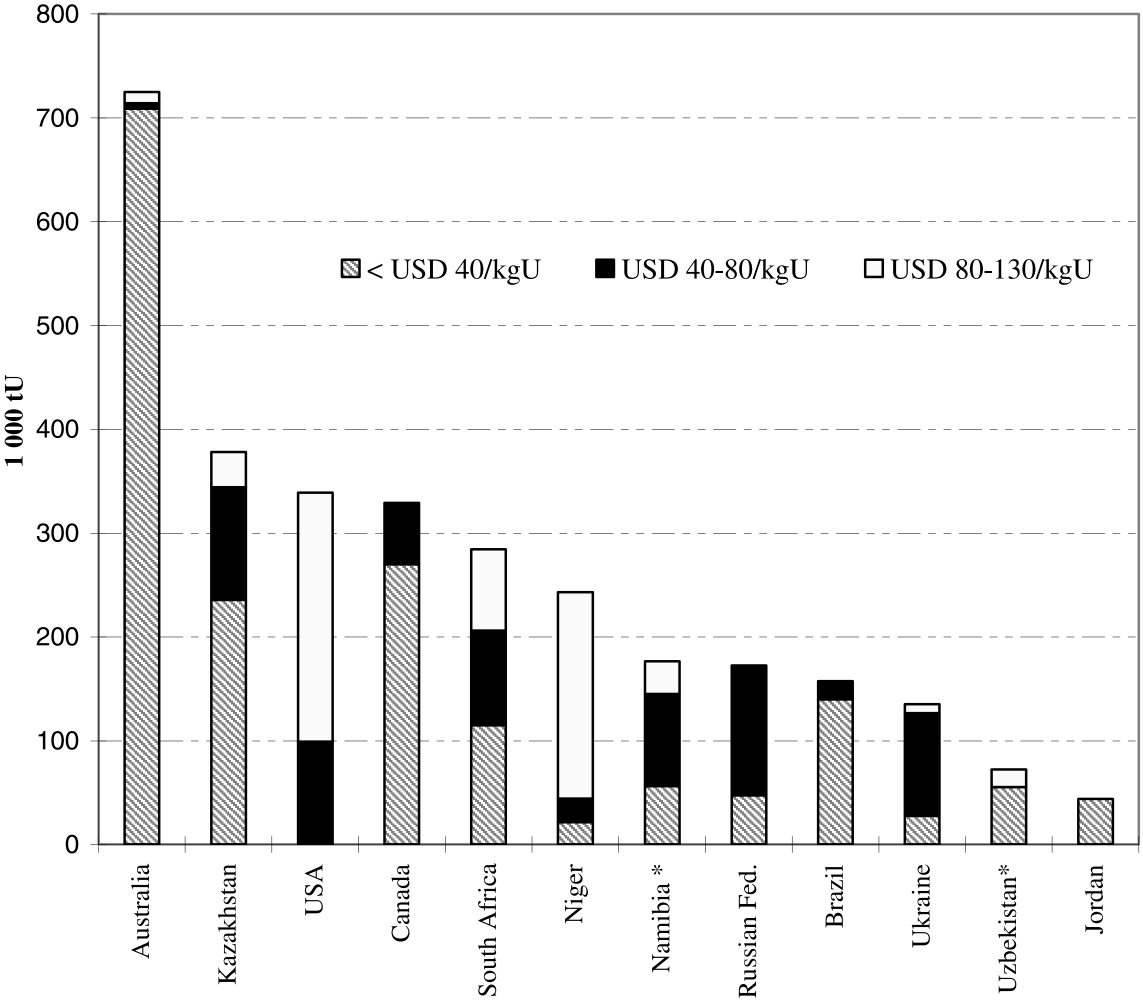
In the low cost (<USD 40/kgU) category, almost all (about 72%) the RAR reported by deposit type belong to the hematite breccia complex (in Australia), unconformity related (in Canada and Australia) and sandstone (in Kazakhstan) categories (Table 8). In the <USD 130/kgU category, sandstone related resources (in the United States, Kazakhstan and Niger) is the most important category, followed by hematite breccia complex and unconformity related deposit types.

Similar observations can be made for the Inferred Resources (Table 9). In the <USD 40/kgU category, resources related to hematite breccia complex (in Australia) are the most important, closely followed by resources related to sandstone deposits (in Kazakhstan). In the <USD 130/kgU category, resources related to sandstone deposits (in Kazakhstan and Russia) are the most important, followed by resources related to hematite breccia complex and metasomatite (in Russia and Ukraine) deposits. Also worthy of mention is the relative importance of resources related to vein-type deposits (mainly in Kazakhstan) in this cost category.

Table 5. **Major Identified Resource changes by country**
(recoverable resources in 1 000 tonnes U)

Country	Resource category	2005	2007	Changes	Reasons
Australia	RAR <USD 130/kgU	747	725	-22	Additional resources defined at Olympic Dam, Ranger, Mt Fitch, Mt Gee, Westmoreland and Valhalla deposits.
	Inferred				
	<USD 40/kgU	343	487	+144	
	<USD 80/kgU	360	502	+142	
	<USD 130/kgU	396	518	+122	
Bulgaria	RAR <USD 80/kgU	6	0	-6	Previously estimated resources considered non-economic after re-evaluation.
	Inferred <USD 80/kgU	6	0	-6	
Canada	RAR <USD 40/kgU	287	270	-17	Depletion of resources by past production.
China	RAR				Increase of known resources in the Zaohuohao (Erdos basin) and Wukueqi (Yili basin) ISL deposits.
	<USD 40/kgU	26	32	+6	
	<USD 130/kgU	38	49	+11	
Jordan	RAR <USD 40/kgU	30	44	+14	Re-evaluation of the Central Jordan deposits.
	Inferred <USD 40/kgU	49	68	+19	
Kazakhstan	RAR				Re-evaluation.
	<USD 40/kgU	279	236	-43	
	<USD 80/kgU	378	344	-34	
	<USD 130/kgU	514	378	-136	
	Inferred				
	<USD 40/kgU	129	282	+153	
	<USD 80/kgU	228	407	+179	
	<USD 130/kgU	302	439	+137	
Niger	RAR				Re-evaluation following development drilling and feasibility studies.
	<USD 40/kgU	173	21	-152	
	<USD 80/kgU	180	44	-136	
	<USD 130/kgU	180	243	+63	
	Inferred				
	<USD 40/kgU	0	13	+ 13	
	<USD 80/kgU	45	31	-14	
	<USD 130/kgU	45	31	-14	
Russia	RAR				Re-evaluation; depletion by mining.
	<USD 40/kgU	58	48	-10	
	<USD 80/kgU	132	172	+40	
	Inferred				
	<USD 40/kgU	22	36	+14	
	<USD 80/kgU	41	323	+282	
	<USD 130/kgU	41	373	+332	
South Africa	RAR				Increase of resources with the re-opening of two gold mines, resulting in their uranium resources becoming potentially exploitable again, and to the results of exploration and development activities.
	<USD 40/kgU	89	115	+26	
	<USD 80/kgU	177	206	+29	
	<USD 130/kgU	256	284	+28	
	Inferred				
	<USD 40/kgU	55	120	+65	
	<USD 80/kgU	72	137	+65	
	<USD 130/kgU	85	151	+65	
Ukraine	RAR <USD 80/kgU	58	126	+68	Re-evaluation of resources and addition of Central, Novokonstantinovskoye and Podgaytsevskoye deposits.
	Inferred <USD 80/kgU	17	58	+41	

Figure 2. **Distribution of Reasonably Assured Resources (RAR) among countries with major resources**



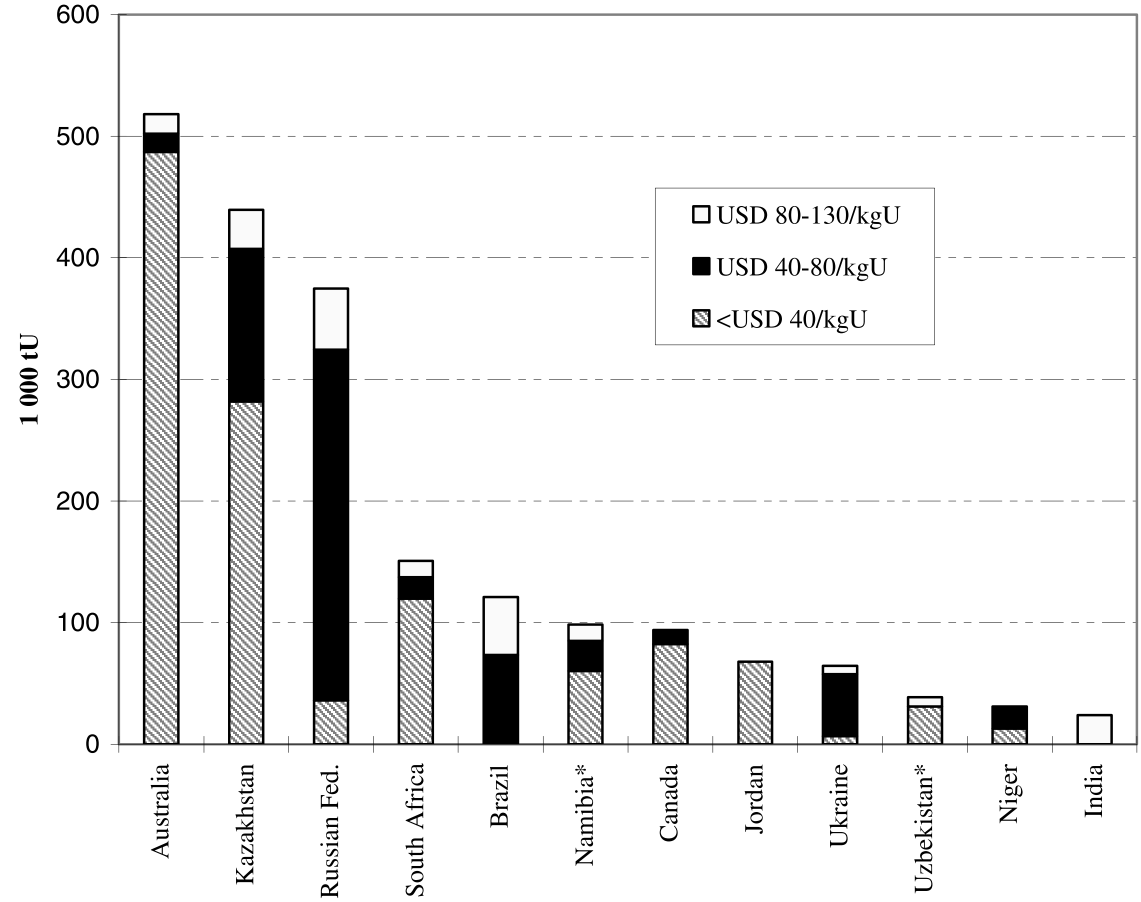
* Secretariat estimate.

Table 6. **Reasonably Assured Resources (RAR) by production method**
(tonnes U)

	<USD 40/kgU	**<USD 80/kgU**	**<USD 130/kgU**
Open-pit mining	300 700	456 700	797 100
Underground mining	541 000	944 200	1 225 500
In situ leaching	312 200	362 500	419 700
Heap leaching*	36 800	52 500	53 600
In-place leaching	300	8 600	8 600
Co-product / by-product	547 100	606 500	606 500
Unspecified mining method	28 300	167 000	227 300
Total	**1 766 400**	**2 598 000**	**3 338 300**

* Secretariat estimate.

Figure 3. **Distribution of Inferred Resources among countries with major resources**



*	Secretariat estimate.

Table 7. **Inferred Resources by proposed production method**
(tonnes U)

	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU
Open-pit mining	202 100	199 300	251 900
Underground mining	265 700	692 400	767 000
In situ leaching	344 400	378 200	389 700
Heap leaching*	12 700	22 300	23 900
In-place leaching	1 500	24 800	24 800
Co-product / by-product	367 000	445 800	493 200
Unspecified mining method	10 200	95 600	180 100
Total	**1 203 600**	**1 858 400**	**2 130 600**

*	Secretariat estimate.

Table 8. **Reasonably Assured Resources (RAR) by deposit type**
(tonnes U)

	<USD 40/kgU	**<USD 80/kgU**	**<USD 130/kgU**
Unconformity-related	424 100	485 200	491 600
Sandstone	347 800	537 300	999 500
Hematite breccia complex	492 300	492 300	499 400
Quartz-pebble conglomerate	88 100	126 400	163 600
Vein	0	89 600	156 800
Intrusive	47 400	131 400	183 700
Volcanic and caldera-related	50 400	155 700	157 800
Metasomatite	121 200	291 300	304 900
Other *	162 300	221 000	284 300
Unspecified	32 800	67 800	96 700
Total	**1 766 400**	**2 598 000**	**3 338 300**

* Includes Surficial, Collapse breccia pipe, Phosphorite and other types of deposits, as well as rock types with elevated uranium content. Pegmatite and black shale are not included.

Table 9. **Inferred Resources by deposit type**
(tonnes U)

	<USD 40/kgU	**<USD 80/kgU**	**<USD 130/kgU**
Unconformity-related	148 300	152 300	158 100
Sandstone	374 800	468 100	524 400
Hematite breccia complex	393 900	399 900	401 500
Quartz-pebble conglomerate	113 700	132 000	138 300
Vein	0	108 500	167 700
Intrusive	61 600	78 800	104 200
Volcanic and caldera-related	1 000	44 600	53 500
Metasomatite	14 800	289 200	368 800
Other *	77 800	133 900	154 400
Unspecified	17 700	51 100	59 700
Total	**1 203 600**	**1 858 400**	**2 130 600**

* Includes Surficial, Collapse breccia pipe, Phosphorite and other types of deposits, as well as rock types with elevated uranium content. Pegmatite and black shale are not included.

Proximity of resources to production centres

A total of eight countries provided estimates of the availability of resources for near-term production by reporting the percentage of Identified Resources (RAR and Inferred Resources) recoverable at costs <USD 40/kgU and <USD 80/kgU that are tributary to existing and committed production centres (Table 10). Resources tributary to existing and committed production centres in 11 countries listed below total 2 337 745 tU at <USD 40/kgU, about 9% above 2005, and 2 757 590 tU at <USD 80/kgU, about a 17% increase compared to 2003. These tributary resources represent about 79% of reported total Identified Resources at <USD 40/kgU and about 62% at <USD 80/kgU.

Table 10. **Identified Resources proximate to existing or committed production centres***

Country	RAR + Inferred recoverable at <USD 40/kgU in Existing or Committed Production Centres			RAR + Inferred recoverable at <USD 80/kgU in Existing or Committed Production Centres		
	Total resources	%	Proximate resources	Total resources	%	Proximate resources
Australia	1 196 000	77	920 920	1 216 000	75	912 000
Brazil	139 600	87	121 452	231 000	66	152 460
Canada	352 400	100	352 400	423 200	84	355 488
China	39 300	NA	NA	61 900	100	61 900
Kazakhstan	517 300	95	491 435	751 600	68	511 088
Namibia**	116 400	90	104 760	230 300	90	207 270
Niger**	34 200	100	34 200	75 200	100	75 200
Russian Fed.	83 600	100	83 600	495 400	37	183 298
South Africa	234 700	61	143 167	343 200	42	144 144
Ukraine	34 100	57	19 437	184 100	48	88 368
Uzbekistan**	86 200	77	66 374	86 200	77	66 374
Total	**2 833 800**		**2 337 745**	**4 098 100**		**2 757 590**

NA Data not available.
* Identified Resources only in countries that reported proximity to production centres; not world total.
** Secretariat estimate.

Undiscovered Resources

Undiscovered Resources (***Prognosticated*** and ***Speculative)*** refer to resources that are expected to occur based on geological knowledge of previously discovered deposits and regional geological mapping. ***Prognosticated Resources*** refer to those expected to occur in known uranium provinces, generally supported by some direct evidence. ***Speculative Resources*** refer to those expected to occur in geological provinces that may host uranium deposits. Both Prognosticated and Speculative Resources require significant amounts of exploration before their existence can be confirmed and grades and tonnages can be defined. Almost all Prognosticated Resources and Speculative Resources are reported as *in situ* resources (Table 11).

Worldwide, reporting of SR is incomplete, as only 26 countries have historically reported resources in this category. Only 16 countries reported SR for this edition, compared to the 25 that reported RAR. A number of countries did not report Undiscovered Resources for the 2007 Red Book, while others indicated that they do not regularly update evaluations of this type of resource. Nonetheless, some of these countries, such as Australia, Gabon and Namibia, are considered to have significant resource potential in as yet sparsely explored areas.

Prognosticated Resources are estimated to total about 2.8 million tU recoverable at <USD 130/kgU (2.5 million tU in 2005), including about 1.9 million tU at <USD 80/kgU (1.7 million tU in 2005). Major changes in Prognosticated Resources between 2005 and 2007 occurred in India (increase from 12 100 tU to 50 900 tU in the <USD 80/kgU cost category), Jordan (increase from 37 500 tU to 84 800 tU in the <USD 130/kgU cost category) and the Russian Federation (increase from 56 300 tU to 276 500 tU in the <USD 40/kgU category). The total for countries reporting Speculative Resources (SR) recoverable at <USD 130/kgU is about 4.8 million tU, an increase of over 240 000 tU compared to the 2005 total. About 3 million tU of additional SR are reported without an estimate of production cost, almost the same amount as in 2005. The most significant change in SR is reported in the Russian Federation (increase from 545 000 tU to 714 000 tU in the <USD 130/kgU cost category). Total reported SR are estimated to amount to a little over 7.7 million tU, up slightly compared to the 2005 total of 7.5 million tU.

Table 11. **Undiscovered Resources***
(in 1 000 tonnes U, as of 1 January 2007)

COUNTRY	Prognosticated Resources		Speculative Resources		
	Cost ranges		Cost ranges		
	< USD 80/kgU	< USD 130/kgU	< USD 130/kgU	Cost range unassigned	Total
Argentina	1.4	1.4	NA	NA	NA
Brazil	300.0	300.0	NA	500.0	500.0
Bulgaria	0.0	0.2	NA	NA	NA
Canada	50.0	150.0	700.0	0.0	700.0
Chile	NA	1.5	NA	3.2	3.2
China	3.6	3.6	4.1	0.0	4.1
Colombia (a)	NA	11.0	217.0	0.0	217.0
Czech Republic	0.2	0.2	0.0	179.0	179.0
Denmark (a)	0.0	0.0	50.0	10.0	60.0
Germany	0.0	0.0	0.0	74.0	74.0
Greece (a)	6.0	6.0	0.0	0.0	0.0
Hungary	0.0	18.4	NA	NA	NA
India	NA	50.9	NA	17.0	17.0
Indonesia (a)	NA	NA	0.0	12.5	12.5
Iran, Islamic Republic of	0.0	4.1	12.2	NA	12.2
Italy (a)	NA	NA	NA	10.0	10.0
Jordan	67.8	84.8	84.8	NA	84.8
Kazakhstan	280.0	300.0	500.0	NA	500.0
Mexico (a)	NA	3.0	NA	10.0	10.0
Mongolia (a)	0.0	0.0	1 390.0	NA	1 390.0
Niger (a)	14.5	24.6	NA	NA	NA
Peru	6.6	6.6	19.7	0.0	19.7
Portugal	1.0	1.5	NA	0.0	NA
Romania (a)	NA	3.0	3.0	0.0	3.0
Russian Federation	276.5	276.5	714.0	0.0	714.0
Slovenia	0.0	1.1	NA	NA	NA
South Africa	34.9	110.3	NA	1 112.9	1 112.9
Ukraine	8.4	22.5	120.0	135.0	255.0
United States (b)	839.0	1 273.0	858.0	482.0	1 340.0
Uzbekistan (a)	56.3	85.0	0.0	134.7	134.7
Venezuela (a)	NA	NA	0.0	163.0	163.0
Vietnam	0.0	7.9	100.0	130.0	230.0
Zambia (a)	0.0	22.0	NA	NA	NA
Zimbabwe (a)	0.0	0.0	25.0	0.0	25.0
Total (reported by countries)**	**1 946.2**	**2 769.0**	**4 797.8**	**2 973.3**	**7 771.1**

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

** Totals may not equal sum of components due to independent rounding.

NA Data not available.

(a) Not reported in 2007 responses, data from previous Red Book.

(b) The USA does not report Inferred or Prognosticated Resources all EAR is classified as Prognosticated.

Other resources and materials

Conventional resources are defined as resources from which uranium is recoverable as a primary product, a co-product or an important by-product, while unconventional resources are resources from which uranium is only recoverable as a minor by-product, such as uranium associated with phosphate rocks, non-ferrous ores, carbonatite, black schists, and lignite. Most of the unconventional uranium resources reported to date are associated with ***uranium in phosphate rocks***, but other potential sources exist (e.g., seawater and black shale). Since few countries reported updated information a comprehensive compilation of unconventional uranium resources and other potential nuclear fuel materials (e.g., thorium) is not possible. Instead, a summary of information documented in 2007 and data reported in past editions is provided below.

Historically phosphate deposits [1] are the only unconventional resources from which a significant amount of uranium has been recovered. Processing of Moroccan phosphate rock in Belgium produced 690 tU between 1975 and 1999 and about 17 150 tU were recovered in the United States from Florida phosphate rocks between 1954 and 1962. As much as 40 000 tU was also recovered from processing marine organic deposits (essentially concentrations of ancient fish bones) in Kazakhstan. Estimated production costs for a 50 tU/year project, including capital and investment, ranged between USD 40/kgU and USD 115/kgU in the United States in the1980s [2].

Unconventional uranium resources were reported by countries in Red Books between 1965 and 1993. Today, only very few countries (Chile, Egypt, Finland, Jordan, Peru and Vietnam) mention or report these resources (Table 12). However, with uranium prices above USD 260-310/kgU, by-product recovery of uranium from unconventional resources, and in particular from phosphate processing facilities, may become economically viable and could again become an important, competitive source of uranium.

Table 12. **Unconventional Resources reported in 2007**
(tonnes U)

Country	Tonnes U	Types of deposit
Chile	5 458	Phosphorite, copper deposits
Egypt	NR	Phosphorite, and black shale deposits
Finland	5 500	Black shale and carbonatite deposits
Jordan	59 360	Phosphorite deposits
Peru	25 600	Phosphorite and polymetallic (Cu, Pb, Zn, Ag, W, Ni) deposits
Vietnam	NR	Phosphorite and coal deposits

NR = not reported.

Table 13 summarises ranges of unconventional resources reported in Red Books between 1965 and 1993 [3]. These figures are incomplete. They do not include all worldwide unconventional resources since large uranium resources associated with the Chattanooga (United States) and Ronneburg (Germany) black shales, which combined total 4.2 million tU, are not listed. Neither are large uranium resources associated with monazite-bearing coastal sands in Brazil, India, Egypt, Malaysia, Sri Lanka and the United States. With the exception of Kazakhstan, unconventional resources are also not reported in former USSR countries.

Table 13. **Unconventional uranium resources** (1 000 tU) **reported in 1965-1993 Red Books**

Country	Phosphate rocks	Non-ferrous ores	Carbonatite	Black schist, lignite
Brazil*	28.0 – 70.0	2.0	13.0	
Chile	0.6 – 2.8	4.5 – 5.2		
Columbia	20.0 – 60.0			
Egypt**	35.0 – 100.0			
Finland			2.5	3.0 – 9.0
Greece	0.5			
India	1.7 – 2.5	6.6 – 22.9		4.0
Jordan	100 – 123.4			
Kazakhstan	58			
Mexico	100 – 151	1.0		
Morocco	6 526			
Peru	20	0.14 – 1.41		
Sweden				300.0
Syria	60.0 – 80.0			
Thailand	0.5 – 1.5			
United States	14.0 – 33.0	1.8		
Venezuela	42.0			
Vietnam				0.5

* Considered a conventional resource in Brazil and is thus included in conventional resource figures for Brazil.
** Includes an unknown quantity of uranium contained in monazite.

The total uranium reported in previous Red Books as unconventional resources, dominated by phosphorite deposits in Morocco (>85%), amounts to about 7.3 – 7.6 million tU. As noted above, this total does not include significant deposits in other countries and is therefore a conservative estimate of the existing unconventional uranium resource base.

Other estimates of uranium resources associated with marine and organic phosphorite deposits point to the existence of almost 9 million tU in four countries alone: Jordan, Mexico, Morocco and the United States [4]. Others estimate the global total to amount to 22 million tU, an estimate cited in the 2005 Red Book [5]. The variation in these estimates shows that these figures should be considered as part of a general mineral inventory rather than conforming to standard categories used in reporting resources. The development of more rigorous estimates of uranium in phosphate rocks is required given that recent uranium spot market prices may justify the economic exploitation of these deposits.

Seawater may also be regarded as a possible source of uranium, due to the large volume of uranium contained (about 4 billion tU) and its almost inexhaustible nature. However, because of the low concentration of uranium in seawater (3-4 ppb), it is estimated that it would require the processing of about 350 000 tonnes of water to produce a single kg of uranium. Nonetheless, with the exception of its high recovery cost, there is no intrinsic reason why at least some of these significant resources could not be extracted from various coast lines at a total rate of a few hundred of tonnes annually.

Research was carried out on uranium recovery from seawater in Germany, Italy, Japan, United Kingdom and United States in the 1970s/80s, but is now known to be continuing only in Japan. Between 2001 and 2003, Japanese researchers tested a braid type recovery system directly moored to the ocean floor, recovering about 1.5 gU over a 30 day test period [6]. The annual recovery factor of such a system is estimated to be about 1 200 tU/year at a recovery cost of over USD 700/kgU. Research is continuing in Japan to improve the recovery factor and cost.

Thorium

Thorium, abundant and widely dispersed, could also be used as a nuclear fuel resource. Most of the largest identifed thorium resources were discovered during the exploration of carbonatites and alkaline igneous bodies for uranium, rare earth elements, niobium, phosphate, and titanium. Today, thorium is recovered mainly from the mineral monazite as a by-product of processing heavy-mineral sand deposits for titanium-, zirconium-, or tin-bearing minerals. Information on thorium resources [1,3] was published in Red Books between 1965 and 1981, typically using the same terminology used for uranium resources at that time (e.g. Reasonably Assured Resources and Estimated Additional Resources I and II, which are now termed Inferred and Prognosticated Resources, respectively). Worldwide thorium resources, which are listed by major deposit types in Table 14, are estimated to total about 6.08 million t Th, including undiscovered resources.

Table 14. **Major thorium deposit types and resources** [3]

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

Table 15 lists these thorium resources on a country by country basis, classified in categories similar to those used for uranium resources.

Table 15. **World thorium resources** (1 000 t Th) [3]

Country	**RAR** < USD 80/kgTh	**EAR I (Inferred)** <USD 80/kgTh	**Identified Resources** <USD 80/kgTh	**Prognosticated**
Australia*	46	406	452	NA
Brazil*	172	130	302	330
Canada	NA	44	44	128
Egypt	NA	100	100	280
Greenland	54	NA	54	32
India	319	NA	319	NA
Norway	NA	132	132	132
Russian Fed.	75	NA	75	NA
South Africa	18	NA	18	130
Turkey	344	NA	344	400 – 500
USA	122	278	400	274
Venezuela	NA	300	300	NA
Others	23	10	33	81
Total	**1 173**	**1 400**	**2 573**	**1 787 – 1 887**

NA Data not available. * Based on updated assessments.

World total thorium resources estimated in the categories RAR, EAR-I (Identified Resources) and Prognosticated Resources listed in Table 15 total 4.4 million t Th, or about 72% of the world thorium resources listed in Table 14. Differences in these estimates are the result of the differing approaches used (e.g. different costs and degrees of geological assurance).

So-called secondary sources of uranium, though small compared with the resources described above, play a significant role in supplying current nuclear fuel requirements and are expected to continue to do so for several years. These resources are discussed in detail in the Uranium Demand section of this volume.

B. URANIUM EXPLORATION

A very significant increase in exploration and development activities occurred in 2005 and 2006, driven by increases in the uranium spot price. These activities were conducted in countries which explored and developed uranium deposits in the past and also in many countries where exploration for uranium had not been conducted for many decades. Since most of these countries did not report exploration and development expenditures, total worldwide uranium exploration and development expenditures are likely higher than what is reported here.

Worldwide uranium exploration continues to be unevenly distributed geographically, with the majority of exploration expenditures being concentrated in areas considered to have the best likelihood for the discovery of economically attractive deposits, mainly ***unconformity-related***, ***sandstone-type*** and ***hematite breccia complex*** deposits.

In 2006, only Australia, Canada, France and Switzerland reported non-domestic exploration and development expenditures amounting to a total USD 214.1 million (Table 16). In 2007, these same four countries are expected to increase non-domestic expenditures to over USD 259.4 million, more than 13 times the 2003 total. Trends in domestic and non-domestic exploration expenditures are depicted in Figure 3.

Domestic exploration and development expenditures generally decreased from 1998 to 2001, then began to slightly increase in 2002 where a total of 18 countries reported domestic expenditures of about USD 95.1 million (Table 17). In 2003 and 2004, 20 and 21 countries, respectively, reported exploration and development activities amounting to about USD 123.8 million and USD 218.8 million, respectively.

In 2005, 19 countries reported domestic exploration and development expenditures totalling about USD 364 million, an increase of about 66% compared to 2004. In 2006, 17 countries reported domestic expenditures totalling about USD 773.8 million, an increase of about 113% compared to 2005 (these figures include conservative Secretariat estimates for Namibia, Niger, United States and Uzbekistan). The bulk of 2006 expenditures were reported in only seven countries: Australia, Canada, China, India, the Russian Federation, South Africa and the United States. These countries together accounted for about 97% of reported domestic exploration and development expenditures. Of reported domestic expenditures, 76% were made in only two countries, Canada and the United States. Overall, domestic exploration and development expenditures are expected to remain strong but decrease slightly to about USD 718 million in 2007 (if conservative Secretariat estimates for Namibia, Niger, United States and Uzbekistan are included), with the most significant increases anticipated in Canada, Kazakhstan and the Russian Federation. Figure 4 portrays these trends, showing the recent, rapid divergence between domestic and non-domestic expenditures.

Table 16. **Non-domestic uranium exploration and development expenditures**
(USD in year of expenditures)

COUNTRY	Pre-2000	2000	2001	2002	2003	2004	2005	2006	2007 (expected)
Australia	NA	NA	NA	NA	NA	1 571	8 855	4 580	4 724
Belgium	4 500	0	0	0	0	0	0	0	0
Canada	16 556	3 667	2 597	2 549	2 547	9 559	53 968 p	124 546 p	139 655 p
China	0	0	0	0	0	0	NA	NA	NA
France	707 603	7 330	7 690	14 370	16 701	59 701	127 500	85 000	115 000
Germany	403 158	0	0	0	0	0	0	0	0
Japan	418 331	NA	NA	NA	NA	NA	NA	NA	NA
Korea, Republic of	24 049	NA	NA	NA	NA	NA	NA	NA	NA
Spain	20 400	0	0	0	0	0	0	0	0
Switzerland	29 657	0	0	0	0	3	0	3	16
United Kingdom	61 263	0	0	0	0	0	0	0	0
United States	260 598	NA	NA	NA	NA	NA	NA	NA	NA
Total	**1 946 115**	**10 997**	**10 287**	**16 919**	**19 248**	**70 834**	**190 323**	**214 129**	**259 395**

Note: Domestic exploration and development expenditures represent the total expenditure from domestic and foreign sources within each country. Expenditures abroad are thus a subset of domestic expenditures.

* Secretariat estimate.

p Provisional data.

NA Data not available.

Table 17. **Industry and government uranium exploration and development expenditures – domestic**
(USD thousands in year of expenditure)

COUNTRY	Pre-2000	2000	2001	2002	2003	2004	2005	2006	2007 (expected)
Argentina	49 454	791	777	265	627	701	966	650	656
Australia	494 953	4 390	2 470	3 020	4 116	9 971	31 366	61 603	70 866
Bangladesh	453	NA	NA	NA	NA	NA	NA	NA	NA
Belgium	2 487	0	0	0	0	0	0	0	0
Bolivia	9 343	NA	NA	NA	NA	NA	NA	NA	NA
Botswana	825	NA	NA	NA	NA	NA	NA	NA	NA
Brazil	186 128	0	NA	NA	NA	449	0	0	463
Cameroon	1 282	0	0	0	0	0	0	0	0
Canada	1 197 013	30 667	16 234	22 876	21 687	78 676	184 921	432 727	458 621
Central African Rep.	21 800	NA	NA	NA	NA	NA	NA	NA	NA
Chile	6 287	214	126	154	115	133	84	100	113
China (a)	0	4 200	6 000	7 200	7 600	9 500	13 500	25 500	33 600
Colombia	19 946	NA	NA	NA	NA	0	0	0	6 000
Costa Rica	364	NA	NA	NA	NA	NA	NA	NA	NA
Cuba	972	NA	NA	NA	NA	NA	NA	NA	NA
Czech Rep. (b)	313 903	44	48	25	56	23	53	132	152
Denmark	4 140	0	0	0	0	0	0	0	0
Ecuador	1 945	NA	NA	NA	NA	NA	NA	NA	NA
Egypt	76 087	10 499	9 404	7 186	5 631	2 589	1 730	1 736	1 751
Finland	13 984	0	0	0	0	210	803	1 798	3 529
France	907 240	0	0	0	0	0	0	0	0
Gabon	102 433	0	0	0	0	0	0	0	0
Germany (c)	2 002 789	0	0	0	0	0	0	0	0
Ghana	90	NA	NA	NA	NA	NA	NA	NA	NA
Greece	17 547	NA	NA	NA	NA	NA	NA	NA	NA
Guatemala	610	NA	NA	NA	NA	NA	NA	NA	NA
Hungary	3 700	0	0	0	0	0	0	0	0
India	262 706	14 368	12 060	11 922	14 172	14 333	16 588	16 422	22 743
Indonesia	15 731	61	23	30	33	31	NA	NA	NA
Iran, Islamic Rep. of	1 857	1 700	1 004	1 389	3 781	3 751	3 723	4 958	8 775
Ireland	6 200	NA	NA	NA	NA	NA	NA	NA	NA
Italy	75 060	NA	NA	NA	NA	NA	NA	NA	NA
Jamaica	30	NA	NA	NA	NA	NA	NA	NA	NA
Japan	19 697	0	0	0	0	0	0	0	0
Jordan	920	0	0	0	0	0	0	0	0
Kazakhstan	6 830	11 035	13 175	11 836	4 372	723	1 169	8 500	26 309
Korea, Rep. of	17 886	0	0	0	0	0	0	0	0
Lesotho	21	NA	NA	NA	NA	NA	NA	NA	NA
Madagascar	5 293	NA	NA	NA	NA	NA	NA	NA	NA

Table 17. **Industry and government uranium exploration and development expenditures – domestic** (contd.)
(USD thousands in year of expenditure)

COUNTRY	Pre-2000	2000	2001	2002	2003	2004	2005	2006	2007 (expected)
Malaysia	10 412	66	NA	NA	NA	NA	NA	NA	NA
Mali	58 693	NA	NA	NA	NA	NA	NA	NA	NA
Mexico	30 306	0	NA	NA	NA	NA	NA	NA	NA
Mongolia	8 153	NA	NA	NA	NA	NA	NA	NA	NA
Morocco	2 752	NA	NA	NA	NA	NA	NA	NA	NA
Namibia	25 631	0	0	0	110	1 747	2 000 *	2 000 *	2 000 *
Niger	206 729	633	1 088	3 126	4 545	4 222	6 400 *	6 400 *	6 400 *
Nigeria	6 950	NA	NA	NA	NA	NA	NA	NA	NA
Norway	3 180	0	0	0	0	0	0	0	0
Paraguay	26 360	NA	NA	NA	NA	NA	NA	NA	NA
Peru	4 776	0	0	0	0	0	0	0	0
Philippines	3 447	5	4	4	2	NA	NA	NA	NA
Portugal	17 618	19	0	0	0	0	0	0	0
Romania	9 903	157	NA	NA	NA	NA	NA	NA	NA
Russian Fed.	52 169	13 300	11 470	10 420	7 241	10 597	24 946	33 496	63 095
Rwanda	1 505	0	0	0	0	0	0	0	0
Slovenia (d)	1 581	NA	NA	NA	NA	NA	NA	NA	NA
Somalia	10 000	NA	NA	NA	NA	NA	NA	NA	NA
South Africa	140 846	0	0	0	73	886	1 593	24 698	15 143
Spain	140 455	0	0	0	0	0	NA	NA	NA
Sri Lanka	43	NA	NA	NA	NA	NA	NA	NA	NA
Sudan	200	0	0	0	0	0	0	0	0
Sweden	47 900	0	0	0	0	0	0	0	0
Switzerland	3 359	0	0	0	0	0	0	0	0
Syria	1 151	NA	NA	NA	NA	NA	NA	NA	NA
Thailand	11 299	NA	NA	NA	NA	NA	NA	NA	NA
Turkey	21 981	0	NA	NA	7	7	23	56	50
Ukraine	6 533	2 107	1 701	1 898	3 415	4 259	4 801	6 168	6 220
United Kingdom	3 815	0	0	0	0	0	0	0	0
United States (e)	2 495 240	6 694	4 827	352	31 300	59 000	77 800	155 300	155 000 *
Uruguay	231	NA	NA	NA	NA	NA	NA	NA	NA
USSR	3 692 350								
Uzbekistan	89 734	14 152	8 516	13 255	13 923	16 995	21 230 *	21 230 *	21 230 *
Vietnam	2 364	104	104	132	980	45	NA	NA	NA
Zambia	25	NA	NA	NA	NA	NA	NA	NA	NA
Zimbabwe	6 902	NA	NA	NA	NA	NA	NA	NA	NA
Total	**12 992 599 (c)**	**115 206**	**89 031**	**95 090**	**123 786**	**218 848**	**364 066**	**773 844**	**718 086**

Note: Domestic exploration and development expenditures represent the total expenditure from domestic and foreign sources within each country. Expenditures abroad are thus a subset of domestic expenditures.

NA Data not available. * Secretariat estimate.

(a) Development expenditures not included.

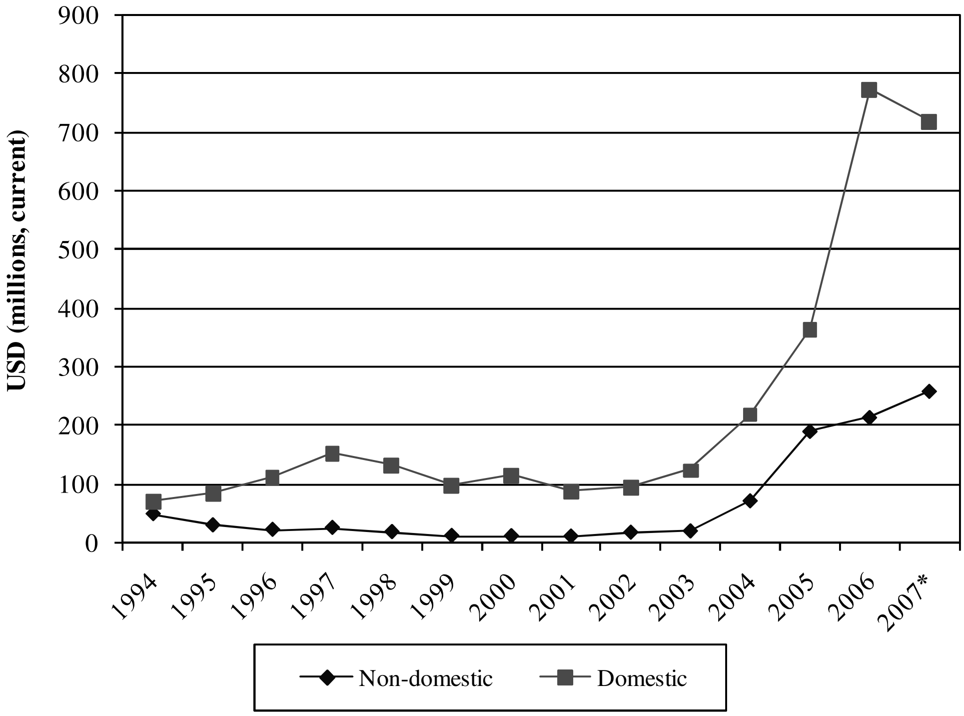
(b) Includes USD 312 560 expended in Czechoslovakia (pre-1996).

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

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

(e) Includes reclamation and restoration expenditures in 2004, 2005 and 2006. In 2006, reclamation and restoration expenditures amounted to USD 50.9 million.

Figure 4. **Trends in exploration and development expenditures**



* 2007 values are estimates.

Current activities and recent developments

North America. In **Canada,** after a steady decrease in domestic exploration and mine development expenditures from 1998 (USD 41.1 million) to 2003 (USD 21.7 million), spending began to grow again, reaching USD 78.7 million in 2004 and over USD 432 million in 2006. In 2007, expenditures are expected to increase by about 6% to USD 458.6 million.

As in previous years, uranium exploration remained focused on areas favourable for the occurrence of deposits associated with Proterozoic unconformities in the Athabasca Basin of Saskatchewan, and to a lesser extent, similar geologic settings in the Thelon and Hornby Bay basins of Nunavut and the Northwest Territories. Significant exploration activities were also conducted in other areas of the country, such as Quebec, Newfoundland and Labrador, Alberta, Yukon, Ontario, Manitoba and British Columbia.

Uranium exploration and surface development drilling amounted to some 547.5 km in 2005, compared to 266.1 km in 2004. More than half of the overall exploration and development expenditures in 2006 can be attributed to advanced underground exploration, deposit appraisal activities, and care and maintenance expenditures associated with projects awaiting production approvals. Basic “grass roots” uranium exploration exceeded USD 200 million (USD 112 million in Saskatchewan alone) in 2006, more than doubling 2005 expenditures of USD 79 million. Over 55% of the combined exploration and surface development drilling in 2005 and 2006 took place in Saskatchewan. Non-domestic exploration expenditures in 2006 amounted to USD 125 million, with activities mainly carried out in Australia and Kazakhstan. In 2007, non-domestic expenditures are expected to increase slightly to about USD 140 million.

In 2006, the **United States** recorded a significant increase in domestic exploration and mine development spending with expenditures that year totalling about USD 155.3 million (although a portion of these expenditures relate to decommissioning and reclamation activities), surging from a mere USD 0.352 million in 2002 and USD 77.8 million in 2005. Expected expenditures for 2007 are not available.

Central and South America. Argentina reported exploration expenditures totalling about USD 1.0 million in 2005, up slightly from about USD 0.7 million in the previous year. Activities included a programme to complete the final feasibility study of the Cerro Solo deposit and evaluation of the surrounding areas. In addition more exploration programmes (vein type deposit at Las Thermas and sandstone type deposits favourable for *in situ* leach mining) are planned in the near future.

No exploration work was carried out in **Brazil** in 2005 and 2006. In 2007, a drilling programme is planned to confirm the continuity of the Cachoeira and Engenho deposits at Lagoa Real (Caetité site).

In 2005-2006, archived information on the uranium potential of **Colombia** was reviewed. Exploration titles for approximately 2 000 km^2 were requested. Exploration expenditures are expected to amount to USD 6 million in 2007, and could increase to about USD 20 million in the following years.

Exploration activities were also conducted in Bolivia, Guyana, Paraguay, Peru, although details were not reported.

Western Europe. Only **Finland** reported domestic exploration expenditures in 2005 (USD 0.8 million) and 2006 (USD 1.8 million). International companies have been reserving claims and acquiring claim areas, but to date only reconnaissance type field studies (ground radiometrics, geological mapping, radon surveys) have been conducted. One company involved carried out first phase trenching and drilling on a discovery site in northern Finland in 2005.

France reported an increase in non-domestic uranium exploration and development expenditures from about USD 60 million in 2004 to over USD 127 million in 2005, before declining to USD 85 million in 2006. Expenditures of over USD 115 million are expected in 2007. French exploration and development activities were reported in Australia, Canada, Finland, Kazakhstan, Mongolia, Niger and Russia.

In 2005 and 2006, several foreign companies applied for exploration and mining titles in **Portugal,** with the Nisa area being the main target. International uranium exploration companies applied for exploration permits in historic mining regions in **Spain** and **Sweden.**

Central, Eastern and South-eastern Europe. The Euratom Supply Agency reported that exploration activities were ongoing in **Hungary.** No fieldwork was conducted in the **Czech Republic** and exploration activities were focused on archiving and processing previously obtained data.

In the **Russian Federation,** exploration activities were concentrated on sandstone deposits amenable to ISL, unconformity-related deposits in Eastern Siberia, the Baltic Shield and the central Voronezh massif regions and for vein-stockwork and volcanic deposits in the Chita region (southern Priargun). Exploration activities, including drilling programmes, continued in the Transural, Vitim and Irkutsk districts, as well as in the north-western region of the country. Work is these areas is planned to continue in 2007. Total exploration and development expenditures in 2006 amounted to USD 33.5 million and are expected to increase to USD 63.1 million in 2007.

In 2005-2006, some exploration activities were performed in the eastern regions of **Slovakia** by a Canadian exploration company.

In **Turkey**, granitic and aciditic intrusive rocks, and sedimentary rocks were explored for radioactive raw material in the Sulakyurt-Kaman region. Similar activity is expected to be conducted in 2007-2008 in the Kirsehir-Nevsehir-Aksaray-Ankara regions.

Ukraine continued exploration for ***vein-type*** and unconformity-related deposits in the Ukrainian shield area. Unconformity type deposits (Verbovskaya, Khotynskaya, Drukhovskaya) were discovered on the western slopes of the Ukrainian shield on the Riphean unconformity. Efforts to estimate thorium resources in the Ukrainian Shield continued. Exploration expenditures totalled about USD 4.8 million in 2005, rose in 2006 to USD 6.2 million and are expected to remain at USD 6.2 million in 2007.

Africa. In **Egypt,** activities were concentrated on exploring for conventional uranium resources in the Eastern Desert granites and sedimentary formations in the Sinai. Unconventional resources, including phosphorite deposits and black shales, are also under investigation. Total expenditures in Egypt have steadily decreased from the high of USD 10.5 million in 2000 to USD 1.7 million in 2005 and 2006. Expenditures are expected to remain at about the same level (USD 1.8 million) in 2007.

In **Niger**, activities focused on resource development in and around the existing mine sites in an effort to expand the resource base in the western Arlit area where several deposits are under development (Ebba, Tamgak and Tabele). New exploration and development projects, with intensive drilling campaigns, were initiated in 2006 on the Imouraren and Azelik deposits and will continue in 2007. Although exploration and development expenditures were not reported by the Government of Niger, annual drilling programmes amounting to 59.9 km in 2005 and 134.6 km in 2006 were reported. In 2007, exploration and development drilling is expected to amount to 160 km.

In **Namibia**, major drilling programmes were conducted to develop the Langer Heinrich (in preparation for mining in 2006), Valencia and Trekkopje deposits during 2005 and 2006.

In **South Africa**, the upsurge in the price of uranium from 2005 onwards prompted a closer look at the Witwatersrand gold reefs where uranium may now comprise a more substantial income contributor than gold. Strong gold prices stimulated renewed interest in exploration for this metal at several locations along the limb of the Witwatersrand Basin, while high uranium prices encouraged some gold mining groups to routinely record uranium concentrations. Some mining companies have also drilled and assayed tailings piles ("slimes") to determine uranium and gold content for possible future exploitation. Renewed interest in uranium occurrences in the Karoo Basin has also been seen in recent years. Total expenditures in South Africa increased from USD 0.9 million in 2004 to USD 1.6 million in 2005 and USD 24.7 million in 2006. In 2007, exploration expenditures are expected to amount to USD 15.1 million.

Exploration activities are also known to have been conducted in Botswana, Cameroon, the Central African Republic, the Democratic Republic of Congo, Gabon, Guinea, Madagascar, Malawi, Morocco, Mozambique, Senegal, Tanzania and Zambia, although details and associated costs were not reported by the governments of these countries.

Middle East, Central and Southern Asia. In **India**, active programmes are being conducted in several provinces, focusing on Proterozoic basins, Cretaceous sandstones, and other promising geological settings. Annual drilling decreased from 46.4 km in 2004 to 35.5 km and 40.1 km in 2005 and 2006, respectively, but is expected to increase to 133.7 km in 2007. Exploration expenditures amounted to about USD 16.6 million and USD 16.4 million in 2005 and 2006, respectively, and are expected to increase to USD 22.7 million in 2007.

In **Iran**, activities included exploration and evaluation of uranium resources associated with Precambrian magmatic and metasomatic complexes in the Bafgh-Robateh-el-Badam province, which includes Khoshumi, Narigan, Chahjuleh, Zarigan and Saghand uranium mines, and also in the Azarbaijan regions. Uranium occurrences in southern Iran are also being investigated, including the Gachin salt plug which has proved to be a surficial uranium deposit. Total expenditures amounted to about USD 3.7 million and USD 4.9 million in 2005 and 2006, respectively, and are expected to increase to about USD 8.8 million in 2007, including funding for a 14 km drilling programme.

In **Kazakhstan**, exploration was conducted in 2005 and 2006 at Moinkum, Inkai, Mynkuduk and Budyonovskoye deposits in the Chu-Sarysu uranium province and the Northern Kharasan deposit in the Syr-Darya uranium province, where several ISL test sites were completed and mining tests were initiated. Geologic and economic re-estimation of the North Kazakhstan province deposits was also initiated in order to define the uranium reserves and potential resources related to the vein-stockwork and unconformity related deposits suitable for underground and open-pit mining. In the coming years, uranium exploration is expected to be restarted in the Chu-Sarysu and Syr-Darya uranium provinces. Total exploration and development expenditures increased from USD 0.7 million in 2004 to USD 1.2 million in 2005, and USD 8.5 million in 2006, and are expected to rise sharply to USD 26.3 million in 2007 as a significant drilling programme (1 438 holes, 661 km) is to be initiated.

Exploration continues in **Uzbekistan** in order to increase uranium production, although details were not reported by the government. During 2006-2007, the State Committee on Geology and Mineral Resources established joint ventures with companies from Japan (Itochu Corporation, JOGMEC) and the Republic of Korea (Korea Resources Corporation) to explore black shale deposits and with the Russian company TENEX to explore sandstone deposits.

South-eastern Asia. No exploration activities were reported in South-eastern Asia, although **Indonesia**, the **Philippines** and **Vietnam** are known to have maintained low level activities aimed at evaluating previously discovered mineralisation.

East Asia. China reported increasing exploration and development expenditures of USD 13.5 million and USD 25.5 million in 2005 and 2006, respectively. China continues to focus exploration efforts on sandstone-type deposits amenable to ISL in the Yili basin of the Xinjiang region and the Erdos basin in Inner Mongolian Autonomous Region. In addition, work was restarted on hydrothermal type deposits in southern China in 2006, after more than ten years of inactivity, resulting in the discovery of vein-type deposits. In 2007, exploration expenditures are expected to amount to USD 33.6 million, featuring an important drilling programme (1 410 holes, 450 km). Non-domestic exploration and development activities were carried out mainly in Kazakhstan and in Niger, although details were not reported.

Exploration continues in **Mongolia**, although details were not reported by the government. Exploration was performed principally by Canadian companies Khan Resources Inc., Western Prospector Group Ltd. and Denison Mines. Activities included development of the Dornot deposit, the Gurvanbulak, Nemer and Mardaingol deposits of the Saddle Hills and the Kharat and Khairkhan deposits of the eastern Gobi region.

Pacific. Exploration continued vigorously in several regions of **Australia**, with annual exploration and development expenditures amounting to about USD 31.4 million in 2005 and about USD 61.6 million in 2006 reported. Exploration was focused on the Frome Embayment (South Australia) for sandstone type deposits, the Gawler Craton- Stuart Shelf region (South Australia) for hematite breccia complex deposits and Arnhem Land (Northern Territory) for unconformity-related deposits. Significant discoveries in 2005 and 2006 included the Four Mile deposit in South Australia (12 720 tU of Inferred Resources), major extensions of the Olympic Dam deposit and extensions of the Valhalla and Skal deposits (Queensland). In 2007, exploration expenditures are expected to increase again to about USD 70.9 million. Australia's non-domestic exploration expenditures amounted to USD 8.9 million in 2005, and USD 4.6 million in 2006, principally funding a major drilling programme to outline additional resources at the Langer Heinrich deposit in Namibia. Non-domestic expenditures are expected to hold steady in 2007 at USD 4.7 million.

C. URANIUM PRODUCTION

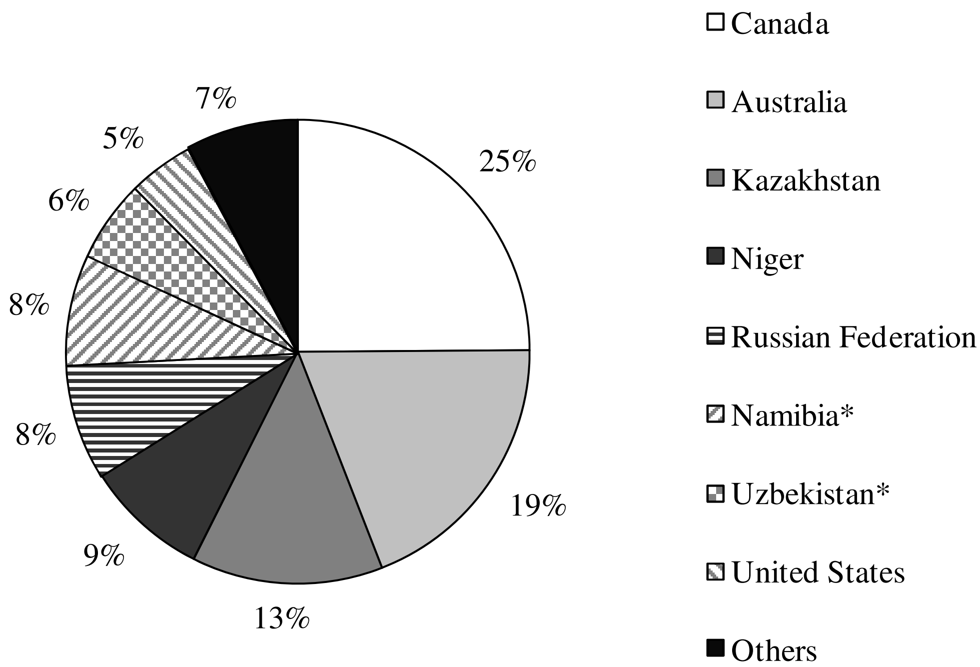
In 2006, uranium was produced in 20 different countries; one more than in 2004 as the Islamic Republic of Iran started production in 2006. However, three of these 20 countries (France, Germany and Hungary) only produced uranium as a consequence of mine remediation efforts. Two countries, Canada and Australia, accounted for 44% of world production in 2006 and just eight countries, Canada (25%), Australia (19%), Kazakhstan (13%), Niger (9%), the Russian Federation (8%), Namibia (8%), Uzbekistan (6%) and the United States (5%), accounted for about 93% of world production in 2006 (Figure 5).

Overall, world uranium production increased from 40 188 tU in 2004 to 41 943 tU in 2005 before declining by about 6% to 39 603 tU in 2006. In 2007, uranium production is expected to increase by a little less than 10% to 43 328 tU.

Within OECD countries, production decreased slightly from 22 019 tU recorded in 2004 and 22 821 tU in 2005 to 19 705 tU in 2006. Production in 2007 is expected to increase marginally to 19 809 tU. Table 18 summarises the significant changes that occurred in production in selected countries between 2004 and 2006. Historical uranium production on a country-by-country basis is provided in Table 19 and Figure 6.[3]

3. Some historical production figures have changed since the last edition of the Red Book as a result of new data made available by member countries.

Figure 5. **Uranium production in 2006: 39 603 tU**



* Secretariat estimate.

Table 18. **Production in selected countries and reasons for major changes** (tonnes U)

Country	Production 2004	Production 2006	Change 2004-2006	Reasons for changes in production since 2002
Australia	8 982	7 593	-1 389	Production decreased at all three mines: at Olympic Dam due to processing difficulties, at Ranger due to high rainfall restricting access to high grade ore, and at Beverley due to technical difficulties.
Canada	11 597	9 862	-1 735	Low grade ore milled at McClean Lake and Rabbit Lake reduced output.
Kazakhstan	3 719	5 281	+1 562	Increased production at existing mines and new mines.
Niger	3 185	3 443	+258	Increased production at Arlit (+342 tU) greater than decreased production at Akouta (-84 tU).
South Africa	747	534	-213	Operational problems at Vaal River operations and maintenance problems at the Nufcor plant.
United States	943	1 805	+862	Production increased at existing mines and mine re-openings.

Table 19. **Historical uranium production**
(tonnes U)

COUNTRY	Pre-2004	2004	2005	2006	Total to 2006	2007 (expected)
Argentina	2 512	1	0	0	2 513	0
Australia	113 305	8 982	9 512	7 593	139 392	7 600
Belgium	686	0	0	0	686	0
Brazil	1 599	159	110	200	2 068	340
Bulgaria	16 357	0	0	0	16 357	0
Canada	375 107	11 597	11 628	9 862	408 194	9 850
China	27 689 *	730 *	750 *	750 *	29 919	750 *
Congo, Democratic Rep. of	25 600 *	0	0	0	25 600	0
Czech Republic (a)	108 649	412	409	375	109 845	309
Finland	30	0	0	0	30	0
France	75 965	6 *(c)	4 *(c)	3 *(c)	75 978	2 *(c)
Gabon	25 403	0	0	0	25 403	0
Germany (b)	219 240	77 (c)	94 (c)	65 (c)	219 476	45 (c)
Hungary	21 043	2 (c)	3 (c)	2 (c)	21 050	3
India	7 963 *	230 *	230 *	230 *	8 653 *	270 *
Iran, Islamic Rep of	0	0	0	5 *	5	20 *
Japan	84	0	0	0	84	0
Kazakhstan (d)	98 409	3 719	4 346	5 281	111 755	7 245
Madagascar	785 *	0	0	0	785	0
Mexico	49	0	0	0	49	0
Mongolia	535	0	0	0	535	0
Namibia	78 736	3 038	3 146	3 067	87 987	3 800
Niger	94 137	3 185	3 322	3 443	104 087	3 633
Pakistan	961 *	38 *	40 *	40 *	1 079 *	40 *
Poland	650	0	0	0	650	0
Portugal	3 717	0	0	0	3 717	0
Romania	17 989	90	90 *	90 *	18 259 *	90 *
Russian Federation	123 036	3 290	3 285	3 190	132 801	3 381
South Africa	153 253	747	673	534	155 207	750
Spain	5 028	0	0	0	5 028	0
Sweden	200	0	0	0	200	0
Ukraine (d)	9 900 *	855	830	808	12 393 *	900
United States	356 482	943	1 171	1 805	360 401	2 000 *
USSR (e)	123 086	0	0	0	123 086	0
Uzbekistan (d)	23 682	2 087	2 300 *	2 260 *	30 329	2 300 *
Yugoslavia	380	0	0	0	380	0
Zambia	102	0	0	0	102	0
OECD	1 280 235	22 019	22 821	19 705	1 344 780	19 809
Total	**2 112 349**	**40 188**	**41 943**	**39 603**	**2 234 083**	**43 328**

* Secretariat estimate.

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

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

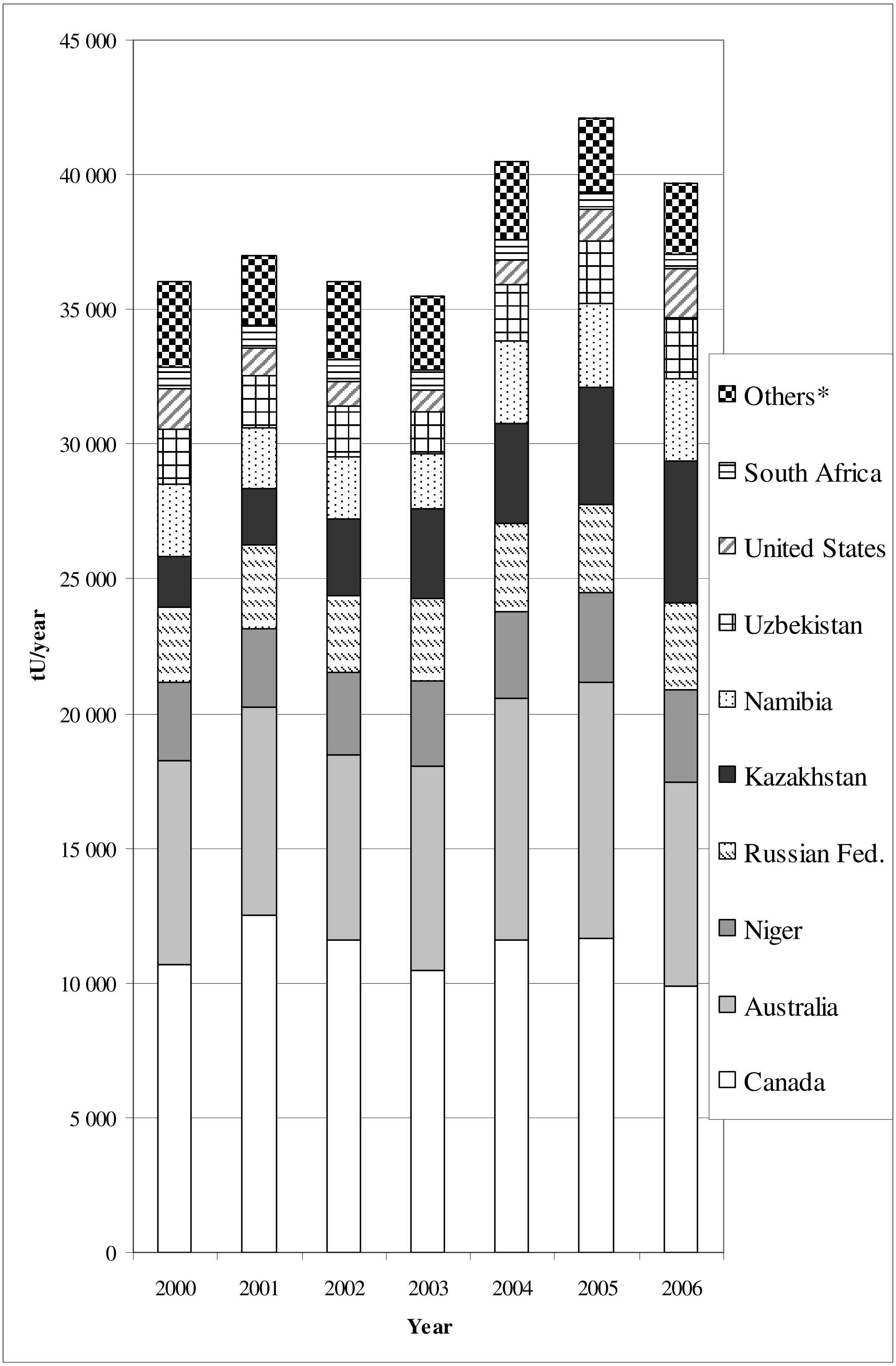
(c) Production comes from mine rehabilitation efforts only.

(d) Production since 1992 only.

(e) Includes production in former Soviet Socialist Republics of Estonia, Kyrgystan, Russian Federation, Turkmenistan, Ukraine and Uzbekistan from 1945 through the end of 1991.

Note: In some cases, alternate historical production figures are provided in the Red Book Retrospective [3].

Figure 6. **Recent world uranium production**



* "Others" includes the remaining producers (Table 19).
Values for China, France, India, Iran, Pakistan, Romania and Uzbekistan are estimates.

Present status of uranium production

North America production, about 30% of the world total in 2006, decreased slightly from 2004 (12 540 tU) to 2006 (11 667 tU). **Canada** remained the world's leading producer, despite the fact that current uranium production remains below full capacity. In 2006, production amounted to 9 862 tU, 15% below 2005 production due to the lower grade ore being milled at McClean Lake and lower than expected ore grades processed at Rabbit Lake. In 2007, production is expected to remain steady at approximately 9 850 tU. A proposal to increase production at McArthur River and Key Lake by some 18% annually (from 7 200 tU/year to 8 500 tU/year) remains under regulatory review. Construction of the Cigar Lake mine was expected to be completed in 2007 but owing to a rock fall that resulted in the mine being completely flooded, production is now not expected until 2011. Production in the **United States** increased to 1 805 tU in 2006, (54% above 2005 production) and is expected to increase to 2 000 tU in 2007. Three ISL operations, in Nebraska, Texas and Wyoming, and underground operations in the Colorado Plateau contributed to the increased production.

Brazil was the only producing country in **South America** in 2005 and 2006. Production decreased from 159 tU in 2004 to 110 tU in 2005, then rose to 200 tU in 2006, as regulatory requirements led to temporary interruptions in the operation of the Lagoa Real production centre. Expansion of this facility to a nominal capacity to 670 tU/year remains on course, however. In **Argentina**, the Sierra Pintada mine of the San Rafael complex, placed on standby in 1999, is expected to restart production in the near future.

Output from **Western Europe and Scandinavia** remained very low in 2006, representing less than 1% of total world production. In **Germany**, 65 tU were recovered from mine rehabilitation activities in 2006 and it is expected that about 45 tU will be recovered in 2007.

Production in **Central**, **Eastern** and **South-eastern Europe** decreased slightly from 4 794 tU in 2004 to 4 375 tU in 2006, or about 11% of world production. In 2007, production is expected to increase slightly to 4 583 tU. Production in the **Czech Republic** amounted to 375 tU in 2006 and it is expected to be reduced slightly to 309 tU in 2007. Production at the Rozna mine was to be terminated in 2008, but in light of higher uranium prices it has since been decided to continue mining as long as it remains profitable. **Hungary** effectively ceased mine production in 1997 and today only small amounts are produced through mine remediation efforts. Production in the **Russian Federation** decreased from 3 290 tU in 2004 to 3 190 tU in 2006. Although the majority came from the Priargunsky mine, 289 tU were produced in 2006 at the Dalur ISL facility (the Dalmatovskoe deposit) in the Transural district. Production is expected to rise slightly to 3 381 tU in 2007. Production in **Ukraine** decreased from 855 tU in 2004 to 808 tU in 2006. Production from the underground mines of Michurinskoye and Vatutinskoye is expected to amount to 890 tU in 2007.

Three countries in **Africa**, Namibia, Niger and South Africa, contributed about 18% to world production in 2006. Overall, production in Africa decreased from 7 167 tU in 2004 to 7 044 tU in 2006. Production in **Namibia** increased slightly from 3 038 tU in 2004 to 3 067 tU in 2006 and is expected to increase further in 2007 as open-pit mining of the Langer Heinrich deposit was initiated at the end of 2006. **Niger**'s output also increased from 3 185 tU in 2004 to 3 443 tU in 2006 and is expected to increase further to 3 633 tU in 2007. In contrast, production in **South Africa** decreased from 747 tU in 2004 to 534 tU in 2006, but is expected to increase to 750 tU in 2007. The decrease in the South African production was due to operational difficulties at the Vaal River operations, which resulted in lower volumes of ore and in turn lower production at the Nufcor plant. Due to commercial considerations, maintenance at this plant had been neglected in previous years, which led to further difficulties that eventually curtailed production. Uranium production in South Africa is primarily determined by the gold content of the ore, since uranium is produced as a by-product or co-product of gold mining.

Production in the **Middle East, Central** and **Southern Asia** increased steadily between 2004 and 2006, totalling 7 811 tU (about 20% of the world total) in 2006, compared to 6 074 tU in 2004. This increase is largely driven by developments in **Kazakhstan**, where production rose from 3 719 tU in 2004 to 5 281 tU in 2006 (a 42% increase). In 2007, production is expected to increase by 37% to 7 245 tU. Production in **Uzbekistan,** estimated to have reached 2 260 tU in 2006, is expected to increase to 2 300 tU in 2007. Iran reported the start of production by open-pit mining of the Gachin deposit and processing at the Bandar Abbas uranium production plant. Production is estimated to have amounted to 5 tU in 2006, but could increase to 20 tU in 2007. **India** and **Pakistan** do not report production data but output is estimated to have remained steady from 2004 to 2006 at 230 tU and 40 tU, respectively.

China, the only producing country in **East Asia**, does not report official production figures. Annual production is estimated to have been 750 tU from 2004 through 2006. Production is expected to increase in 2007 however, since the Qinlong underground mine was recently opened and the Yining ISL mine has been expanded. These developments are expected to add 200 tU/year nominal capacity, when full scale production is achieved.

Australia, the only producing country in the **Pacific** region, reported a significant decrease from 8 982 tU in 2004 to 7 593 tU in 2006 (a 20% decline from 2005 production of 9 512 tU). Production decreases at all three mines were recorded in 2006, at Olympic Dam due to processing difficulties, at Ranger due to higher than average rainfall restricting access to high grade ore and at the Beverley ISL facility due to operational difficulties. Production in Australia is expected to remain at about 7 600 tU in 2007.

Ownership

Table 20 shows the ownership of uranium production in 2006 in the 20 producing countries. Domestic mining companies controlled about 71.3% of 2006 production, compared to about 69.3% in 2004. Non-domestic mining companies controlled about 28.7% of 2006 production with approximately 10.2% controlled by government-owned companies and 18.5% by privately-owned companies.

Table 20. **Ownership of uranium production based on 2006 output**

COUNTRY	Domestic mining companies				Non-domestic mining companies				TOTAL
	Government-owned		Privately-owned		Government-owned		Privately-owned		
	tU	%	tU	%	tU	%	tU	%	
Australia	0	0.0	1 983	26.1	0	0.0	5 610	73.9	7 593
Brazil	200	100.0	0	0.0	0	0.0	0	0.0	200
Canada	0	0.0	7 193	72.9	2 617	26.5	52	0.5	9 862
China*	750	100.0	0	0.0	0	0.0	0	0.0	750
Czech Republic	375	100.0	0	0.0	0	0.0	0	0.0	375
France*	2	87.7	1	12.3	0	0.0	0	0.0	3
Germany	65	100.0	0	0.0	0	0.0	0	0.0	65
Hungary	2	100.0	0	0.0	0	0.0	0	0.0	2
India*	230	100.0	0	0.0	0	0.0	0	0.0	230
Iran, Islamic Rep of*	5	100.0	0	0.0	0	0.0	0	0.0	5
Kazakhstan	3 759	71.2	712	13.5	0	0.0	810	15.3	5 281
Namibia*	107	3.5	2 960	96.5	0	0.0	0	0.0	3 067
Niger	1 157	33.6	0	0.0	1 440	41.8	846	24.6	3 443
Pakistan*	40	100.0	0	0.0	0	0.0	0	0.0	40
Romania*	90	100.0	0	0.0	0	0.0	0	0.0	90
Russian Federation	3 190	100.0	0	0.0	0	0.0	0	0.0	3 190
South Africa	0	0.0	534	100.0	0	0.0	0	0.0	534
Ukraine *	808	100.0	0	0.0	0	0.0	0	0.0	808
United States*	0	0.0	1 805	100.0	0	0.0	0	0.0	1 805
Uzbekistan*	2 260	100.0	0	0.0	0	0.0	0	0.0	2 260
Total	**13 040**	**32.9**	**15 188**	**38.4**	**4 057**	**10.2**	**7 318**	**18.5**	**39 603**

* Secretariat estimate.

Employment

Although the data are incomplete, Table 21 shows that employment levels at existing uranium production centres increased slightly from 2004 to 2006, and are expected to continue to do so in 2007, mainly due to the development of new projects in Kazakhstan. Table 22 provides, in selected countries, employment directly related to uranium production (excluding head office, R&D, pre-development activities, etc).

Table 21. **Employment in existing production centres of countries listed**
(in person-years)

COUNTRY	2000	2001	2002	2003	2004	2005	2006	2007 (expected)
Argentina	70	62	60	60	60	60	60	80
Australia (a)	527	550	502	655	743	889	959	1 054
Brazil (b)	48	128	128	140	140	140	140	140
Canada (c)	1 026	973	972	965	985	1 067	1 152	1 300
China	8 500	8 200	8 000	7 700	7 500	7 000	7 300	7 400
Czech Republic	2 887	2 641	2 507	2 426	2 409	2 312	2 251	2 263
Germany (d)	3 115	3 004	2 691	2 444	2 230	2 101	1 835	1 757
India	4 000	4 200	4 200	4 200	4 200	4 200	4 300	4 300
Iran, Islamic Rep of	0	0	0	0	0	0	200	200 *
Kazakhstan	4 100	4 000	3 770	3 870	5 120	6 522	6 941	7 845
Namibia	902	785	782	NA	NA	NA	NA	NA
Niger	1 680	1 607	1 558	1 606	1 598	1 657	1 741	1 930
Portugal	47	30	11	0	0	0	0	0
Romania	2 150	2 000 *	2 000 *	2 000 *	2 000 *	2 000 *	2 000 *	2 000 *
Russian Federation	12 500	12 325	12 800	12 785	12 670	12 551	12 575	12 751
Slovenia (d)	79	69	48	45	40	28	20	12
South Africa	160	150	150	150	150	150	150	150
Spain	134	58	56 (d)	56 (d)	56 (d)	56 (d)	58 (d)	58 (d)
Ukraine	NA	NA	NA	NA	4 380	4 350	4 310	4 310 *
United States	401	245	277	204	299	524	600	600 *
Uzbekistan	7 331	7 300	8 370	8 460	8 560	8 620 *	8 700 *	8 700 *
Total	**49 657**	**48 327**	**48 882**	**47 766**	**53 140**	**54 227**	**55 292**	**56 850**

NA Not available. * Secretariat estimate.

(a) Olympic Dam does not differentiate between copper, uranium, silver and gold production. Employment has been estimated for uranium-related activities.

(b) Employment directly related to uranium production.

(c) Employment at mine sites only.

(d) Employment related to decommissioning and rehabilitation.

Table 22. **Employment directly related to uranium production and productivity**

COUNTRY	2004		2005		2006	
	Production employment (person-years)	Production (tU)	Production employment (person-years)	Production (tU)	Production employment (person-years)	Production (tU)
Australia	743	8 982	889	9 512	959	7 593
Brazil	140	159	140	110	140	200
Canada	985	11 597	1 067	11 628	1 152	9 862
China	6 750	730*	6 300	750*	6 700	750*
Kazakhstan	3 732	3 719	4 873	4 346	4 460	5 281
Namibia	NA	3 038*	NA	3 146*	NA	3 067*
Niger	1 388	3 185	1 591	3 322	1 678	3 443
Russian Fed.	4 746	3 290	4 778	3 285	4 804	3 190
South Africa	60	747	60	673	65	534
Ukraine	1 790	855	1 760	830	1 720	808
United States	173	943	445	1 171	878	1 805
Uzbekistan	7 050	2 087	7 130*	2 300*	7 200*	2 260*

NA Data not available.
* Secretariat estimate.

Production methods

Uranium is mainly produced using open-pit and underground mining techniques processed by conventional uranium milling. Other mining methods include *in situ* leaching (ISL); co-product or by-product recovery from copper, gold and phosphate operations; heap leaching and in-place leaching (also called stope or block leaching). Stope/block leaching involves the extraction of uranium from broken ore without removing it from an underground mine, whereas heap leaching involves the use of a leaching facility on the surface once the ore has been mined. Small amounts of uranium are also recovered from mine water treatment and environmental restoration activities.

Historically, uranium production has principally involved open-pit and underground mining. However, over the past two decades, ISL mining, which uses either acid or alkaline solutions to extract the uranium directly from the deposit, has become increasingly important. The uranium dissolving solutions are injected into, and recovered from, the ore-bearing zone using a system of wells. ISL technology is currently being used to extract uranium from sandstone deposits only and in recent years has become an increasingly important method of uranium production. In 2006, production by ISL exceeded production by open-pit mining and in 2007 this trend is expected to continue.

The distribution of production by type of mining or "material sources" for 2003 through 2007 is shown in Table 23. The category "Other methods" includes recovery of uranium through treatment of mine waters as part of reclamation and decommissioning.

As shown in Table 23, open-pit and underground mining with conventional milling continue to be the dominant uranium production technologies, accounting for 67.5% of total production in 2005 and 64.1% in 2006. The increase in ISL since 2002 resulted from increased production in Australia, China, Kazakhstan (increasing by 35% from 2004 to 2006), the Russian Federation, the United States and Uzbekistan. The contribution from co-product/by-product recovery, which declined from 11% in 2004 to 8.6% in 2006, mainly resulted from reduced production at the Olympic Dam mine in Australia.

In 2007, open-pit and underground mining are expected to continue to account for a majority of the world's uranium production (61.4% of total production), although both open-pit and underground shares are expected to decrease slightly. Production using ISL technology is expected to increase its relative share due to increasing production expected in Kazakhstan (a 37% increase from 2006 to 2007). In the near future, ISL could increase in significance further if planned projects in Kazakhstan, the Russian Federation, the United States and Uzbekistan are brought into production. On the other hand, implementation of a major increase in capacity at Olympic Dam, currently the subject of a feasibility study, would ensure a continued important role for the co-product/by-product category.

Table 23. **Percentage distribution of world production by production method**

Production method	**2003**	**2004**	**2005**	**2006**	**2007** (expected)
Open-pit	29.8	27.5	28.1	24.2	23.7
Underground	41.6	39.1	39.4	39.9	37.7
In situ leaching	18.4	20.0	20.0	24.9	27.7
In place leaching*	<0.1	<0.1	<0.1	<0.1	<0.1
Co-product/by-product	9.7	11.0	10.3	8.6	8.4
Heap leaching**	1.9	2.2	1.9	2.2	2.4
Other methods***	0.5	0.2	0.3	0.2	0.1

* Also known as stope leaching or block leaching.
** A subset of open-pit mining, since it is used in conjunction with open-pit mining.
*** Includes mine water treatment and environmental restoration.

Projected production capabilities

To assist in developing projections of future uranium availability, member countries were asked to provide projections of ***production capability*** through 2030. Table 24 shows the projections for ***existing and committed production centres*** (A-II columns) and for existing, committed, ***planned and prospective production centres*** (B-II columns) in the <USD 80/kgU category through 2030 for all countries that either are currently producing uranium or have the potential to do so in the future. Note that both the A-II and B-II scenarios are supported by local RAR and Inferred Resources in the <USD 80/kgU category.

Several current or potential uranium producing countries, including China, India, Malawi, Mongolia, Namibia, Pakistan, Romania, United States and Uzbekistan, did not report projected production capabilities. Projections of future production capability for Pakistan and Romania in Table 24 are based on reports that these countries intend to meet their future domestic reactor requirements with domestic production.

The reported production capability of existing and committed production centres in 2007 is about 54 370 tU. Expected 2007 production of 43 328 tU thus represents 80% of the stated production capability. For comparison, 2005 uranium production was 41 943 tU, about 84% of the 2005 production capability. Total production capability for 2007, including planned and prospective centres, is about 56 855 tU, 5 290 tU more than the 2005 total capability of 51 565 tU, with significant increases in Kazakhstan (2 800 tU), Namibia (1 000 tU) and South Africa (730 tU). Clearly, an expansion in production capability driven by recent uranium price increases is underway.

According to the information compiled for this volume, the uranium production industry is projected to undergo a significant expansion during the next five to ten years as existing production centres are expanded (Australia, Canada, Kazakhstan, Niger and the Russian Federation) and new production centres are brought online (Canada, Jordan, Kazakhstan, Malawi, Namibia, Niger, the Russian Federation, South Africa, the Ukraine, and United States). Later, closure of existing mines due to resource depletion is expected to be offset by the opening of new mines and plants. As currently projected, production capability of existing and committed production centres would reach over 95 630 tU/year in 2015. Total potential production capability (including planned and prospective production centres) is currently projected to rapidly climb to over 117 000 tU/year in 2015.

Changes in production facilities

Production capability at existing and committed production centres has increased only slightly between 2001 (45 310 tU), when uranium prices began to increase, 2003 (47 170 tU) and 2005 (49 720 tU). Driven by recent uranium spot price increases, production capability at existing and committed production centres is projected to increase to 54 370 tU in 2007. Significant new production capability is planned for the near-term both through the expansion of existing production centres and the opening of new mines. Some of the significant changes that are expected in the next few years include:

Planned mine re-openings or expansion of existing facilities

2007 China (Expansion of Fuzhou to 200 tU).

2007 India (Production at Banduhurang mine in sandstone).

India (Production centre at Bagjata mine in vein).

2008 Australia (Ranger: Construction of a laterite treatment plant to produce 340 tU/year, over seven years).

2009 Niger (Expansion of Somair plant production capability, and construction of a heap leaching unit – 700 tU/year).

2010 Canada (McArthur River and Key Lake expansion to produce 8 800 tU/year).

2010 Kazakhstan (Southern Zarechnoye, 1 000 tU/year).

Brazil (Caetité expansion to 340 tU/year)

2013 Australia (Proposed Olympic Dam expansion, to produce 12 720 tU/year).

Table 24. **World uranium production capability to 2030**
(in tonnes U/year, from RAR and Inferred Resources recoverable at costs up to USD 80/kgU, except as noted)

COUNTRY	2007		2010		2015		2020		2025		2030	
	A-II	B-II	A-II	B-II	A-II	B-II	A-II	B-II	A-II	B-II	A-II	B-II
Argentina	120	120	500	500	500	500	500 *	500 *	500 *	500 *	500	500 *
Australia	9 400	9 400	10 200	10 200	10 200	19 000	10 200	22 400	5 500	17 700	5 500	17 700
Brazil	340	340	420	420	1 100	1 100	1 100 *	1 100 *	1 100	1 100	1 100 *	1 100 *
Canada	14 990	14 990	17 730	19 270	17 730	19 270	17 730	19 270	17 730	19 270	17 730	19 270
China*	940	1 040	940	1 040	1 200	1 200	1 200	1 200	1 200	1 200	1 200	1 200
Czech Republic	500	500	200	200	50	50	50	50	40	40	30	30
India*	295	980	980	980	980	1 200	1 000	1 600	1 000	2 000	1 000	2 000
Iran, Islamic Rep. of	20	20	70	70	100 *	100 *	100 *	100 *	100 *	100 *	100 *	100 *
Jordan	0	0	2 000	2 000	2 000	2 000	2 000 *	2 000 *	2 000 *	2 000 *	2 000 *	2 000 *
Kazakhstan	7 000	7 000	18 000	18 000	21 000	22 000	20 000	23 000	20 000 *	23 000 *	20 000 *	23 000 *
Malawi*	0	0	1 270	1 270	1 270	1 270	0	0	0	0	0	0
Mongolia*	0	0	150	500	150	500	150	500	150	500	150	500
Namibia*	5 000	5 000	6 000	7 000	8 000	9 000	6 000	8 000	5 000	7 000	5 000	7 000
Niger	4 000	4 000	4 500	4 500	10 000 *	10 000 *	5 700 *	5 700 *	5 700 *	5 700 *	5 000 *	5 000 *
Pakistan (a)	65	65	65	110	90	110	235	380	360	530	360 *	530 *
Romania (a)	100	100	200	200	200	200	300	300	300	300	300	300
Russian Federation	3 400	3 400	4 700	5 000	7 400	12 000	8 000	18 000	8 000	18 000	8 000	18 500
South Africa (b)	2 000 *	2 000 *	4 860	4 860	4 860	6 320	4 860	6 320	4 860	6 320	4 860	6 320
Ukraine	1 000	1 000 *	1 500 *	1 500	2 000 *	2 000	2 700 *	2 700	3 700 *	3 700	3 700 *	3 700
United States (c)	2 900	4 600	3 400	6 100	3 800	6 600	3 700	6 500	3 100	5 600	3 100 *	5 600 *
Uzbekistan (c)	2 300	2 300	3 000	3 000	3 000	3 000	3 000	3 000	3 500	3 500	3 500 *	3 500 *
TOTAL	54 370	56 855	80 685	86 720	95 630	117 420	88 525	122 620	83 840	118 060	83 130	117 850

A-II Production Capability of Existing and Committed Centres supported by RAR and Inferred Resources recoverable at <USD 80/kgU.

B-II Production Capability of Existing, Committed, Planned and Prospective Centres supported by RAR and Inferred Resources recoverable at <USD 80/kgU.

* Secretariat estimate.

NA Data not available or not reported.

(a) Projections are based on reported plans to meet domestic requirements.

(b) From resources recoverable at costs of <USD 40/kgU.

(c) Data from previous Red Book.

Recent mine openings

2005

Kazakhstan	(Kendala JSC- Central Mynkuduk, 2 000 tU/year in 2010)

2006

Iran	(Bandar Abbas, 21 tU/year)
Namibia	(Langer Heinrich, 1 000 tU/year)

New mines planned (date indicates estimated start of production)

2007

China	(Qinlong, 100 tU/year)
Kazakhstan	(Appak LLP-West Mynkuduk, 1 000 tU/year in 2010)
Kazakhstan	(Karatau LLP- Budenovskoye, 1 000 tU/year in 2009)
South Africa	(Uranium One – Dominium & Rietkuil, 1 460 tU/year in 2010)

2008

Australia	(Honeymoon, 340 tU/year)
Kazakhstan	(Semizbai-U LLP – Semizbai, 500 tU/year)
Kazakhstan	(Kyzylkum LLP – Kharasan-1, 3 000 tU/year in 2010)
Kazakhstan	(Southern Inkai, 1 000 tU/year)
Kazakhstan	(Irkol, 750 tU/year)
Kazakhstan	(Baiken-U LLP– Kharasan, 2 000 tU/year in 2014)
Kazakhstan	(Akbastau JV JSC – Budenovskoye, 3 000 tU/year)
Namibia	(Trekkopje, 1 600 tU/year)
Russia	(Khiagda, 1 000 tU/year, 2 000 tU in 2015)

2009

Iran	(Saghand, 50 tU/year)
Malawi	(Kayelekera, 1 270 tU/year)
Namibia	(Valencia, 1 000 tU/year)

2010

Canada	(Midwest, 2 300 tU/year)
India	(Tummalapalle, 220 tU/year)
Russia	(Gornoe, 600 tU/year)

2011

Brazil	(Itataia, 680 tU/year)
Canada	(Cigar Lake, 6 900 tU/year)
India	(Mohuldih, 30 tU/year)
Niger	(Imouraren, 5 000 tU/year)
Niger	(Azelik, 700 tU/year)
Russia	(Olov, 600 tU/year)

2012

India	(Lambapur-Peddagattu, 130 tU/year)
India	(Killeng-Pyndengsohiong, 340 tU/year)
Russia	(Elkon, 5 000 tU/year)

2015

Ukraine	(Severinskoye, 1 200 tU/year)

2010-2030

Kazakhstan	(Central Moinkum, 1 000 tU/year)
Kazakhstan	(Zhalpak, 1 000 tU/year)

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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><th></th><th colspan="3">IDENTIFIED RESOURCES</th><th colspan="3">UNDISCOVERED RESOURCES</th></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**

<table>
<tr><th colspan="2"></th><th colspan="2">IDENTIFIED RESOURCES</th><th colspan="2">UNDISCOVERED RESOURCES</th></tr>
<tr><td rowspan="3">Recoverable at costs</td><td><USD 40/kgU</td><td>REASONABLY ASSURED RESOURCES</td><td>INFERRED RESOURCES</td><td rowspan="2">PROGNOSTICATED RESOURCES</td><td rowspan="3">SPECULATIVE RESOURCES</td></tr>
<tr><td>USD 40-80/kgU</td><td>REASONABLY ASSURED RESOURCES</td><td>INFERRED RESOURCES</td></tr>
<tr><td>USD 80-130/kgU</td><td>REASONABLY ASSURED RESOURCES</td><td>INFERRED RESOURCES</td><td>PROGNOSTICATED RESOURCES</td></tr>
</table>

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.

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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*
     i. 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.
     ii. 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)

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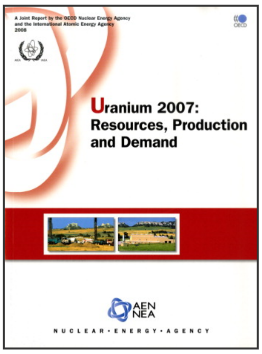

From:

Uranium 2007

Resources, Production and Demand

Access the complete publication at:

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

Please cite this chapter as:

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

DOI: https://doi.org/10.1787/uranium-2007-3-en