NUCLEAR FUEL RESERVES

1. Introduction

Light-water reactors are the primary type of nuclear power reactor operated throughout the world. These reactors are fueled with uranium that has been enriched from the naturally occurring concentration of 0.71% ^{235}U to ~5% ^{235}U (1). Most of the commercial nuclear fuel that has been produced to date has been manufactured by enriching natural uranium. Another source of enriched uranium for civilian nuclear reactor fuel is available from the dismantlement of nuclear weapons from the stockpiles of the United States and the Russian Federation (former Soviet Union). The deenrichment of highly enriched uranium (HEU) and the use of plutonium in a mixed-oxide fuel cycle provide the potential for an additional, readily available reserve for civilian nuclear fuel.

2. Uranium Mineral Resources

The Organization for Economic Cooperation and Development's Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA) estimate reasonably assured resources (RAR) of uranium in three cost categories: \$40/kg U or less; \$40/kg U to \$80/kg U; and \$80/kg U to \$130/kg U (2). Costs include the direct costs of mining, transporting, and processing the uranium ore; the costs of associated environmental and waste management; the costs where applicable of maintaining nonoperating production units; in the case of ongoing projects, any capital costs which remain unamortized; the capital cost of providing new production units where applicable, including the costs of financing; indirect costs such as office overheads, taxes, and royalties where applicable; and future exploration and development costs wherever required for further ore delineation to the stage where it is ready to be mined. Sunk costs, such as the costs for geologic exploration and land acquisition, are not usually taken into consideration for the determination of uranium costs for these three categories (3).

The U.S. Department of Energy (DOE) and the NEA/IAEA employ similar terms to classify uranium resources, as (4) reasonably assured, estimated additional (EA), or speculative. The NEA/IAEA divides the estimated additional resources into two types, EAR-I and EAR-II, describing known resources and undiscovered ones, respectively (5).

Reasonably assured resources include uranium that occurs in known mineral deposits of delineated size, grade, and configuration in which the estimated quantities could be recovered within the given range of production costs using proven mining and processing technologies (5). EAR-I includes uranium deposits in addition to RAR that are inferred from direct geological evidence, extensions of well-explored deposits, or in deposits in which geologic continuity has been established but insufficient data exist to permit classification as RAR (5). EAR-II includes uranium in addition to EAR-I that is expected to occur in deposits for which evidence is primarily indirect and are believed to exist in well-defined geological trends (6). The speculative resources (SR) category includes uranium that is thought to exist, primarily on the basis of indirect

evidence and geologic extrapolations, in deposits that are deemed discoverable with existing exploration techniques (6).

3. Geochemical Nature and Types of Deposits

The crust of the earth contains ~2–3 ppm uranium, with alkalic igneous rocks tending to be more uraniferous that basic and ferromagnesian igneous rocks (7). Elemental uranium oxidizes readily. The solubility and distribution of uranium in rocks and ore deposits depend primarily on its valence state; uranium is highly soluble in the six-valent state and relatively insoluble in the four-valent state. Uraninite, the most common mineral in uranium deposits, contains the four-valent ion (7).

A classification system for the major types of uranium ore deposits was revised by the IAEA in 1988–1989 replacing the classification system developed previously (8). This system assigns the uranium resources of the world to various categories on the basis of their geological setting. The 15 main categories of uranium ore deposit types arranged according to their approximate economic significance include (*1*) unconformity-related deposits; (*2*) sandstone deposits; (*3*) quartz-pebble conglomerate deposits; (*4*) vein deposits; (*5*) breccia complex deposits; (*6*) intrusive deposits; (*7*) phosphorite deposits; (*8*) collapse breccia pipe deposits; (*9*) volcanic deposits; (*10*) surficial deposits; (*11*) metasomatite deposits; (*12*) metamorphite deposits; (*13*) lignite; (*14*) black shale deposits; (*15*) other types of deposits. The main features of these deposits are described below:

1. **Unconformity-related deposits:** Deposits of the unconformity-related type occur spatially close to major unconformities. These deposits usually developed during the period ~1800–800 million years ago in intracratonic basins. Deposits also developed during Phanerozoic time. Examples of unconformity-related deposits include the ore bodies at Cluff Lake, Key Lake, and Rabbit Lake in northern Saskatchewan, Canada, and those in the Alligator Rivers area in northern Australia (8).
2. **Sandstone deposits:** A majority of the ore deposits of this type are contained in rocks that were deposited under marginal marine or fluvial conditions. Lacustrine and eolian sandstones are also mineralized, but uranium deposits are much less common in these rocks. The host rocks are almost always medium to coarse-grained poorly sorted sandstones containing pyrite and organic matter of plant origin. The sediments are commonly associated with tuffs. Unoxidized deposits of this type consist of pitchblende and coffinite in arkosic and quartzitic sandstones. Upon weathering, secondary minerals such as carnotite, tuyamunite and uranophaneare formed. The Tertiary, Jurassic, and Triassic sandstones of the Western Cordillera of the United States account for most of the uranium production in that country. Cretaceous and Permian sandstones are important host rocks in Argentina. Other important uranium deposits are found in Carboniferous deltaic sandstones in Niger; in Permian lacustrine siltstones in France; and in Permian sandstones of the Alpine region. The

deposits in Precambrian marginal marine sandstones in Gabon have also been classified as sandstone deposits (9).

3. **Quartz-pebble conglomerate deposits:** Known quartz-pebble conglomerate ores are restricted to a specific period of geologic time. These ore types occur in basal Lower Proterozoic beds unconformably situated above Archaean basement rocks composed of granitic and metamorphic strata. A number of commercial deposits are located in Canada and South Africa with some subeconomic occurrences reported in Brazil and India (10).
4. **Vein deposits:** The vein deposits of uranium are those in which uranium minerals fill cavities such as cracks, fissures, pore spaces, breccias, and stockworks. The dimensions of the openings have a wide range, from the narrow pitchblende filled cracks, faults and fissures in some of the ore bodies in Europe, Canada, and Australia to the massive veins of pitchblende at Jachymov, Shinkolobwe, and Port Radium (11).
5. **Breccia complex deposits:** Deposits of this group were developed in Proterozoic continental regimes during anorogenic periods. The host rocks include felsic volcanoclastics and sedimentary rocks. The ores generally contain two phases of mineralization, an earlier strata bound and a later transgressive one. The principal ore deposit of this type is found at the Olympic Dam site in South Australia. Deposits, which may also belong to this category, occur in Zambia, Zaire, and the Aillik Group in Labrador, Canada (11).
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 of this category include the uranium occurrences in the porphyry copper deposits such as Bingham Canyon and Twin Butte in United States, the Rossing deposit in Namibia, the Ilimaussaq deposit in Greenland, Palabora in South Africa, and the deposits in the Bancroft area, Canada (11).
7. **Phosphorite deposits:** Sedimentary phosphorites contain low concentrations of uranium in fine grained apatite. Uranium of this type is considered an unconventional resource. Significant examples of these uranium ore types include the deposits in Florida, where uranium is recovered as a by-product, and the large deposits in North African and Middle Eastern countries (12).
8. **Collapse breccia pipe deposits:** The primary occurrence of this ore type is in circular, vertical pipes filled with down-dropped fragments. Uranium is concentrated in the permeable breccia matrix and in the accurate fracture zones enclosing the pipe. An example of this type of deposit is found in the Arizona Strip in Arizona (12).
9. **Volcanic deposits:** Uranium deposits of this type are strata bound and structure bound concentrations in acid volcanic rocks. Uranium is commonly associated with molybdenum, fluorine, etc. Type examples are the uranium deposits Michelin in Canada, Nopal I in Chihuahua, Mexico, Macusani in Peru, and numerous deposits in China and the CIS (12).

10. **Surficial deposits:** Uraniferous surficial deposits may be broadly defined as uraniferous sediments, usually of Tertiary to Recent age that have not been subjected to deep burial and may or may not have been calcified to some degree. The uranium deposits, associated with calcrete, which occur in Australia, Namibia and Somalia in semiarid areas where water movement is chiefly subterranean are included in this type. Additional environments for uranium deposition include peat and bog, karst caverns as well as pedogenic and structural fills (12).
11. **Metasomatite deposits:** Included in this grouping are uranium deposits in alkali metasomatites (albitites, aegirinites, alkali-amphibole rocks) commonly intruded by microcline granite. Type examples are the deposits Espinharasin Brazil, Ross Adams in Alaska as well as the Zheltye Vody deposit in Krivoy Rog area, Ukraine (12).
12. **Metamorphic deposits:** Uranium deposits belonging to this class occur in metasediments and/or metavolcanics generally without direct evidence of postmetamorphic mineralization. Examples include the deposits at Forstau, Austria (12).
13. **Lignite:** Deposits of this type, generally classified as unconventional uranium resources occur in lignite and in clay and/or sandstone immediately adjacent to lignite. Examples are uraniferous deposits in the Serres Basin, Greece, North and South Dakota, and Melovoe, in the CIS (13).
14. **Black shale deposits:** Low concentrations of uranium occur in carbonaceous marine shales. Also these resources are considered unconventional resources for the purpose of this report. Examples include the uraniferous alumshale in Sweden, the Chatanooga Shale in the United States, but also the Chanziping deposit of the "argillaceous-carbonaceous-siliceous-pelitic rocks" type in the Guangxi Autonomous Region in China and the deposit of Gera-Ronneburg, in the eastern portion of Germany (13).
15. **Other deposits:** Included in this grouping are those deposits that cannot be classified with the deposit types already mentioned. These include the uranium deposits in the Jurassic Todilto Limestone in the Grants district, New Mexico (13).

The first six geologic ore types listed above, together with selected types from category seven, are considered conventional resources. These categories represent a majority of the uranium producing geologic formations worldwide in 1992. Very low grade resources, which are not now economic or from which uranium is only recoverable as a minor by-product are considered unconventional resources (14).

4. Domestic Uranium Reserves

The U.S. estimates of uranium resources for reasonably assured resources, estimated additional resources, and speculative resources at costs of $66, 110, and 220/kg of uranium are given in Table 1 (15). These estimates include only conventional uranium resources which primarily include sandstone deposits of the

Colorado Plateaus, the Wyoming basins, and the Gulf Coastal Plain of Texas. Marine phosphorite in central Florida, western United States, Africa and other areas contain low grade uranium containing 30–150 ppm U, that can be recovered as a by-product from wet-process phosphoric acid.

5. Foreign Uranium Reserves

The OECD/NEA and IAEA issue an annual report on world uranium resources, production (2). NEA/IAEA data for reasonably assured and estimated additional resources at costs of <$40, 40–80, and $80–130/kg of uranium are given in Table 2 (16). These resources total ~3.2 million metric tonnes for RAR and ~1.4 million metric tones for EAR-I.

A summary of other reported undiscovered conventional uranium resources, with and without cost range estimates, is provided in Table 3 (17). These resources, which total ~11.3 million metric tonnes, include estimates that are not strictly consistent with standard NEA/IAEA definitions. These estimates include EAR-II and SR (18).

6. Resources

As of 1 January, 2003, RAR recoverable at costs of $40/kg U or less were estimated at 1,730,495 tonnes U. Reasonably assured resources recoverable at costs of $40/kg U to $80/kg U were estimated at an additional 727,657 tonnes U and RAR recoverable at costs of $80–130/kg U were estimated at an additional 706,486 tonnes U. Estimated additional resources in the $40/kg U or less cost category were ~792,782 tonnes U. Estimated additional resources in the $40–80 kg/U category were estimated as ~285,980 tonnes U. Estimated additional resources in the $80–130 kg/U category were estimated as ~337,080 tonnes U.

Total RAR and EAR, recoverable at costs of $130/kg U or less, are estimated at 3.165 million tonnes U and 1.416 million tonnes U, respectively, as of 1 January, 2003. There remains very good potential for the discovery of additional uranium resources of conventional type, as reflected by estimates of Reported Undiscovered Conventional Resources (EAR-II) and SR. Based on reported estimates, this potential is ~11.269 million tonnes U. Over two-thirds of this potential occurs in Canada, Kazakhstan, Mongolia, South Africa, and the United States. There are also large tonnages of unconventional resources of uranium, most of which are associated with marine phosphate deposits (22 million tonnes U) and U dissolved in seawater (4000 million tonnes U). The technology to recover uranium from phosphates is mature but high recovery costs limit the utilization of these resources (19). Laboratory tests to extract uranium from seawater have been completed. However, recovery costs on the order of $300/kg U are currently prohibitive (19).

7. Production

Cumulative production of uranium since the late 1930s has totaled about 2 million tonnes U (20). Uranium production in 2002 of 36,042 tonnes U was only ~54% of World reactor requirements of 66,815 tonnes U (21). The remaining inventory requirements were met from inventory draw down. A worldwide production shortfall has developed since 1990 when production exceeded reactor requirements by ~1000 tonnes U/year.

8. Capability

The uranium production industry will continue to experience moderate change during the next 10–20 years. In 2005, existing and committed capability will decrease to ~45,295 tonnes U/year. However, additions of planned and prospective production centers will make available an additional 5850 tonnes U/year. This addition will increase total capacity to 51,155 tonnes U/year.

The expected closure of a number of existing mines due to resource depletion will cause existing and committed capability to decrease to 43,059 tonnes U/year in 2010. The addition of planned and prospective centers would make available an additional 20,880 tonnes U/year, raising the total capacity to 63,939 tonnes U/year in 2010. Annual production capability is expected to continue to decline to ~43,612 tonnes U/year in 2015 and 43,005 tonnes U/year in 2020 (22).

9. Supply Projections

Primary uranium production is insufficient to meet world uranium requirements. In 2002, uranium production (36,042 tonnes U) provided only ~54% of world reactor requirements (66,815 tonnes U). Remaining requirements were met by secondary sources (23), which include stocks and inventories of natural and enriched uranium, both civilian and military in origin; nuclear fuel produced by reprocessing of spent reactor fuels and form surplus military plutonium; uranium produced by reenrichment of depleted uranium tails. A major source of secondary supply of uranium is from the reduction of nuclear weapons stockpiles.

10. Demand

The demand for uranium in the commercial sector is primarily determined by the requirements of power reactors. At the beginning of 2003, there were 441 nuclear power plants operating worldwide, having a combined capability of ~364 GWe. Forecasts for installed capacity, although uncertain, are indicative of future growth for nuclear capacity to the year 2020. The capacity in 2020 is expected to range from ~418 GWe for the low case to ~483 GWe for the high case. The low case represents growth of ~15% from 2003 capacity, while the high case represents a net increase of ~33% from 2003 capacity (24).

World annual uranium requirements in 2003 were estimated at ~68,435 tonnes natural uranium equivalent. Reactor-related requirements are expected to rise by 10–29% between 2003 and 2020, reaching 73,495 tU in the low case and 86,070 tU in the high case (25).

11. Nuclear Fuel Production from HEU ''Deenrichment''

In February 1993, the United States and the Russian Federation signed The Agreement between the Government of the United States and the Government of the Russian Federation Concerning the Disposition of HEU from nuclear weapons. This agreement to blend down 500 metric tons of Russian HEU to low enriched uranium (LEU) for peaceful use in commercial reactors represents the equivalent of ~153,000 tU. As of 30 September 2003, ~193 metric tons of HEU have been downblended and 5705 metric tons of low enriched uranium fuel has been delivered to the United States for use in commercial reactors. These deliveries represent the dismantlement of 7733 nuclear warheads (26).

In 2002, the United States and Russian governments approved an amendment to the Agreement's implementing contract that established market-based pricing terms for the delivery of low enriched uranium derived from 30 tonnes of HEU/year through the year 2013. These annual deliveries will displace ~9000 tonnes of natural uranium and represent ~10–13% of world annual uranium requirements from 2003 to 2013 (26).

The United States has committed to the disposition of ~174 tonnes of surplus HEU with ~153 tonnes planned to eventually be blended down for use as LEU fuel in research and commercial nuclear reactors. In 2003, ~39 tonnes of HEU had already been converted to LEU. The remainder will be converted over the next few years, through ~2016. About 50 tonnes of HEU are being transferred to U.S. Enrichment Corporation (USEC) for down blending to yield ~647 tonnes of LEU fuel. This represents ~6000–7000 tonnes of natural uranium (27).

Deenrichment of HEU from ~93%–3% ^{235}U can be accomplished using the depleted tails from the original enrichment process. These tails contain on the average 0.20% ^{235}U. The deenrichment of 1 t of HEU uses 32 t of tails, yielding approximately 33 t of fuel having an enrichment of 3% ^{235}U. Producing the same amount of 3% enriched uranium from natural sources would require ~150 t of natural uranium metal. Therefore, 1 t of HEU is equivalent to 150 t of natural uranium (28).

12. Mixed-Oxide Nuclear Fuel

A potentially substantial source of fissile material (^{235}U and ^{239}Pu) that could displace primary production of uranium lies in the constituents of spent nuclear fuel form power plants. Upon discharge for a commercial reactor, spent nuclear fuel contains ~96% of the fissionable material originally present in the fresh fuel. In addition, fissile plutonium (^{239}Pu) was during the operation of the reactor by the capture of a neutron by ^{238}U. This plutonium can be recycled and used as fuel

in commercial reactors in the form of mixed-oxide fuel (MOX). This fuel consists of a blend of uranium dioxide and plutonium dioxide (29).

In January 2003, there were 34 reactors, ~8% of the world reactor fleet, licensed to use MOX fuel (29). These reactors were located in Belgium, China, France, Germany, India, Russia, Sweden, and Switzerland. Japan is also planning to employ MOX fuel technology though its use as been delayed. MOX reprocessing and fuel fabrication facilities currently exist, or are under construction, in Belgium, China, France, India, Japan, Russia, and the United Kingdom. The production and use of MOX fuel is summarized in Table 4 (30).

In September 2000, the United States and Russian concluded a surplus plutonium disposition agreement under which both countries agreed to dispose of 34 tonnes of surplus weapons-grade plutonium within the next 25 years. Both countries agreed to dispose of surplus plutonium by fabricating it into MOX fuel for irradiation in existing commercial nuclear reactors. This results in conversion of the plutonium into a form that cannot be readily used to make nuclear weapons (29).

The 68 tonnes of weapons-grade plutonium will displace ~7000–8000 tonnes of natural uranium over the 25 year period. This represents <1% of world annual uranium requirements over that period (29).

13. Toxicology of Uranium

The two primary effects associated with the introduction of uranium species into the human body are the development of cancer, primarily due to radiation induced tissue damage in the lung, and renal damage with possible kidney failure due to uranium ingestion (31). Soluble uranium compounds affect the respiratory system, liver, blood, lymphatics, kidneys, skin, and bone marrow. The insoluble uranium compounds affect the skin, bone marrow, and lymphatics. Lung cancer incidence has been noted to increase in uranium mine workers, especially those who smoke. Acute chemical toxicity produces damage primarily to the kidneys in the form of necrosis of the renal tubular epithelium leading ultimately in acute cases to kidney failure (32).

The U.S. Nuclear Regulatory Commission (NRC) regulates the protection of the health and safety of the public by issuing Standards for Protection Against Radiation (10 CFR 20, Appendix B) (33). In addition, the U.S. Environmental Protection Agency (EPA) issues National Primary Drinking Water Regulations (40 CFR 141) that address radioactive contamination of drinking water supplies. The maximum allowable effluent concentrations for release of uranium to air, water and sewer systems depends on the individual isotope of uranium due to half-life differences (10 CFR 20). These concentration limits for naturally occurring uranium isotopes (^{234}U, ^{235}U, and ^{238}U) range from 3×10^{-12} micro-Curies per milliliter (μCi/mL) for releases to air to 3×10^{-7} μCi/mL for releases to water. The EPA regulations for uranium in drinking water limit the concentration to levels to 30 micrograms per liter (μg/L) [40 CFR 141.66 (e)] (34).

Handling of soluble uranium compounds requires appropriate clothing to prevent skin contact and eye protection to prevent any possible eye contact. Protective clothing requirements for insoluble uranium compounds should prevent

repeated or prolonged skin contact. Eye protection for use in handling insoluble uranium compounds should prevent any possibility of eye contact. Respirators should always be worn to prevent inhalation of uranium dust, fumes, or gases (35).

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Table 1. **U.S. Uranium Reserves and Resources (tonnes U)**[a]

Resource category and state	<$66/kgU	<$110/kgU	<$220/kgU
RAR	120,202	403,697	641,380
New Mexico	38,102	154,675	256,733
Wyoming	48,081	164,654	263,991
Texas	2,722	10,433	17,237
Arizona, Colorado, Utah	20,412	55,792	77,111
Others	10,885	18,143	26,308
Potential Resources (EAR)	988,831	1,501,391	2,199,923
Potential Resources (EAR)	594,206	1,011,511	1,578,501
Total	*1,703,239*	*2,916,599*	*4,419,804*

[a]*Uranium Industry Annual 2002*, Energy Information Agency, U.S. Department of Energy, DOE EIA-0478 (2002), Washington, D.C., May 2003, p. 35.

Table 2. **Uranium Resources (tonnes U)**

	RAR, tonnes U[a]			EAR, tonnes U[b]		
Country	<$40/kgU	$40–80/kgU	$80–130/kgU	<$40/kgU	$40–80/kgU	$80–130/kgU
Algeria	0	19,500	0	0	0	0
Argentina	4,780	100	2,200	2,860	0	5,700
Australia	689,000	13,000	33,000	276,000	11,000	36,000
Brazil	26,235	59,955	0	0	57,140	0
Bulgaria	1,665	4,205	0	1,650	4,650	0
Canada	297,264	36,570	0	86,560	18,150	0
Cent. African Republic	0	6,000	6,000	0	0	0
Chile	0	0	560	0	0	885
China	26,235	8,825	0	5,890	8,800	0
Congo, Dem. Rep. of	0	1,350	0	0	1,275	0
Czech Republic	0	830	0	0	90	0
Denmark	0	0	20,250	0	0	12,000
Finland	0	0	1,125	0	0	0
France	0	0	0	0	0	9,510
Gabon	0	0	4,830	0	0	1,000
Germany	0	0	3,000	0	0	4,000
Greece	1,000	0	0	0	6,000	0
Hungary	0	0	0	0	0	13,800
India	0	0	40,980	0	0	18,935
Indonesia	0	320	4,300	0	0	1,155
Iran, Islamic Republic of	0	0	370	0	0	700
Italy	0	4,800	0	0	0	1,300
Japan	0	0	6,600	0	0	0
Kazakhstan	280,620	104,005	145,835	131,220	106,560	79,380
Malawi	0	8,775	0	0	0	0
Mexico	0	0	0	0	0	525
Mongolia	7,950	38,250	0	8,250	7,500	0
Namibia	57,262	82,035	31,235	57,142	16,418	13,525
Niger	89,800	12,427	0	125,377	0	0
Peru	0	1,215	0	0	1,265	0
Portugal	0	7,470	0	0	1,450	0

Russian Federation	52,610	71,440	18,970	15,860	18,400	86,960
Slovenia	0	2,200	0	0	5,000	5,000
Somalia	0	0	4,950	0	0	2,550
South Africa	119,184	112,480	83,666	49,313	17,627	13,400
Spain	0	2,460	2,465	0	0	6,380
Sweden	0	0	4,000	0	0	6,000
Thailand	0	0	5	0	0	5
Turkey	0	6,845	0	0	0	0
Ukraine	15,380	19,250	30,030	900	3,835	6,675
United States	0	102,000	243,000	0	0	0
Uzbekistan	61,510	0	18,110	31,760	0	7,080
Vietnam	0	0	1,005	0	820	4,615
Zimbabwe	0	1,350	0	0	0	0
Total	*1,730,495*	*727,657*	*706,486*	*792,782*	*285,980*	*337,080*

[a]Uranium 2003: Resources, Production and Demand, Joint Report of OECD Nuclear Energy Agency and International Atomic Energy Agency, OECD Publications Service, Paris, 2004, p. 15.

[b]Uranium 2003: Resources, Production and Demand, Joint Report of OECD Nuclear Energy Agency and International Atomic Energy Agency, OECD Publications Service, Paris, 2004, p. 16.

Table 3. **Reported Undiscovered Conventional Resources (tonnes U)**[a]

	EAR-II, tonnes U		SR, tonnes U	
Country	<$80/kgU	<$130/kgU	<$130/kgU	Cost range unassigned
Argentina	0	1,400	0	0
Brazil	120,000	120,000	0	500,000
Bulgaria	2,200	2,200	16,000	0
Canada	50,000	150,000	700,000	0
Chile	0	2,300	0	2,400
China	3,600	3,600	4,100	0
Columbia	0	11,000	217,000	0
Czech Republic	200	200	0	179,000
Denmark	0	0	50,000	10,000
Egypt	0	0	0	100
Germany	0	0	0	74,000
Greece	6,000	6,000	0	0
India	0	15,500	0	17,000
Indonesia	0	0	0	4,100
Iran, Islamic Republic of	0	3,400	4,500	6,000
Italy	0	0	0	10,000
Kazakhstan	290,000	310,000	500,000	0
Mexico	0	3,000	0	10,000
Mongolia	0	0	1,390,000	0
Niger	9,500	9,500	0	0
Peru	6,600	6,600	19,700	0
Portugal	0	1,500	5,000	0
Romania	0	3,000	3,000	0
Russian Federation	56,300	104,500	545,000	0
Slovenia	0	1,100	0	0
South Africa	34,900	110,300	0	1,112,900
Ukraine	0	1,600	0	255,000
United States	839,000	1,273,000	858,000	482,000
Uzbekistan	56,300	85,000	0	146,600
Venezuela	0	0	0	163,000
Vietnam	0	7,900	100,000	130,000
Zambia	0	22,000	0	0
Zimbabwe	0	0	25,000	0
Total	*1,474,600*	*2,254,600*	*4,437,300*	*3,102,100*

[a]Uranium 2003: Resources, Production and Demand, Joint Report of OECD Nuclear Energy Agency and International Atomic Energy Agency, OECD Publications Service, Paris, 2004, p. 21.

Table 4. **MOX Production and Use (in metric tonnes of equivalent natural U)**[a]

Country	Pre-2000[b]	2000[b]	2001[b]	2002[b]	2003 (estimated)[b]
MOX production					
Belgium	307	26	79	0	90
China	NA	NA	NA	NA	NA
France	NA	NA	NA	1120	1000
India	NA	NA	NA	NA	NA
Japan	650	15	20	0	NA
Russian Federation	NA	NA	NA	NA	NA
United Kingdom	300	NA	NA	NA	NA
Total Production	*1257*	*41*	*99*	*1120*	*1090*
MOX use					
Belgium	281	52	0	53	26
France	NA	800	800	800	800
Germany	NA	324	324	504	NA
India	NA	NA	NA	NA	NA
Japan	NA	NA	NA	NA	NA
Russian Federation	NA	NA	NA	NA	NA
Switzerland	677	151	111	53	NA
United Kingdom	NA	NA	NA	NA	NA
Total Use	*958*	*1327*	*1235*	*1410*	*826*

[b]Uranium 2003: Resources, Production and Demand, Joint Report of OECD Nuclear Energy Agency and International Atomic Energy Agency, OECD Publications Service, Paris, 2004, p. 59.
[b]Not available = NA.