PRODUCTION, INVENTORIES AND HEU IN THE WORLD URANIUM MARKET: PRODUCTION'S VITAL ROLE

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Abstract

This paper analyses recent uranium supply and demand relationships and projects supply through 2010. It discusses how the extremely depressed record low market prices have led to the ongoing annual inventory drawdown of over 25 000 t U resulting from the current 45% world production shortfall. It describes how the policy of the European Union and anti-dumping related activities in the USA are restricting imports of uranium from CIS producers to a majority of the world's nuclear utilities. These factors are reducing low priced uranium supply and forcing buyers to again obtain more of their requirements from producers. It discuses how the sale of Low Enriched Uranium (LEU) produced from of 550 t High Enriched Uranium (HEU) from Russia and Ukraine could potentially supply about 15% of world requirements through 2010. However, legislation currently being developed by the US Congress may ration the sale of this material, extending the LEU supply well into the next century. While the low cost supply is decreasing, nuclear generation capacity and its uranium requirements are projected to grow at about 1.5% through 2010. Demand for new uranium purchases is however, increasing at the much higher rate of 25-30% over the next 10–15 years, because of the increasingly large amount of unfilled demand of reactor operators. This increasing demand in the face of decreasing supply is resulting in a market recovery in which the spot price for non-CIS produced uranium has risen over 25% since October 1994. Prices will continue to increase as the market equilibrium shifts from a balance with alternative excess low priced supply to an equilibrium between production and demand. This change is taking place as the inventory is further depleted, CIS import restrictions are becoming more fully enforced and the rate at which LEU from HEU will enter the market is expected to become more clearly defined. It is anticipated that production must increase from current levels of about 32 000 t U/year, supplying 55% of requirements, to about 60 000 t U/year or greater to meet 80 to 90% of worldwide reactor requirements through 2010 (and beyond). The necessary production increase will occur *only after* market prices have risen to cover full production costs plus a profit. Higher prices are absolutely essential to assure production's vital role in supplying the future fuel supply of the world's nuclear reactors.

WORLD URANIUM MARKET OVERVIEW

During 1994 the average annual spot uranium price again fell to an all-time low, as the worldwide uranium industry continued to produce at far below world reactor requirements. Both uranium producers and buyers continued to have great difficulty in planning for the future because of uncertainty introduced by political decisions that will, in part, define the fundamental nature of the future uranium market. The political decisions relate to the demilitarization of high enriched uranium (HEU) from warheads for use in civilian fuel and the changing restrictions on the sale of uranium produced in the Commonwealth of Independent States (CIS).

Over the last 6 years there have been severe reductions in nearly all phases of the world uranium industry, caused by a massive oversupply that led to the lowest market prices ever recorded. The crisis has been complicated by the merger of the uranium markets of the previously mutually exclusive areas, formerly known as WOCA (the world outside centrally planned economies area) and non-WOCA[1]. This led to the sale on the world market of uranium produced by the CIS, followed by legal and political initiatives in the European Union and the United States of America designed to stabilize the market and protect WOCA producers.

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1 While the WOCA and non-WOCA designations are no longer applicable, these terms are nevertheless still useful for describing the present transition to a fully integrated world market.

The rapid drawdown from the WOCA uranium inventory has brought the inventory to a level where market analysts conclude there is little excess material available for sale. The approaching exhaustion of the excess WOCA inventory and the restrictions on the purchase of CIS produced uranium are respectively, eliminating and controlling, these alternative supply sources. This is happening when the demand for uranium not under contract is projected to increase at a high rate.

Many market participants perceive that the oversupplied condition that has existed for over 15 years will continue because the introduction of low enriched uranium (LEU) derived from HEU warheads will provide an additional low priced supply. Results of analysis indicate, however, that the fundamental supply and demand balance is changing to a balance between production and demand. The near exhaustion of excess WOCA inventory and restrictions on CIS produced uranium substantially reduces the low priced supply. It is expected in the near term that insufficient LEU produced from HEU will be offered for sale to offset this reduction in supply. This will result in a relative shortage causing market prices to continue their increase. This reduction of supply alternatives occurs at a time when demand for uranium is sharply rising. Analysis shows unfilled requirements are increasing at a compounded rate of 25 to 30% per year.

In the longer term the majority of the supply will have to come from new production. The LEU from the 550 t of warhead HEU purchased by the United States of America from Russia (500 t) and Ukraine (50 t) and other surplus supplies from the USA will probably meet between 5 and 17% of WOCA requirements through 2010. Maintaining production at 1994 levels would meet only about 47% of world requirements through 2010. Therefore production will have to increase substantially to meet the requirements not met by other supply sources. New production will only be available, however, if market prices rise sufficiently to pay production costs and provide for a return on investment. It appears that the current market price may continue to rise to price levels that stimulate the increased production that is essential for meeting future reactor requirements.

Uranium market prices

Sales on the world uranium market consist of two types: immediate or near term delivery, referred to as spot sales, and longer term multi-annual sales made under contract. The most commonly quoted market indicator for the spot price is the NUEXCO exchange value (or NEV)[2]. Similar indicators are also published by NUKEM (price range) and others. In this publication, reference is made to the NUEXCO exchange value. As was reported in previous years, the annual average spot price peaked in mid-1978 at US $112.85/kg U ($43.40/lb U_3O_8)[3]. By 1990 the average price had fallen to $25.40/kg U ($9.75/lb U_3O_8) and continued its decline in 1991 and 1992, with a yearly average of $20.67/kg U ($7.95/lb U_3O_8) in 1992. This price range represented a historical low (Fig. 1).

Restrictions on imports into the USA resulting from settlement agreements between the US Government and governments within the CIS, as well as actions by the European Union, led to the development of a two price system for spot sales made after October 1992. For countries with no import restrictions, the 1993 price averaged $18.57/kg U ($7.13/lb U_3O_8), while for those countries with restrictions the price averaged $26.00/kg U ($10.00/lb U_3O_8). The unrestricted price started 1994 at $18.20/kg U ($7.00/lb U_3O_8), remained relatively constant, but increased modestly to $18.72/kg U ($7.20/lb U_3O_8) in December. The annual average for 1994 was an all time low of $18.24/kg U ($7.05/lb U_3O_8). For those countries with restrictions on imports the price averaged $24.35/kg U ($9.31/lb U_3O_8). Following the increase started in November 1994, the restricted spot price continued to climb in 1995, reaching $31.20/kg U ($12.00/lb U_3O_8) during early May. (Fig. 2). This 30%

[2] Published by NUEXCO until December 1994, and TradeTech after this date.

[3] All prices are reported in current US dollars.

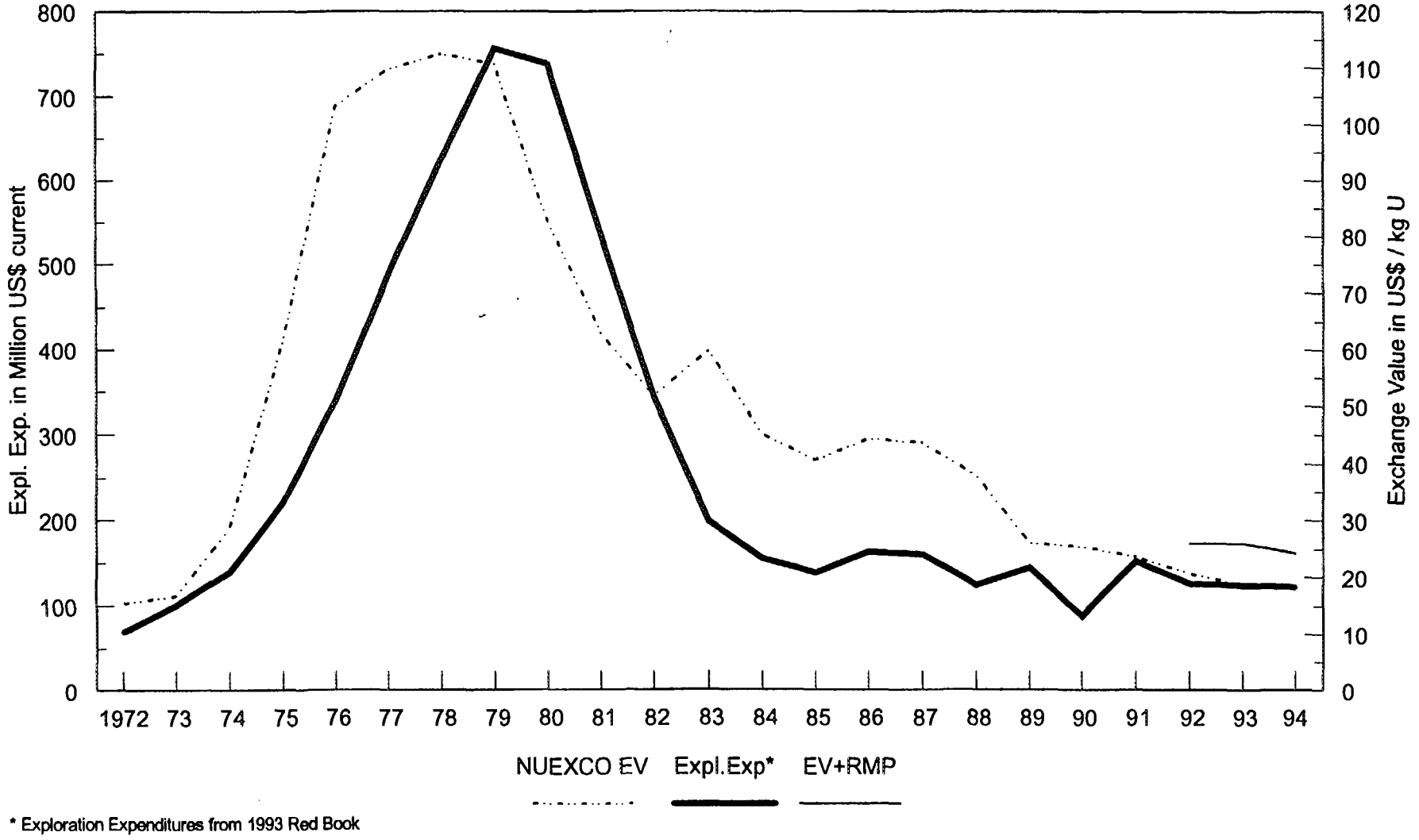
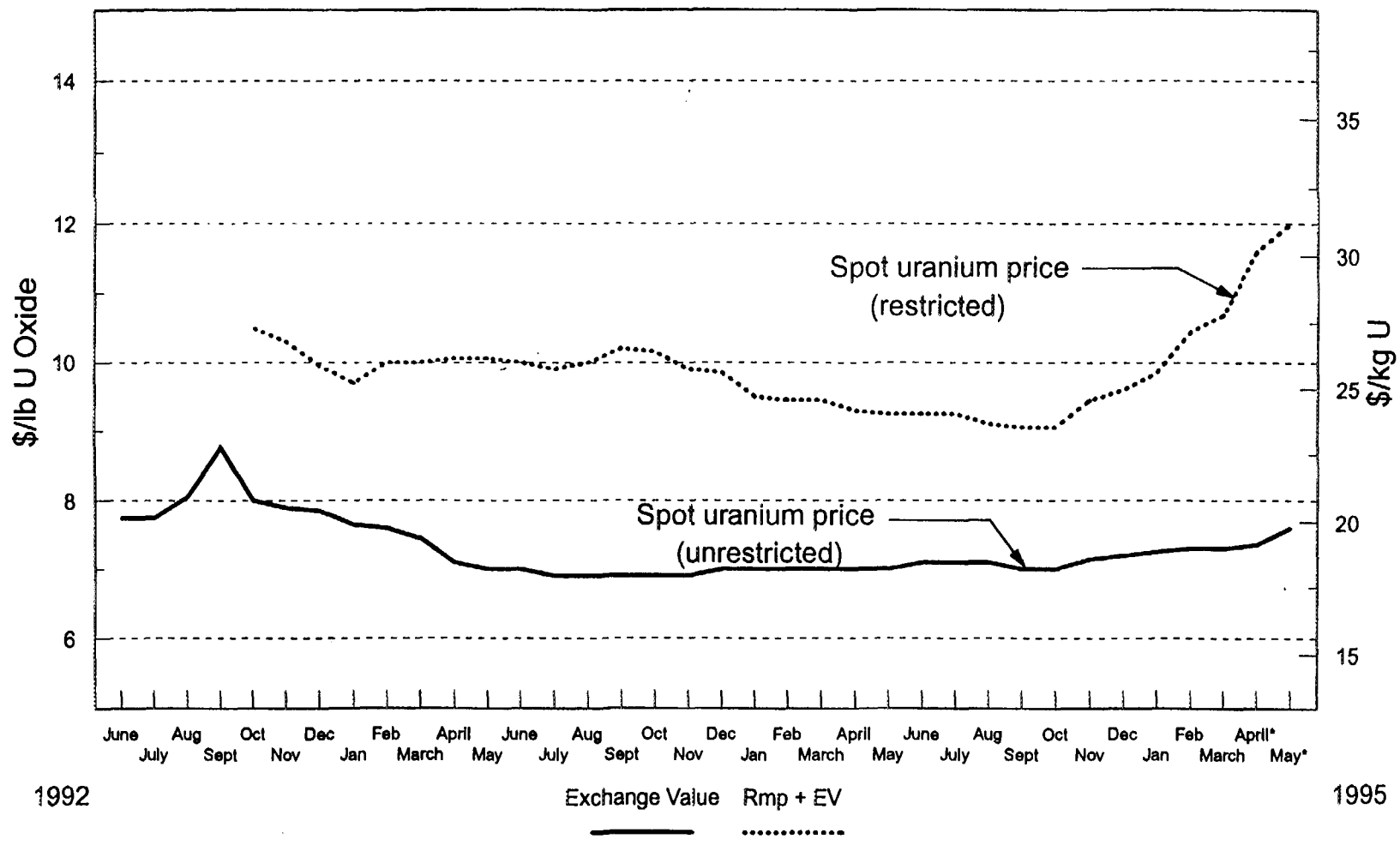


FIG.1. WOCA uranium exploration expenditures vs. average NUEXCO exchange values.



From NUEXCO

* from TRADETEC

Rmp = Restricted Market Penalty

FIG. 2. Recent spot market prices.

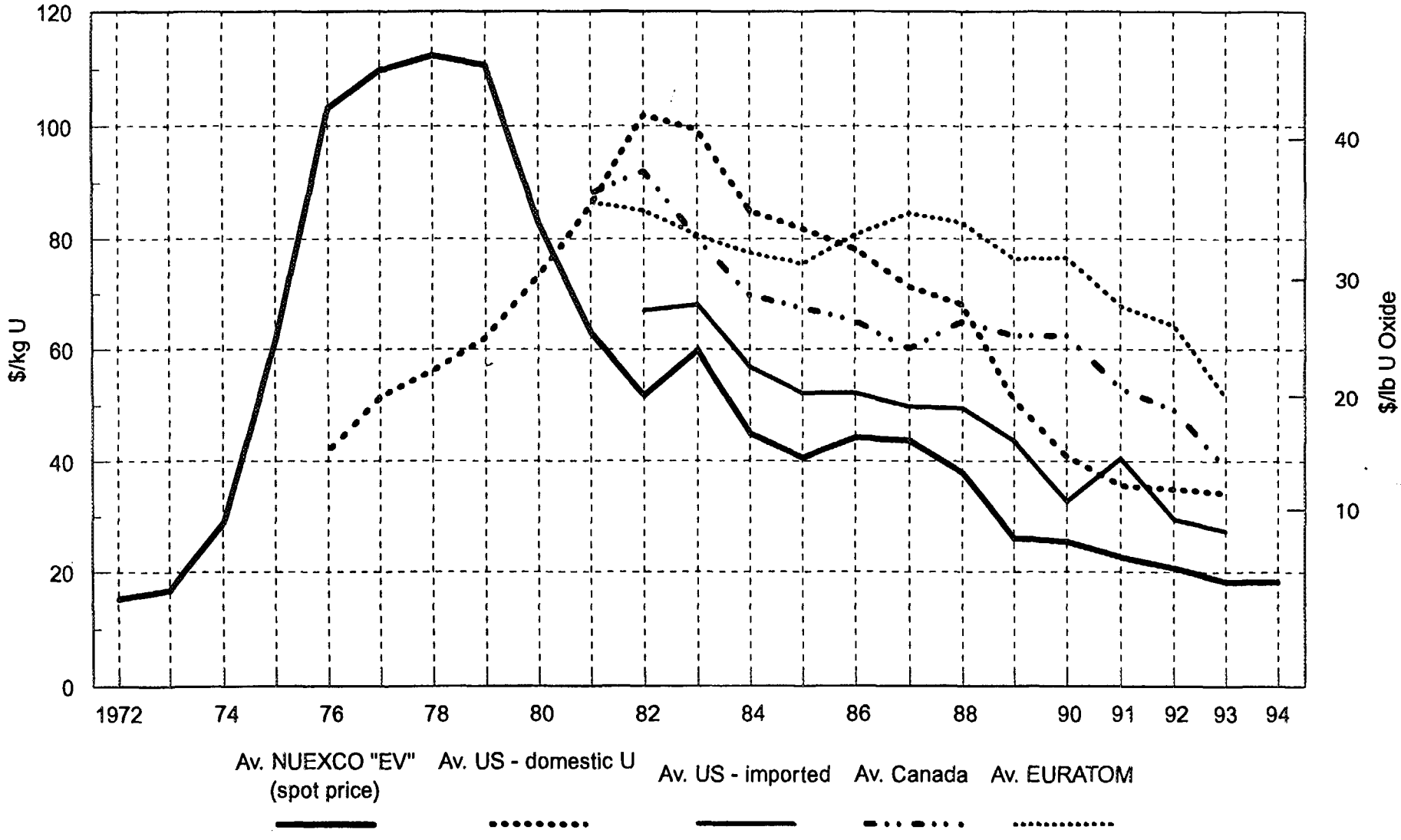


FIG.3. Development of selected uranium prices.

increase over 6 months brought the spot price to its highest value since November 1988. The unrestricted price also recorded an 8% increase since October 1994.

Limited data on long term contract prices are available. Fig. 3 shows a comparison of the average delivered prices for Australia, Canada, the USA and Euratom. With the exception of Euratom which reports both spot and multi-annual prices, these prices are based on variable amounts of both spot and long term sales. All average delivered uranium prices were lower in 1993, the most recent year for which data is available. This continued a general decline in all uranium prices that started in the early 1980s.

MAJOR MARKET EVENTS

Three major events have taken place in the last few years that significantly impact the future uranium supply through the end of the century and beyond. These events are: 1) anti-dumping related activities in the United States, 2) restrictions on the sales of CIS produced uranium in the European Community and 3) plans for Russia, Ukraine and USA to demilitarize HEU weapons material. The first step in weapons conversion involved the signing of a purchase agreement by the United States for 500 t HEU warhead material from the Russian Federation. Ukraine has also agreed to give up 50 t HEU warhead material. The US is currently evaluating both their natural and enriched uranium inventory and have announced preliminary plans to sell surplus material as reactor fuel.

Anti-dumping settlement agreements and amendments

One of the greatest influences on uranium trade resulted from the Anti-dumping Petition in the USA. In October 1992, DOC announced that final suspension agreements were signed with the Republics of Russia, Kazakhstan, Ukraine, Kyrgyzstan, Uzbekistan and Tajikistan. The suspension agreements established quotas on the importation of all uranium products from all of the CIS Republics except Kyrgyzstan and Tajikistan.

The suspension agreements prohibit any CIS uranium imports to the USA until the market price reaches \$13 per pound U_3O_8 (\$33.80/kg U). The market price is determined by the DOC and some CIS uranium is still allowed to be imported (irrespective of the DOC market price) under grandfathered contracts (subject to DOC approval) entered into with US utilities before March 5, 1992. At this price (\$13 per pound U_3O_8), the total amount of nuclear material allowed to be imported into the USA is 2.9 million pounds U_3O_8 (1115 t U) equivalent. Larger amounts are allowed to be imported as the price increases. A total of 15.8 million pounds U_3O_8 (6077 t U) equivalent would be permitted above \$20 per pound U_3O_8 (\$52/kg U) equivalent. Above \$21 per pound (\$54.6/kg U), no limits exist except for a ceiling on Russian material of 5.5 million pounds U_3O_8 (2115 t U) equivalent. As a result of termination of the settlement agreements by Tajikistan and Ukraine, these two countries can import uranium (excluding HEU from Ukraine) to the US provided they pay anti-dumping duties [1].

The DOC marked price has remained below \$13 per pound U_3O_8 since the settlement agreements were signed with the CIS countries and therefore no uranium subject to the settlement agreements has been purchased by US utilities. As of 1 April 1995 the DOC-determined price was \$12.06/lb U_3O_8 (\$31.36/kg U). Continued upward movement in the market could soon bring the DOC-determined price above \$13.00/lb U_3O_8 thereby allowing the sale in the USA of uranium produced by Kazakhstan and Uzbekistan.

Agreement with Russian Federation renegotiated

As part of the consideration for the 500 t HEU purchase, Russia and the USA renegotiated the settlement agreements between the two countries relating to the US anti-dumping proceedings. The amended agreements, signed on 12 March 1994, will give Russian uranium more access to the US market. Under this amendment, which defers the settlement agreement until 2003, slightly over 2500 t U equivalent of Russian origin can be imported to the US in 1994 and 1995, if that material is matched with "newly produced" US natural uranium. This amendment also authorizes additional matching deliveries of natural uranium up to, but not exceeding, specified levels set for each of the years 1996 through 2003. This level starts from about 740 t U in 1996 increasing to around 1650 t U by 2003 [2].

By 1 April 1995 approved matched uranium sales under the amended settlement agreement with Russia had reached 1850 t U or 74% of the first year quota. This involved fourteen uranium sales and 1 enrichment contract [3].

Agreement with Kazakhstan renegotiated

On 27 March 1995 the Republic of Kazakhstan and DOC signed an amendment to the Kazakhstan Suspension Agreement. The Amendment lasts for 2 years and allows the import to the US of 385 t U (1 million pounds U_3O_8) after the DOC-determined price reaches \$12/lb U_3O_8 (\$31.20/kg U). In exchange, Kazakhstan agreed to stop the use of its uranium in "by-pass" uranium enrichment sales. The DOC-determined price for 1 April 1995 was \$12.06/lb U_3O_8 (\$31.36/kg U). Under the amendment Kazakhstan was permitted to import 195 kg U (500 000 lbs U_3O_8) until October 1995, the date the next DOC price determination is made [3].

The DOC and Uzbekistan are also negotiating an amendment to their suspension agreement. At the time of the preparation of this paper the amendment had not yet been signed.

European Community policy regarding CIS uranium imports

Because of concerns for the potential market destabilizing effects of large imports of CIS origin uranium that were being offered on the European Community market at prices judged to bear no relation to cost of production in Western terms, corrective measures were established by the European Commission and Euratom Supply Agency. The measures are essentially based on the Agency's exclusive right to conclude contracts as provided for in Article 52 of the Euratom Treaty. In response to a question put to the European Parliament during the November 1992 session the Commission provided the following response:

"By virtue of Article 2 (d) and (c) of the Euratom Treaty, the Community must ensure that all users in the Community receive a regular and equitable supply of ores and nuclear fuels and ensure the establishment of the basic installations necessary for the development of nuclear energy. For this purpose, the Euratom Supply Agency was established which, under the provisions of Chapter VI of the Euratom Treaty - and more particularly its Article 52, 2 (b) - has inter alia an exclusive right to conclude contracts for the supply of nuclear materials. Massive imports at extremely low prices, coming from the CIS republics risk endangering the diversification of the Community's supply sources and hence its long-term security of supply and the viability of its production industries. That is why the Supply Agency, in exercising its right to conclude contracts is ensuring the Community does not become over-dependent on any single source of supply beyond reasonable limits and that the acquisition of nuclear materials from CIS republics takes place at prices related to those on the market; that is to say prices which reflect cost of production and are compatible with prices of producers in market economy countries." [4].

According to the Euratom Supply Agency: "In practice, the approach of the Euratom Supply Agency was pragmatic and flexible and took into account the different aspects of the specific situations of the utilities concerned and any divergences of opinions expressed. Reaction to the Agency's approach have been generally positive. Transacting parties have increasingly informed the Supply Agency of their intentions in advance of the finalization of contractual terms. This in turn has meant that in only a very few cases was it necessary to introduce modifications to any contracts or not to proceed with their conclusion."[4]

Prior to 1994 Euratom acted to limit the amount of EC purchases of CIS uranium to about 3000 t U per year. In 1994 the CIS uranium imports to the EC increased to a little over 4000 t U [3]. Euratom also indicated that they continue to monitor the policy and maintain the option of eventually changing the policy.

New supply — US purchase of warhead high enriched uranium from the Russian Federation and Ukraine

Significant amounts of uranium from demilitarized nuclear weapons are expected to enter the civilian market after 2000 as the result of purchase agreements between the Russian Federation, Ukraine and USA. Worldwide efforts to reduce nuclear weapons led to the June 1994 agreement between the Russian Federation and the USA for the transfer to the United States Enrichment Corporation (USEC) of LEU blended from HEU from dismantled Russian nuclear weapons in exchange for cash payments by the USEC. Under the 20 year agreement the USA will pay about $11.9 thousand million (in 1993 dollars) in exchange for 500 t HEU having an assay of 90% or more of ^{235}U. This will be blended down, prior to shipment to the USA, to 15.3 million kg U containing 4.4% ^{235}U, equivalent to 153 000 t U (natural). The USEC will purchase 10 t HEU per year for the first 5 years and 30 t HEU per year over the next 15 years.

In a parallel tripartite agreement of the same date between Russian Federation, Ukraine and USA, an additional 50 t HEU in Ukrainian nuclear weapons is to be part of the purchase agreement. Under agreement of 6 June 1994 the Russian Federation proposed to ship 30 t HEU as UF_6 or UO_2 to the US; this HEU was derived from dismantled Ukraine weapons. The material would be blended down to LEU in the US under the direction of Matek, a joint venture planned to help implement the US-Russian HEU sales. Matek consists of 2 US firms with a 20% interest and 6 Russian firms with a 80% interest. The 550 t HEU under these agreements is equivalent to about 168 400 t U (natural). [2].

The first shipment of LEU blended from HEU under the Russian/US agreement, scheduled for June 1994, was delayed due to difficulties in resolving the transparency issue (i.e. assurance that the LEU is warhead derived material). The first shipment of about 30 t LEU, equivalent to about 1 t HEU, is expected in the spring of 1995. There has been speculation that this LEU could enter the market at the annual rate of up to 17 500 t U, starting as early as 2003. The settlement agreements between the Russian Federation and the USA preclude large quantities of this material from being sold prior to 2003 as it may only be sold in "market-neutral" transactions during this period.

URANIUM PRODUCTION, SUPPLY AND DEMAND

Production

The 1994 world uranium production is estimated to be 31 300 t U (Fig. 4). This is about 5% less than the estimated 1993 production of 32 200 t U and 48% less than the 1988 level [1]. Estimated 1994 production in the former WOCA was 22 000 t U. In general, 1994 uranium production in most countries remained the same or decreased from the previous year. Canada was a major exception where production increased by about 380 t U or 5%, while there were smaller increases in Namibia,

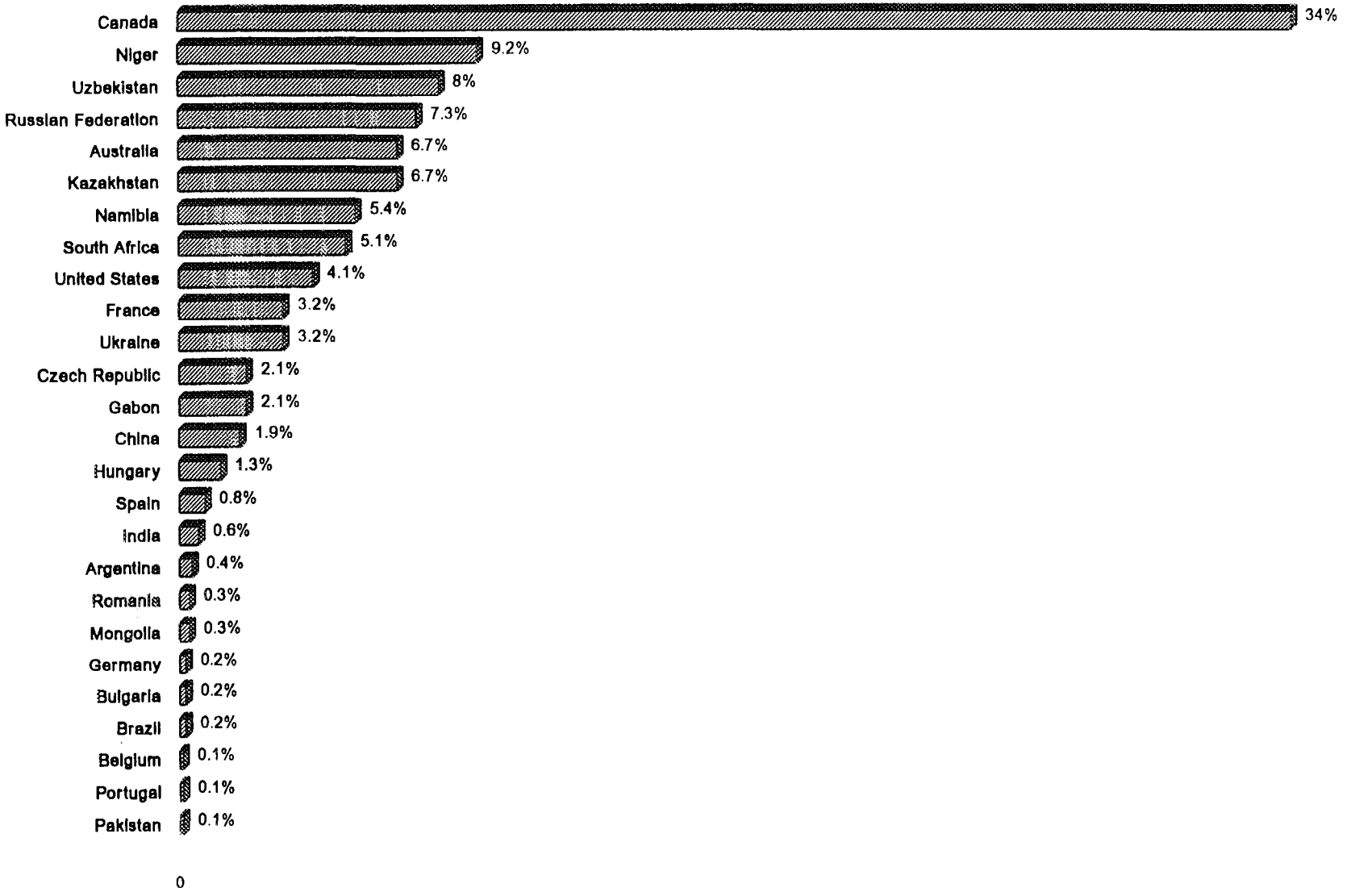


FIG. 4. Estimated 1994 world uranium production and rank (total 31 400 t U).

Spain and the US. The largest decrease was in France, where production fell by 40% to about 1000 t U. In 1994, production took place in 26 countries. Recovery of uranium was stopped in Germany bringing to an end production in what was the world's third largest producing industry. However, nearly 90% of the 1994 world uranium production occurred in 11 countries that each produced 1000 t U or more. They are: Australia, Canada, France, Kazakhstan, Namibia, Niger, the Russian Federation, South Africa, Ukraine, the USA and Uzbekistan. Most of the remainder was produced in China, the Czech Republic, Gabon and Hungary. Canada continued its position as the world's largest producer, increasing its share to over 30% of the total.

Supply and demand

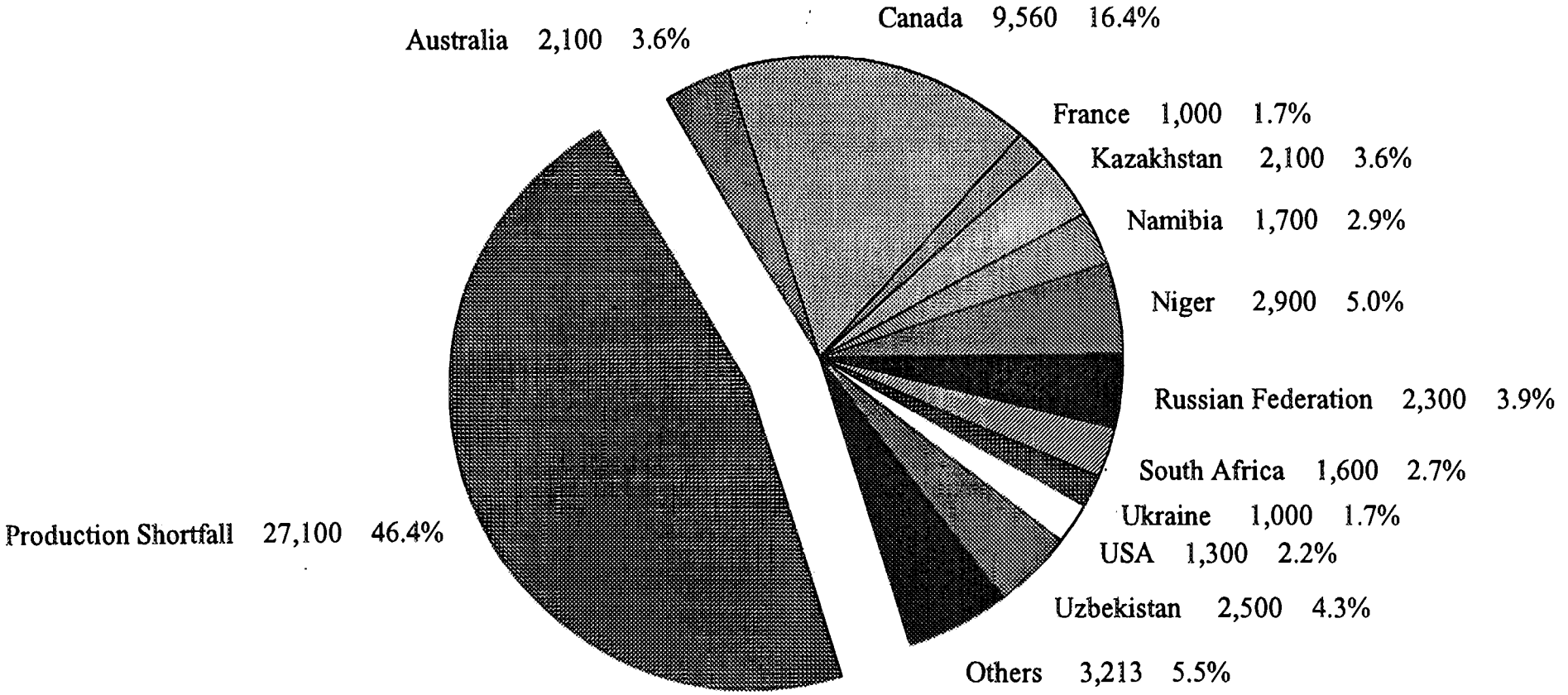
In 1994 the estimated world production of 31 300 t U met only 54% of the world reactor requirements of 58 400 t U (Fig. 5). World uranium production has been below world requirements since about 1990 (Fig. 6). Non-WOCA production, estimated at 9500 t U was about equal to non-WOCA requirements in 1994. It had exceeded non-WOCA demand since 1988, the first year that production estimates are available for the country group (Fig. 7). In 1994, estimated WOCA production of 21 900 t U met only 44% of WOCA requirements of about 49 200 t U (Fig. 8). There was a resulting worldwide shortfall of about 27 100 t U and a WOCA shortfall of about 27 300 t U. Today the uranium market no longer conforms to the traditional supply and demand model of producers selling only to utilities. Secondary market transactions have also been important in recent years. Such transactions include sales, loans and exchanges of natural and enriched uranium by utilities and brokers, including all transactions except the direct purchase by a utility of uranium from a domestic or foreign producer.

WOCA supply and inventory

In the former WOCA, uranium production has been below reactor requirements since 1987. The gap between production and requirements grew from about 4000 t U in 1988 to about 27 700 t U in 1993 and remained nearly the same at 27 200 in 1994 (Table I). The cumulative production shortfall over this period was about 124 000 t U. For the same period uranium imports to the USA and the European Community from the former USSR and its successor States increased from 105 t in 1988 to about 5600 t U in 1991 and then decreased and stabilized in the 4000 to 5000 t U range in 1992 and in 1993 [4, 5, 6]. In 1994 these imports are estimated to be 9450 t U. This included 4000 t U and 2000 t U, respectively for the EU and US. An additional 3450 t U of CIS produced uranium was enriched in Europe and then imported to the US (i.e. the "by-pass" option discussed below) [7]. The imports for the period totalled nearly 24 000 t U. This left an accumulated shortfall of nearly 95 000 t U (or about 250 million pounds U_3O_8). A small part of this shortfall was met by imports from China and through imports of CIS and other non-WOCA produced uranium to countries other than those of the European Union and the USA.

Starting in 1994 a portion of the US supply was also met through the so-called "by-pass option". Under this acquisition strategy US nuclear utilities elected to buy CIS produced uranium that was then enriched in Europe before its import to the US. Nukem reported that in 1994 US utilities bought nearly 3450 t of CIS uranium that was enriched in Europe [7]. Under the Settlement Agreements between the US and CIS countries this was viewed as a substantial transformation of the CIS produced uranium, thereby making it exempt from import restrictions. When this practice rapidly increased in 1994, the parties to the US anti-dumping litigation concluded this was a circumvention of the agreements and asked the US Department of Commerce to disallow the practice in the future.

Based on this analysis, it is estimated that a cumulative WOCA supply shortfall of about 85 000 t U occurred during the period 1988–1994. This shortfall was met by drawdown of WOCA inventories. Drawdown is estimated to be continuing in 1995 at a rate of 15 000 to 20 000 t U/annum.



World Demand: 58,400 t U / World Production: 31,300 t U

Others: Argentina, Belgium, Brazil, Bulgaria, China, Czech Republic, Gabon, Germany, Hungary, India, Mongolia, Pakistan, Portugal, Romania and Spain

FIG. 5. Estimated 1994 world uranium production vs. reactor related demand.

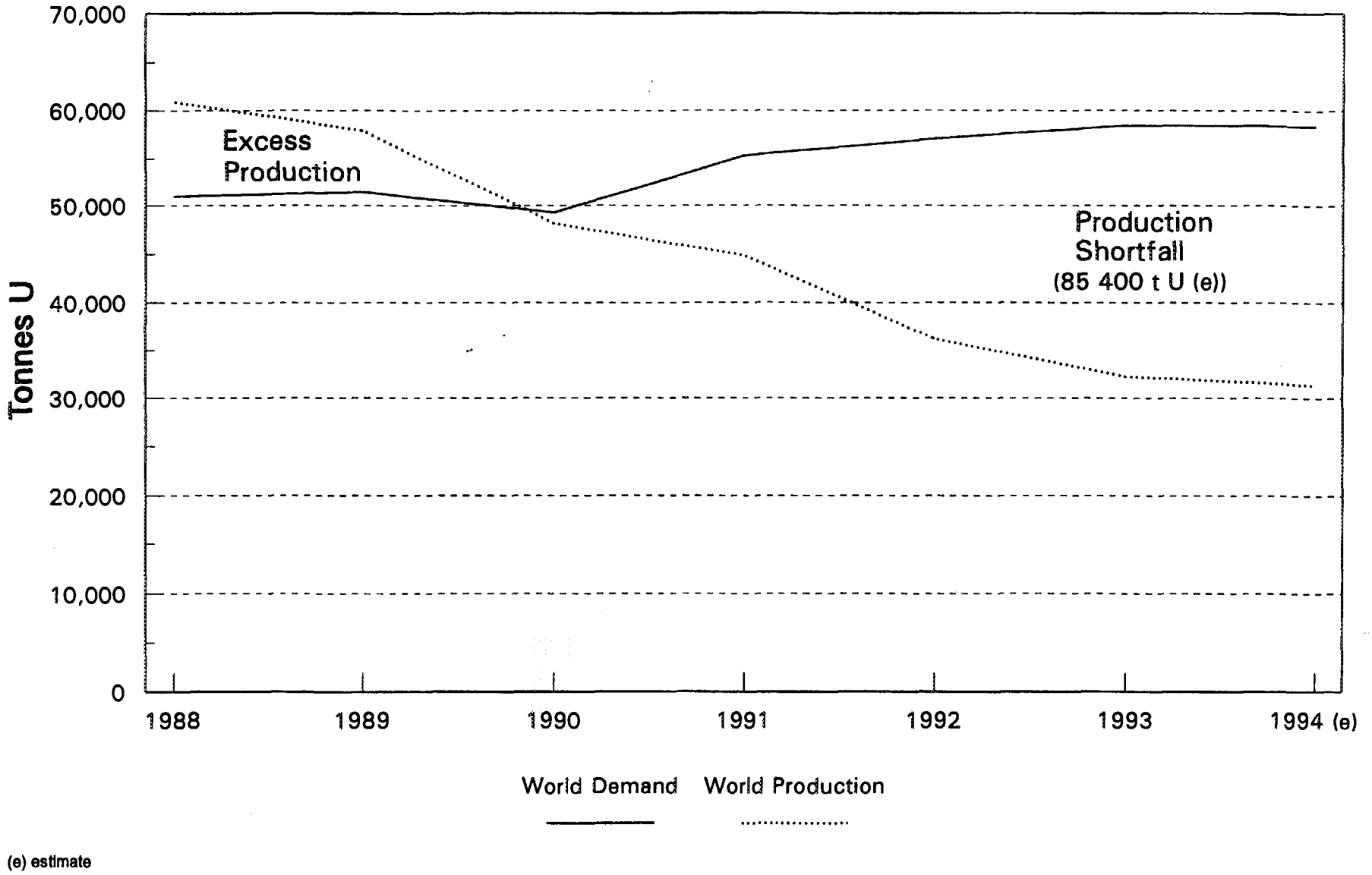


FIG. 6. World uranium production and demand.

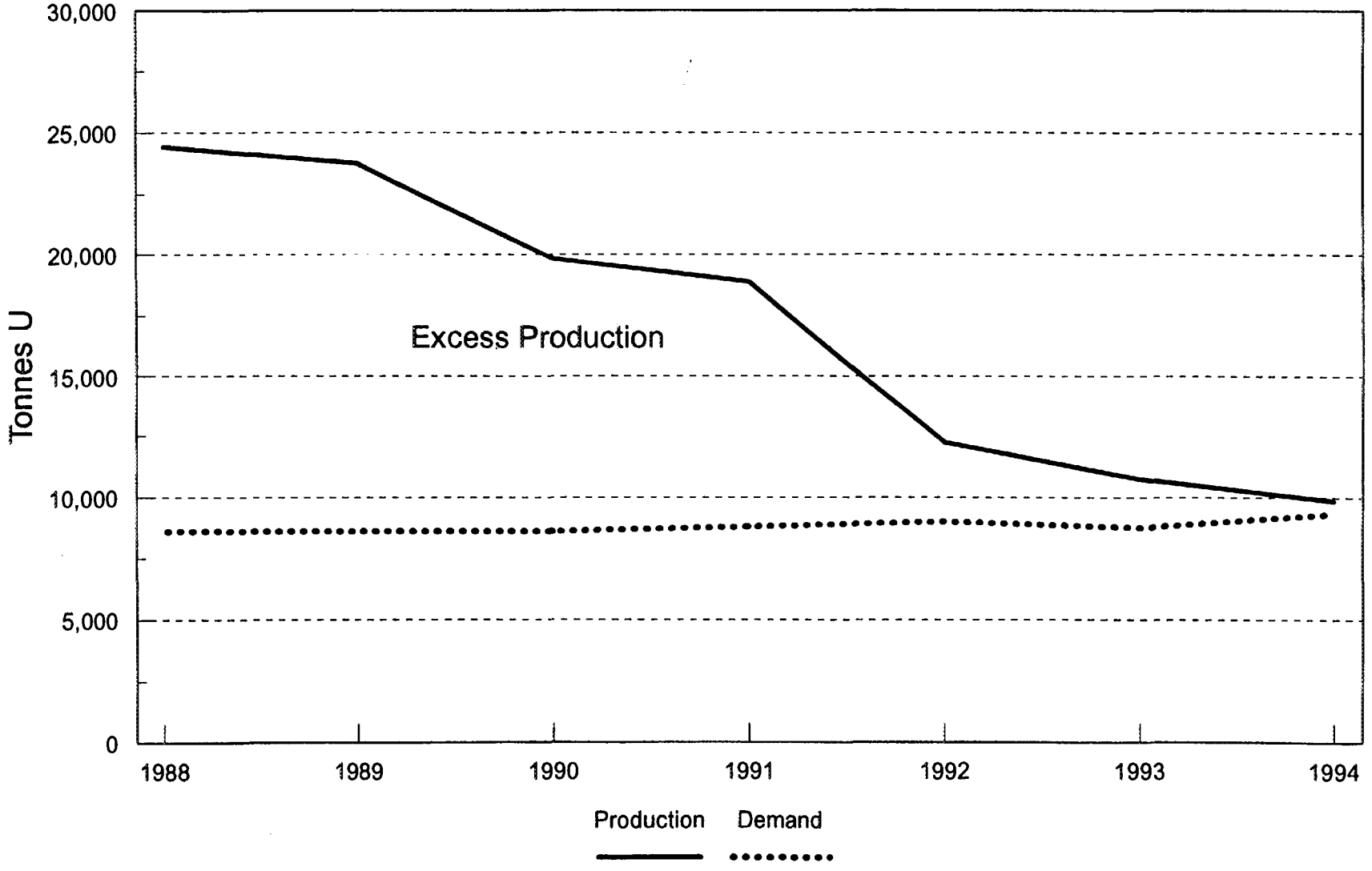


FIG. 7. Non-WOCA production and demand.

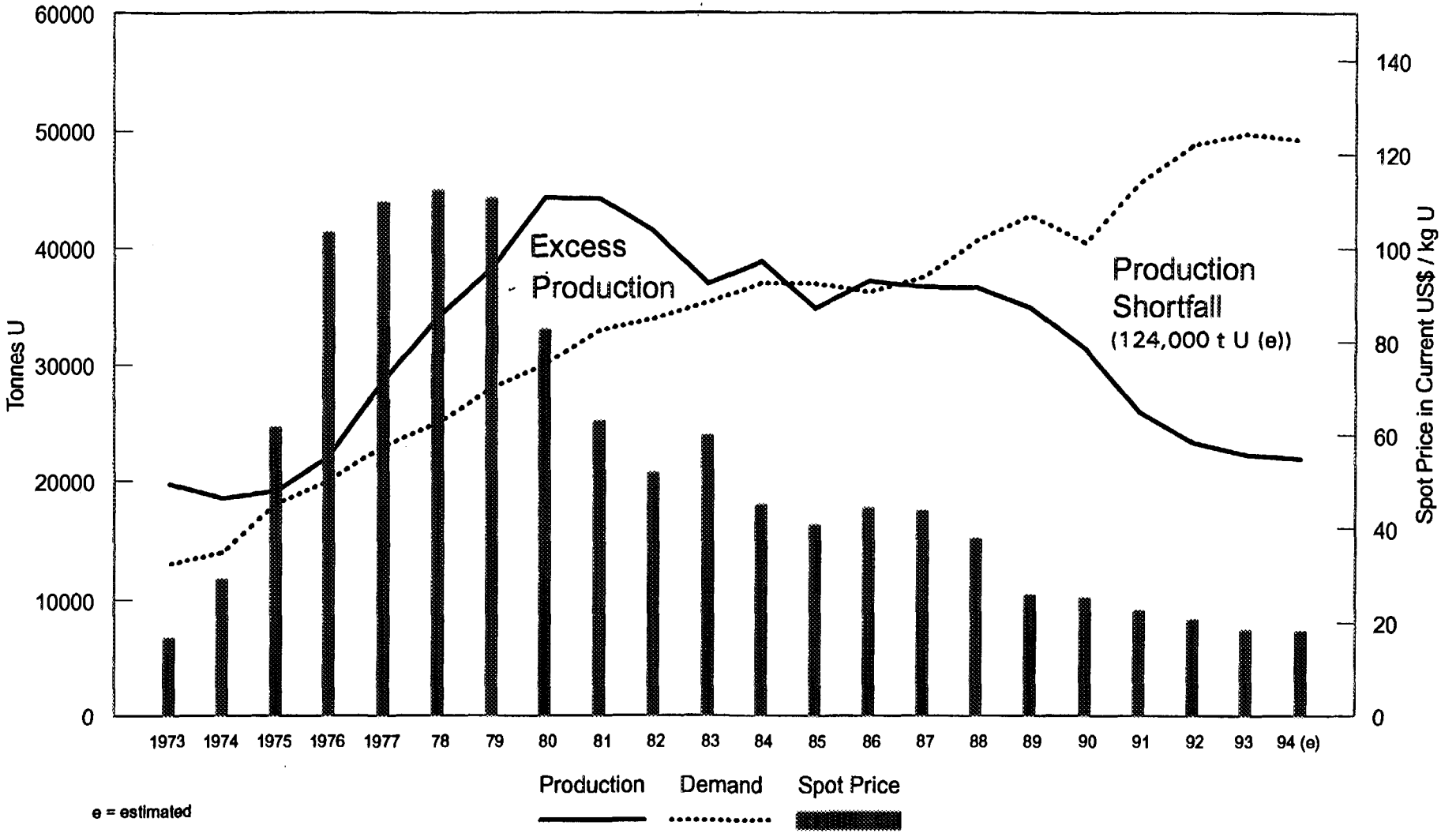
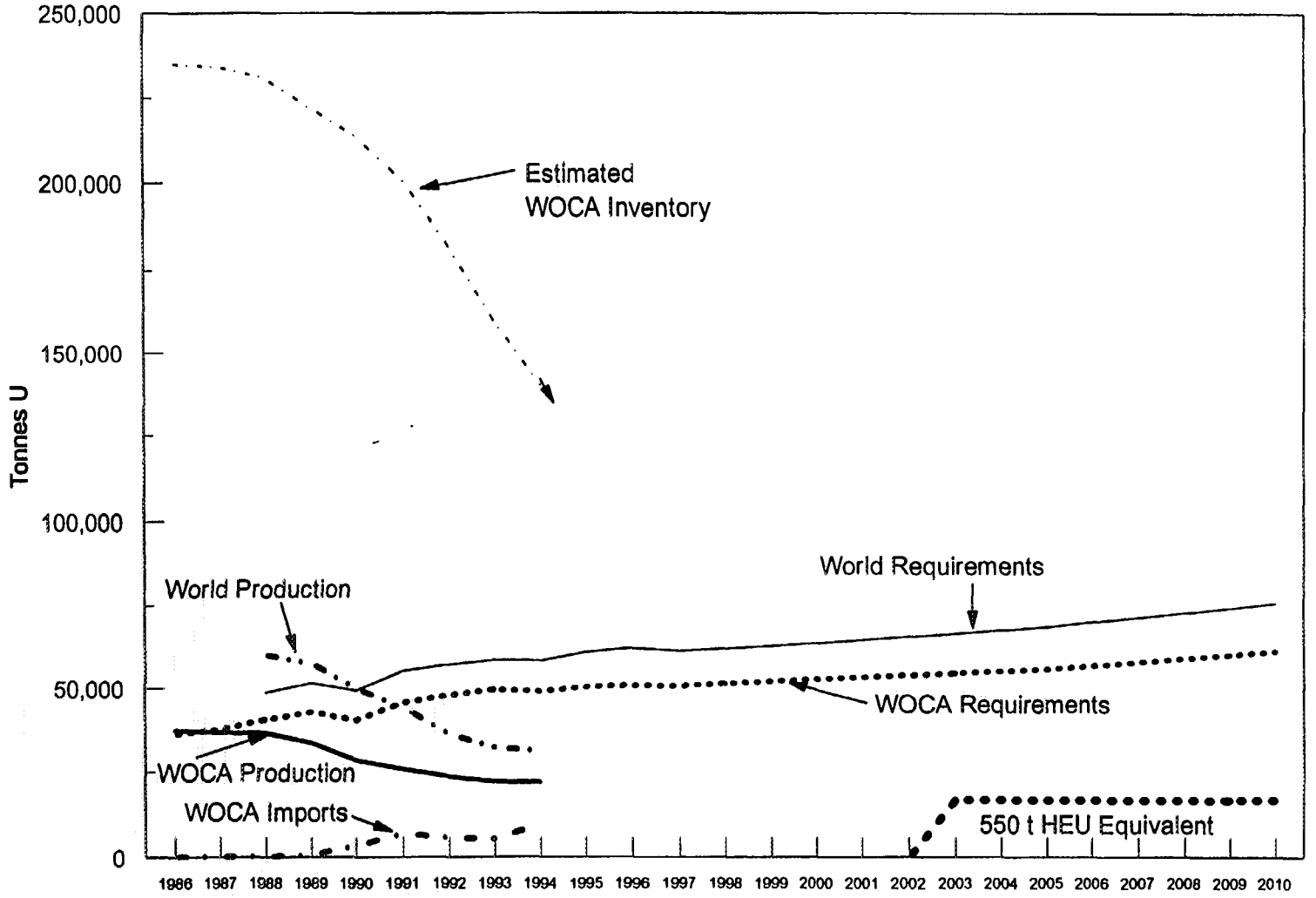


FIG. 8. WOCA uranium production and demand vs. NUEXCO spot price.



Not accounting for: CIS civilian stockpiles; U.S. and CIS HEU other than 550 t HEU from Russian Federation and Ukraine

FIG. 9. Historical development of uranium supply and demand.

The inventories being used to fill the production gap consist of material in the civilian sector (utilities, governments, producers, traders and others). The civilian stocks include strategic stocks, pipeline inventory and excess stocks available on the market. Based on analysis of published reports, the total former WOCA non-military inventory was estimated to be between 130 000 to 150 000 t U as of 1 January 1995 [8, 9, 10, 11]. Of this amount WOCA utilities are estimated to hold about 115 000 t. This is about 2.3 times annual WOCA utility requirements. Although an estimated 15% of the utility inventory is excess and could readily be offered for sale, a major portion comprises strategic stock mandated by law or company policy and will not be offered for sale. Fig. 9 summarizes these supply and demand relationships.

HEU inventory

There is little information regarding uranium inventory held by the Russian Federation. Their civilian stocks could easily surpass the 130 000 to 150 000 t U held in WOCA civilian stockpiles. It was reported by V.N. Mikhailov, Russian Minister for Nuclear Industry, that the Russian Federation's HEU inventory is 1200 t, plus or minus 15% (i.e. 1020 to 1380 t) [12]. The total military stocks held by the nuclear weapon States, consisting of fissile material in a variety of forms, may be several times greater than the civilian portion.

In June 1994, the DOE released information on its highly enriched uranium program in its Interim Uranium Inventory Report [13]. Between 1945 and 1992, when HEU production ceased, cumulative HEU production in the United States was 994 t. About 259 t is currently in DOE inventories, excluding HEU stored at the Pantex site, Texas. Of this amount 50 to 120 t was identified as potential excess. Proposals have been made in conjunction with the US fiscal 1996 budget to sell some portion of the material. Under the Energy Policy Act of 1992, USEC is to be the exclusive marketing agent for US enriched uranium.

Potential schedule for sale of 550 t HEU from Russia and Ukraine

Once it was announced that the 550 t HEU warhead material from the Russian Federation and Ukraine would be blended to LEU and sold for use as reactor fuel it became clear that the sales could have a major impact on the uranium market. The greatest uncertainty impacting the market has been the schedule of deliveries for this material; both the timing and amounts.

It is now probable the schedule for delivery of the 550 t HEU, as well as both US surplus HEU and other uranium, will be set by the US Congress. Legislation related to privatization of the USEC was introduced by Senator Pete Domenici (Republican, New Mexico) in Senate Bill 755. This bill includes a schedule to ration the flow of uranium and separative work units (SWU) drawn from the former US, as well as Russian and Ukraine weapons, until well into the next century. The bill was sponsored by Senator Domenici, Chairman of the Senate Subcommittee on Energy Research & Development of the Energy and Natural Resources Committee and was co-sponsored by other Senators with an interest in the bill [14]. It is anticipated this legislation will not be passed until the second half 1995.

In addition to setting a schedule for sale of HEU derived LEU, the proposed legislation attempts to help the Russian Federation by providing access to cash from the sale of the components of LEU drawn from military HEU. It is also intended to help the US uranium mining companies by delaying and restricting the flow of the material into the market, where its sale could depress the market.

Under the proposal, natural uranium from the DOE stockpile could be sold starting 1 January 1998. The maximum amount that could be sold in one year would be 4 million pounds UF_6, equivalent to 1040 t U natural. Annual sales could not however, exceed 10% of the UF_6 equivalent

content of the total amount of natural uranium transferred from the DOE to USEC. The sale of LEU transferred from DOE to USEC could also not exceed 800 000 SWU in any calendar year. This is equivalent to about 1100 t U natural.

In summary, the proposed legislation would provide for sale of a maximum of about 1100 t U/year natural equivalent following passage of the bill. This could continue until 1 January 1998 when an additional 1040 t U, or 2140 t U/year could be sold to 1 January 2002. From 2002 through 2011 about 4740 t U natural equivalent/year could be sold, increasing to about 7340 t U natural equivalent/year after 1 January 2012. This schedule would supply about 6% of the WOCA requirements of 877 000 t U through 2010. It includes management of the 550 t Russian and Ukraine HEU, as well as the surplus USDOE HEU, LEU and natural uranium stockpiles.

The first uranium sold under this framework could result from a 15 December 1994 agreement between DOE and USEC where about thirteen tonnes HEU would be transferred to USEC and blended to LEU. This would yield about 3075 t U natural equivalent being sold over 3 to 5 years starting in 1995 [15].

The other uncertainties regarding future WOCA supply are related to: the full impact of the settlement agreements and their amendments; and the disposition of the potential for additional HEU entering the market from both the USA and the Russian Federation; the remaining Russian stockpile of natural or low enriched uranium (LEU). The disposition of the worldwide weapons plutonium stockpile is expected to have only a minor impact on the supply and demand balance for nuclear fuel.

Early indications of a recovering uranium market

In 1994 the world uranium production industry continued in a very depressed state. As in 1993, the market is highly dependent on political decisions that are subject to change. Any analysis of the uranium market must take this uncertainty into account. There were, however, some indications in 1994 and early 1995 that the sixteen year trend of falling uranium prices and decreasing production related activity may be ending and the market may be in an early stage of recovery.

They include: excess WOCA inventory is rapidly being drawn down and is nearing exhaustion; the decrease in 1994 uranium production relative to the previous year was the smallest since 1989; and Cameco, the world's largest producer, increased its production. In Canada the amount of uranium specified in new export contracts signed by Canadian producers and approved by the Canadian government increased from 4330 t U in 1993 to 15 200 t U in 1994. The completion of fourteen matched uranium sales under the amended US-Russia suspension agreement is expected to stimulate production in these 2 countries. The rapid rise in spot price starting in November 1994 suggests the sixteen year market decline may be at an end. The bankruptcy of a major uranium trading organization early in 1995 may be contributing to market instability placing additional upward pressure on market prices. While these events may be early indications of a market recovery, uncertainty may continue until a sustained recovery is underway and political intervention is further reduced.

FUTURE TRENDS IN SUPPLY AND DEMAND

World reactor requirements and unfilled demand

All projections of future uranium related activities depend on the uranium market. There will be little or no increase in any activities, including exploration, project development and/or production, unless uranium market prices increase. Making projections regarding market trends is fraught with difficulties, primarily because of the uncertainty regarding the availability of future supplies. Future demand is well known through to the year 2000 and can be reasonably estimated through to 2010.

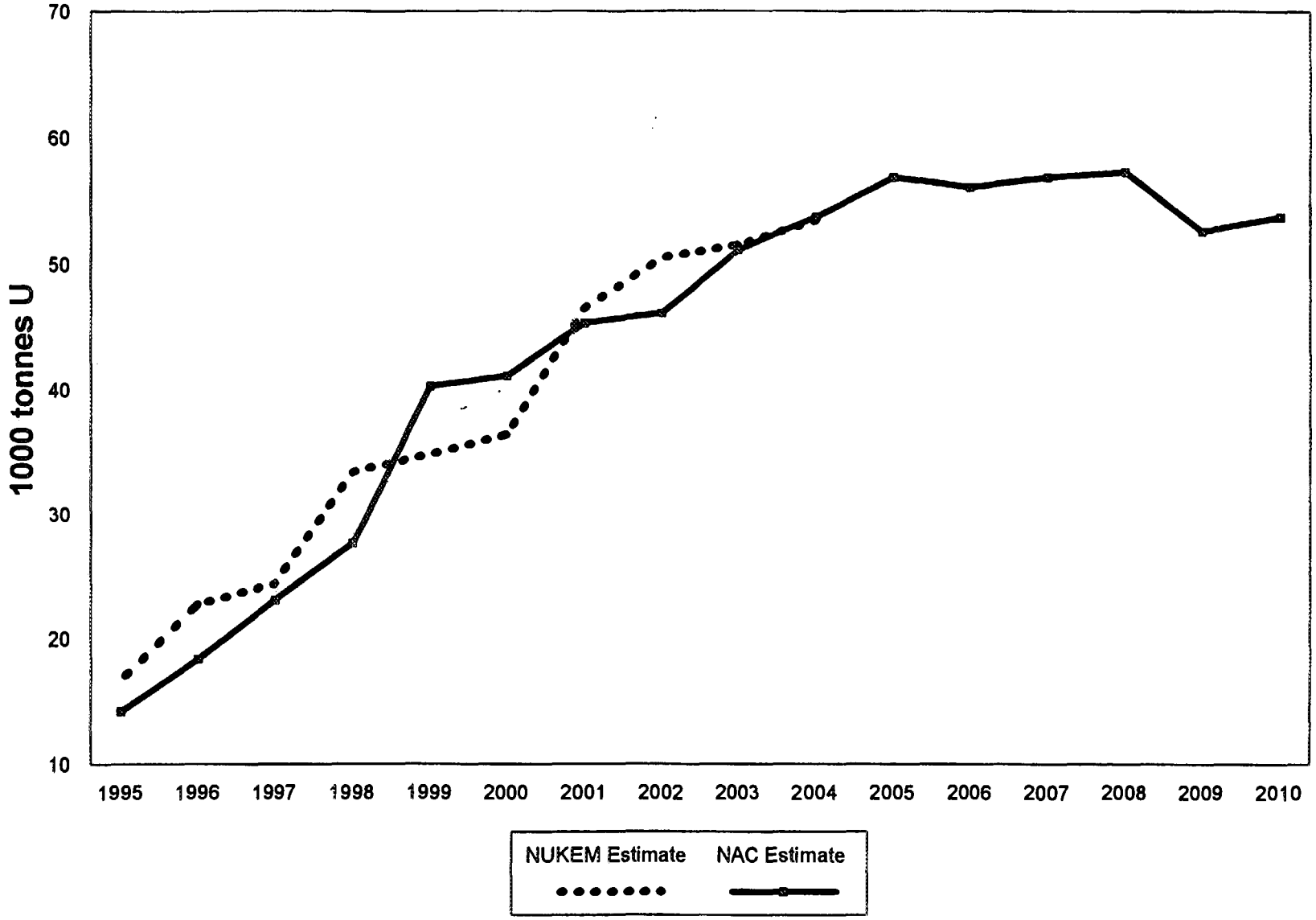


FIG. 10. Worldwide buyer unfilled needs.

The projected annual reactor requirements for both WOCA and non-WOCA up to 2010 are summarized in Table II [1].

On the basis of existing trade agreements and considerations of technology, it is expected that much of the non-WOCA demand will be met by non-WOCA supply over the next 10-15 years. The primary uncertainties related to meeting WOCA demand include the access of CIS produced uranium to the WOCA market and the amount and schedule for sales of HEU derived material. However, the existing US anti-dumping settlement agreements and the policy of the European Union regarding CIS uranium imports have helped reduce uncertainty in these market parameters. This situation could change if there are further substantial amendments to the US-CIS settlement agreements or Euratom policy.

Based on the analysis of WOCA inventory drawdown and the current restrictions on CIS uranium imports it is possible to make projections regarding a likely market price recovery. Whereas the available excess WOCA inventory is rapidly being depleted, the need for new uranium production contracts is expected to rise sharply over the next 15 years [10,16]. Projections of worldwide uranium requirements not covered by contracts indicate that demand for new production contracts will increase from about 16 000 t U in 1995 to about 50 000 t U in 2002. This is a compounded annual growth rate of nearly 30%. After 2002 the requirements will continue to increase, reaching around 55 000 t U in 2005 (Fig. 10). This rapid growth rate, equalling new annual uranium sales of about 5000 t U, or nearly equivalent to the annual production of Canada's Key Lake project, should put substantial upward pressure on uranium prices. This imbalance between demand for new production and available production capacity should be increased by the low level of project development in recent years.

Supply projection

Two projections of the known and anticipated uranium supply sources are made to consider how the future supply may develop. The projections include a high case supply with LEU from HEU entering the market at an annual rate of 17 000 t U natural equivalent and a low case supply with LEU entering at an annual rate not exceeding 4740 t U natural equivalent. All other supply contributions remain the same. The projections take into consideration existing and committed, as well as planned and prospective WOCA production centres, supply from western reprocessing, and LEU from 550 t HEU warhead material plus surplus HEU, LEU and U natural from the USA. It is assumed that the requirements of former non-WOCA will be met from non-WOCA supplies, and that at least 5000 t per year of CIS produced uranium will continue to be sold in the WOCA market. The projections assume that the available WOCA excess inventory will be exhausted within one to two years.

The projections do not take into account potential increased CIS sales allowed with rising market prices under terms of the CIS/US settlement agreements. Nor are matched sales that are taking place under the amended settlement agreement with Russia included. There is a practical limit to CIS sales based on production capability and a cap on Russian import until at least 2003.

The projections use a WOCA production capability based on an 85% capacity utilization of the 1993 Red Book data [1]. This consists of about 29 000 t U/year of Existing and Committed capacity and a potential of up to about 10 000 t U/year of Planned and Prospective annual capability by 2000. This is shown in Fig. 11.

Production from reprocessing is based on the projection of WOCA mixed oxide (MOX) fuel fabrication capacities from the 1994 IAEA Year Book [17]. This supply source is projected to be 850, 3000, 4000 and 4000 t U (natural equivalent), respectively in 1995, 2000, 2005 and 2010. It totals about 46 000 t U equivalent and is estimated to meet about 5% of WOCA requirements through 2010.

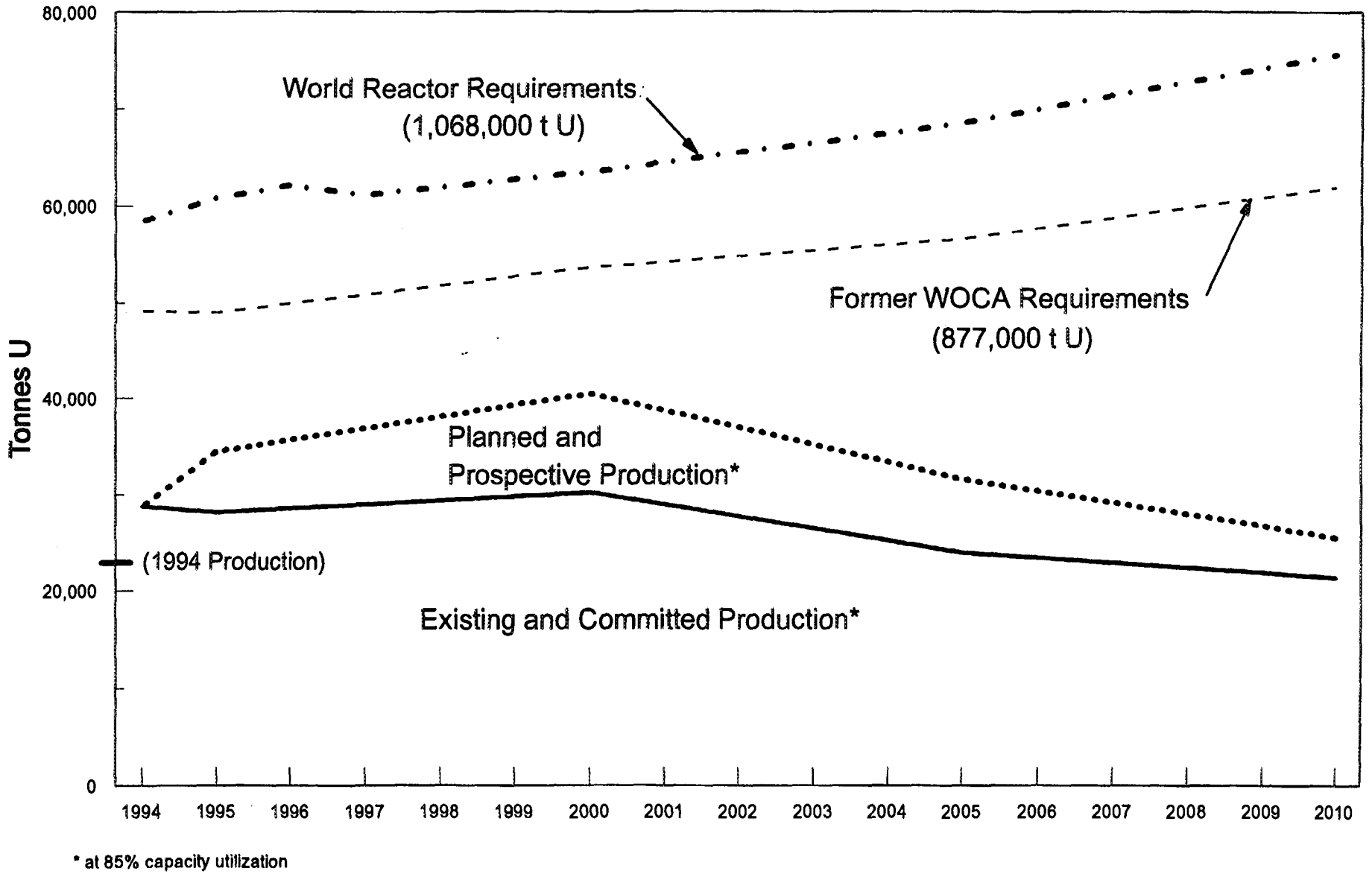


FIG. 11. WOCA short term annual uranium production capability.

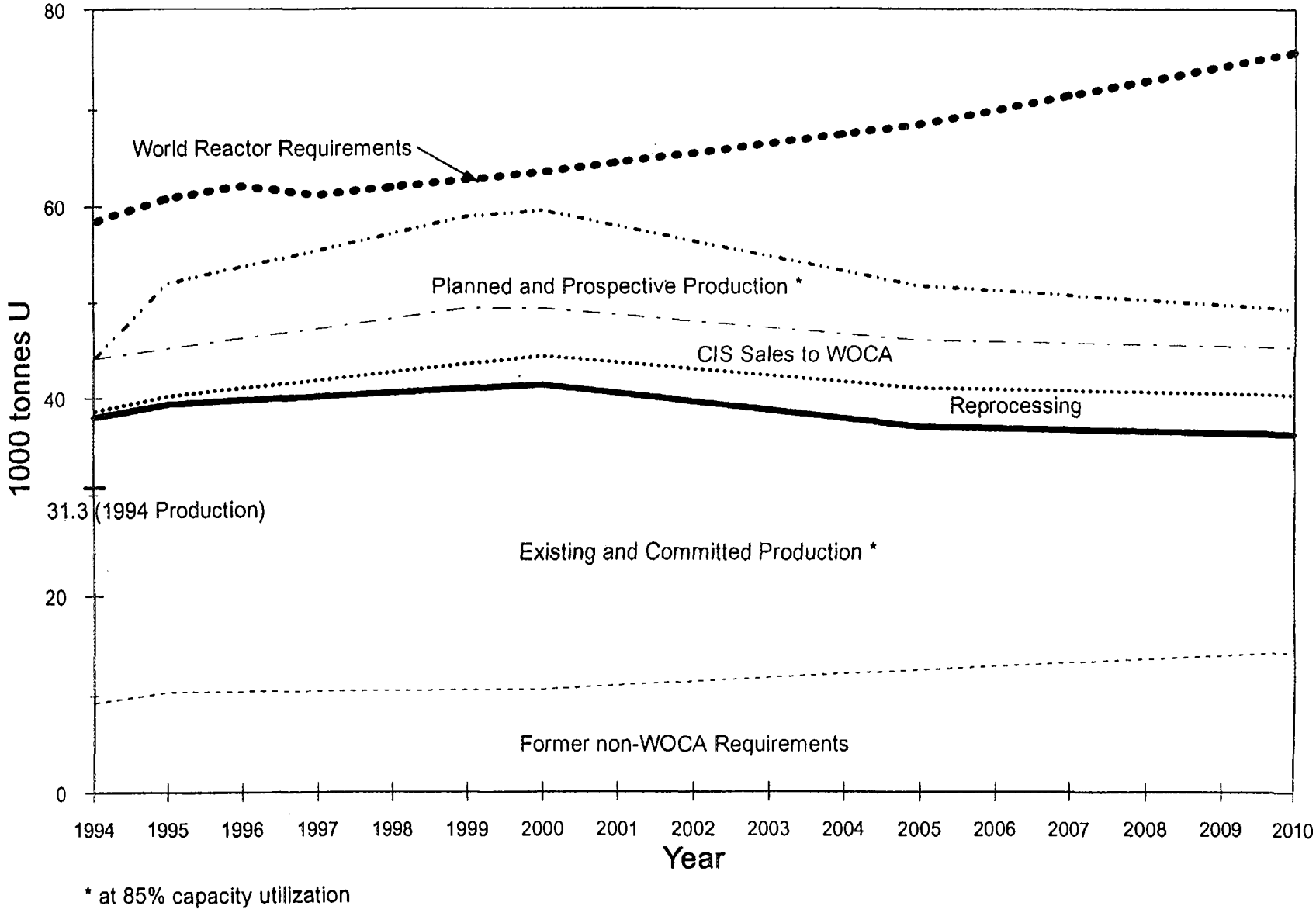


FIG. 12. Projected supplies through 2010.

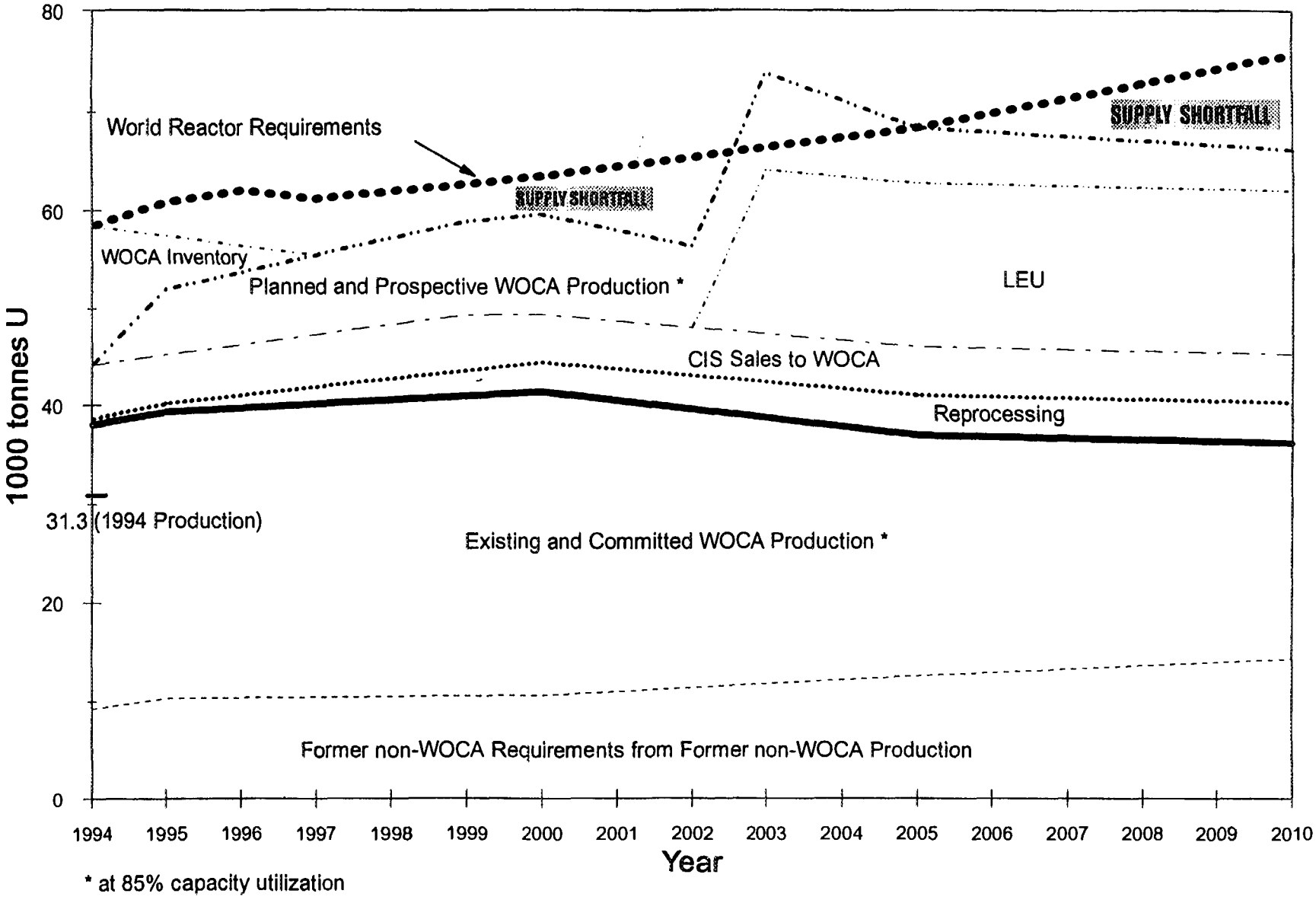


FIG. 13. Projected uranium supplies through 2010 (high LEU case).

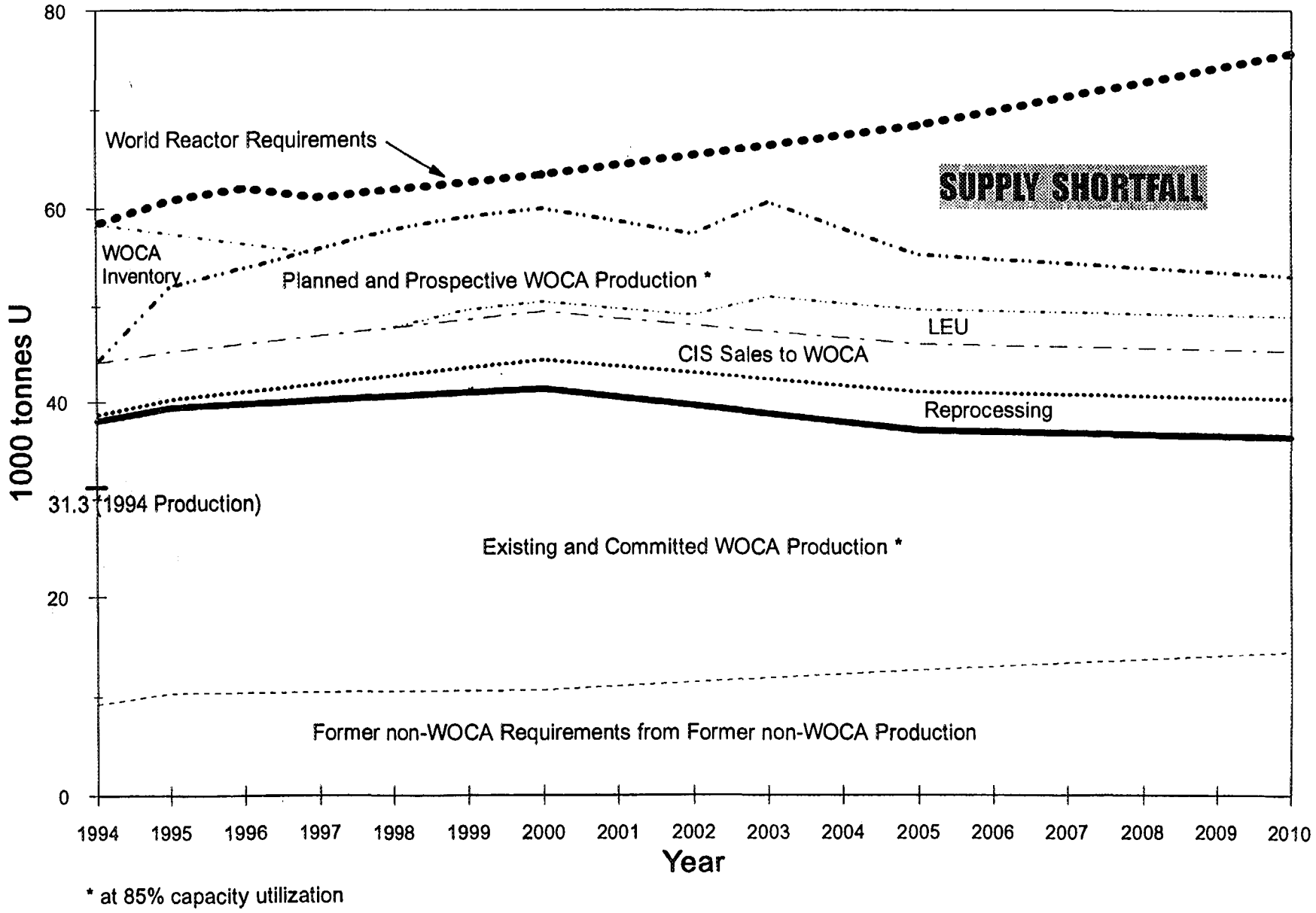


FIG. 14. Projected uranium supplies through 2010 (low LEU case).

Fig. 12 is a projection of all indicated supply sources excluding HEU and other US government surplus uranium.

The high supply LEU projection (Fig. 13) is based on the 550 t HEU under the sales agreement(s) between the Russian Federation, Ukraine and the USA. This represents nearly 168 000 t U natural equivalent. It is projected to enter the market starting in 2003 at the rate of about 17 000 t U per year and continue through 2012. In this scenario the LEU equals over 15% of the WOCA requirements from 1995 to 2010. Additional surplus US HEU, LEU and U natural would probably not enter the market until 2012.

Based on the assumptions above, a supply shortfall will continue throughout the projection period except for years 2002 to 2005. With the exception of this short period when world requirements are exceeded, all of the supply sources are insufficient to meet world requirements between 1995 and 2010.

The low supply LEU case (Fig. 14) is based on the proposal in Senator Dominici's Bill 755 introduced to the US Congress and discussed above. In this case the identified supply sources always fall below world requirements. The shortfall varies from a minimum of about 3000 t U in 2000, increasing to a maximum of nearly 25 000 t U by 2010. For world requirements to be met, world production will have to increase by about 80% within a few years and then continue to increase over the next 15 years. This would require a rapid buildup of planned and prospective production facilities, as well as additional new projects that are not presently defined.

The short term instability is increased by the low level of world production which is currently meeting only about 55% of world demand.

CONCLUSIONS

The uranium supply is evolving under a restricted worldwide market. The vastly oversupplied condition that existed for about 16 years drove spot prices to all time lows in 1994.

The excess low-priced supply that drove down the prices was comprised of excess WOCA civilian inventories and production from CIS countries. The low market prices, together with the curtailment of government purchases under the centrally planned economies of the former COMECOM, forced production cutbacks and the closure of production facilities worldwide. As a result, production met only about 55% of world reactor requirements in 1994.

The low production levels caused the drawdown of inventories worldwide. This impact was greatest in WOCA where stockpiles have been drawn down annually at the rate of about 15 000 to 20 000 t U since 1991. It appears the excess WOCA inventory is now essentially exhausted. Political and legal restrictions on the sales of CIS produced uranium to the USA and the European Union also limit this supply. The changes in two low cost supply sources have greatly reduced their market influence.

A steady market price increase starting in November 1994 has, over 6 months, resulted in the restricted spot price rising by 30% to \$12/pound U_3O_8 (\$31.20//kg U). The price of unrestricted uranium has also increased 8% to about \$7.60/pound U_3O_8 (\$19.76/kg U) over this period.

The purchase by the US of 550 t HEU warhead material from the Russian Federation and Ukraine is expected to provide a new uranium supply equivalent of about 168 400 t U natural, that may enter the market after 2002. Additional supply is expected from the release of excess US government stockpiles of natural uranium, LEU and HEU. Some analysts have projected that this government controlled material could enter the market at rates as high as about 17 000 t U natural equivalent per year. There are now indications that the US Congress will pass legislation rationing

the flow to the market of both the CIS and US uranium (and SWU) until well into the next century. Draft legislation before Congress would limit the cumulative amount of this uranium supply to not more than 6% of WOCA reactor requirements through 2010.

Based on analysis in this report, it is concluded that substantial additional uranium production is required to meet reactor requirements under both the low and high sale scenarios for military derived material. It is projected that world uranium production will have to increase within a very few years by at least 60 to 80% over 1994 levels to meet world reactor requirements.

The recent spot market price increase may indicate that the worldwide supply and demand relation is already undergoing the necessary change that will result in increased uranium production. For this to happen prices will have to continue their increase to a level where producers can pay all their costs of production and make a profit on their investment. This must occur before production can play its vital role in meeting 80 to 90% or more of the world reactor requirements through 2010 and beyond.

TABLE I. CIS URANIUM IMPORTS TO THE US AND EC AND WOCA INVENTORY DRAWDOWN

Year	WOCA Demand	WOCA Production[a]	Shortfall	CIS Imports[b]	Inventory Drawdown[c]
1988	40 564[d]	36 500	4 064	105	3 959
1989	42 694[e]	33 580	9 114	534	8 580
1990	40 342[e]	28 562	11 780	3 427	8 353
1991	45 596[e]	25 779	19 817	5 625	14 192
1992	47 921[a]	23 651	24 270	5 243	19 027
1993	49 688[a]	22 000[g]	27 688	4 216	23 472
1994[f]	49 165[a]	21 900[g]	27 265	9 450[g]	17 815
Total	**315 970**	**191 972**	**123 998**	**28 600**	**95 398**

a. Source: Ref. [1].
b. Data for 1988–1993 are from the US Department of Energy (Energy Information Administration) [6] and the Euratom Supply Agency [4, 5].
c. Drawdown does not account for CIS Imports to WOCA countries other than the USA and European Community, nor for Chinese imports to WOCA.
d. Source: Ref. [5].
e. Source: Ref. [6].
f. Estimated data including production and CIS imports to the European Community of 3000 t U.
g. IAEA estimate, includes 2000 US, 4000 Euratom and 3450 from CIS uranium enriched in Europe and imported to the USA.

TABLE II. PROJECTED ANNUAL REACTOR URANIUM REQUIREMENTS TO 2010 [1]

	1995	2000	2005	2010	Aggregate 1995-2010 (%)
World Total	60 800	63 500	68 400	75 700	1 068 000 (100)
Former Non-WOCA	10 300	10 600	12 600	14 400	191 000 (17.9)
Former WOCA	50 500	52 900	55 800	61 300	877 000 (82.1)

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