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The Global Nuclear Fuel Market Supply and Demand 2001-2020

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This paper provides a summary of the findings and conclusions of the 2001 supply and demand report of the World Nuclear Association ("WNA"). (1) The report, the first for the WNA, is the tenth in a series of reports since the foundation of The Uranium Institute in 1975. The objective of the report is to provide an updated, objective view of the fuel cycle markets as of mid 2001. It highlights the important developments that have taken place since the previous report in 1998, and addresses the future trends in the market, to provide the readers with the elements to build on their own understanding.

The report followed previous practice by making use of the information and experience of the member companies of the WNA. A Working Group, comprised of a balanced group of representatives from member companies was formed to oversee the drafting of the report, of which the author was the chairperson. Again with previous practice, questionnaires to both member and non-member companies and organisations active in the nuclear fuel cycle were used to update the information base of the WNA and to assist in the production of the forecasts described and included in the report. Confidentiality of the answers was secured by having a firm of chartered accountants aggregate the data on a regional basis before making it available to the WNA. This allowed access to information that would otherwise not be made available and resulted in the usual high response rate.

Other members of the WNA also offered their expertise through advice and suggestions. These sources were supplemented, where necessary, by judgements applied by the WNA, based on published materials and other reliable sources of information.

Trends in Energy and Nuclear Power

Energy consumption in the world has risen by 3.3% per annum over the past 30 years, faster than the annual population growth of 2%. Energy growth has been fastest in the developing countries, but also continues to grow in the industrialized countries.

Nuclear power has maintained its share of world electricity production at roughly 17% since 1990 (Figure 1). In the European Union nuclear power represents roughly one-third of the total electricity generation, with individual countries such as France and Belgium in excess of 70% and 50%, respectively. In Japan and South Korea, where nuclear reactor construction is most active, nuclear power represents about one-third and 40% of electricity. In the United States, nuclear energy provides roughly 20% of total electricity.

Since the last report in 1998, restructuring of the electricity supply industry has accelerated in many countries. Governments are seeking to introduce competition by changing the structure and regulation of the electricity supply industry. This is placing a greater emphasis on improving the short term economic performance of electricity generation. Electricity markets have become more competitive and nuclear power has had to prove its ability to compete with the other electricity sources.

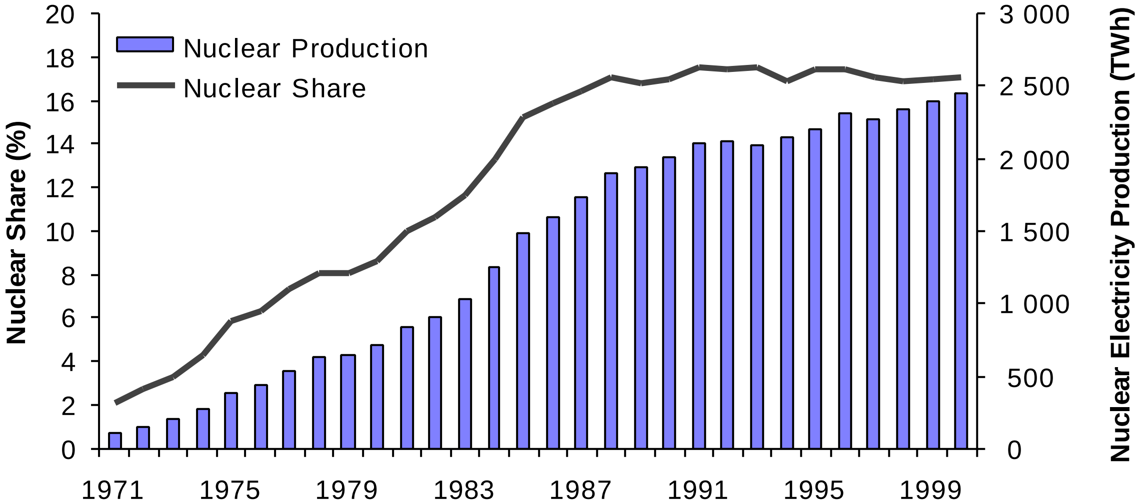

Figure 1 World nuclear electricity production, and nuclear share of total generation, 1971 - 2000.

The nuclear power generating industry is responding in a number of ways. First, with an improvement in average load factors (or capacity factors), a measure of the amount of power generated during the year as a percentage of power that could be generated if the reactor had operated at full power continuously. Load factors for the world nuclear industry have increased from 68% in 1990 to 78% in 2000. Most dramatic has been the improvement in the United States, where load factors have increased from about 66% in 1990 to 88% in 2000. Load factors have been improved by better maintenance and outage planning and by increasing the fuel cycle length. Second, nuclear power performance has improved by uprating the capacity of existing plants through capital expenditures on plant components, such as modifying the steam generators.

Extending the lifetime of existing nuclear plants to the extent of their technical lifetimes is economically attractive. Nuclear power has been characterized by high initial capital costs and low fuel costs. Therefore nuclear power is more economic the longer a plant is operated, by allowing the capital to be amortized over more lifetime generation. The vast majority of reactors likely to be in operation in the world by 2020 are already in service today. Therefore the WNA had to look at their age structure (Figure 2) in assessing the future nuclear generating capacity. In the United States, a procedure has been established to consider life extensions. In 2000, five reactors were granted 20-year life extensions, effectively giving the reactors 60-year lives, and there are roughly another 40 reactors with life extensions under review or where the operators have given notice they will be seeking life extension.

On the other hand, opposition to nuclear power continues to have a negative impact on nuclear power generation in some countries. In Sweden one nuclear reactor was closed prematurely in 1999. In 2001, the German utilities and their government signed an agreement which will limit the lives of that country' s nuclear plants. As a result plants will be shut before the end of their nominal lifetimes. In addition, there may be cases where, for economic reasons, some plants will be closed prior to the end of their technical lifetime.

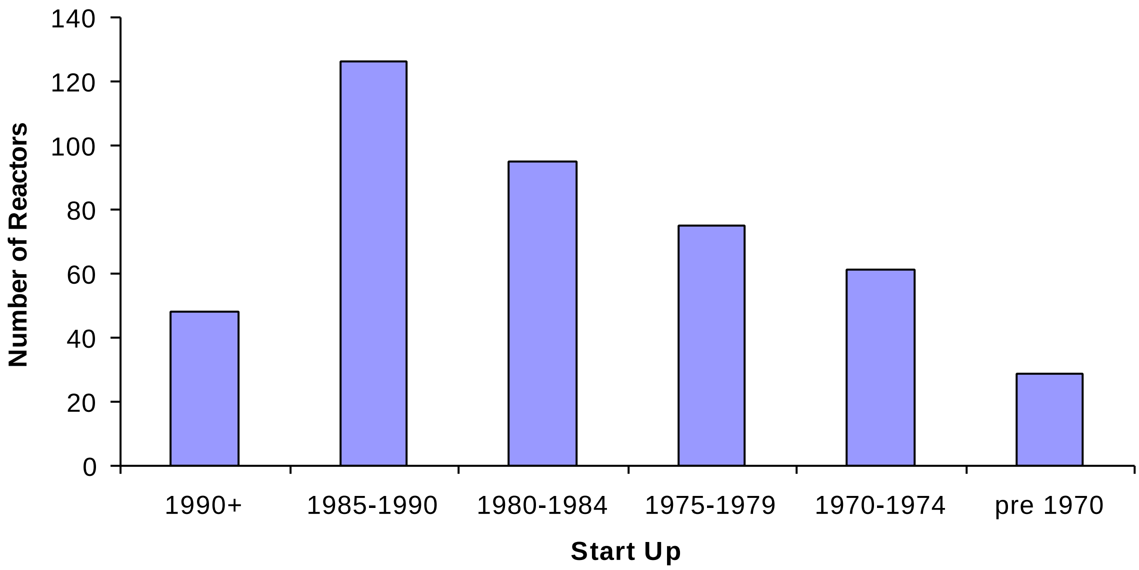

Figure 2 Age structure of nuclear generating capacity, by year of startup.

Another factor that may prove to be important in the long term for nuclear power is the growing international concern over the threat posed by global warming. In 1997, the Kyoto agreement called in principle for tough emission targets. Agreeing on how to achieve these targets has proven to be elusive to date. Nuclear power plants provide a very significant source of emissions avoidance, and could do considerably more. Much remains to be done to achieve full recognition of nuclear power' s potential role by the general public. But that is an issue for another paper.

The above elements have been taken into consideration in revising the forecasts of nuclear generating capacities in individual countries, but other factors were also accounted for, including cost competitiveness, reactor construction plans, and public policy and acceptance issues. Particular attention was paid to those countries expected to see the largest increase in installed nuclear generating capacity, namely China, Japan, Korea and the United States.

To reflect the range of uncertainties that surround any forecast, three scenarios have been developed. In the reference scenario nuclear power development is expected to continue on a path similar to recent years. For countries with existing nuclear power programmes, and expansion plans backed by long-term national policy, these will be continued. But for countries with no nuclear units, no development is assumed. The reference scenario assumes, with the exception of Germany, that all existing units will remain in operation for their nominal operating lifetimes, and that in several countries operating lifetimes will be extended beyond this period. For many reactor types, an operating lifetime of 50 to 60 years is considered feasible from a technical and safety point of view.

In the upper scenario it is assumed that over the next decade the economics of nuclear power improves relative to alternative electricity generation sources; that there is progress on public acceptance of waste management and decommissioning, which eventually reduces opposition to nuclear power; and that concern about the impacts on the environment of fossil fuels continues to increase. The upper scenario sees a revival of nuclear power.

In the lower scenario it is assumed that investment in nuclear power will be curtailed in favour of alternative electricity generation options; that political opposition to nuclear power remains strong in many countries; as a consequence, that some existing plants close before their nominal lifetimes; and that fewer reactor lifetimes will be extended, leading to a slow, long-term decline in nuclear capacity.

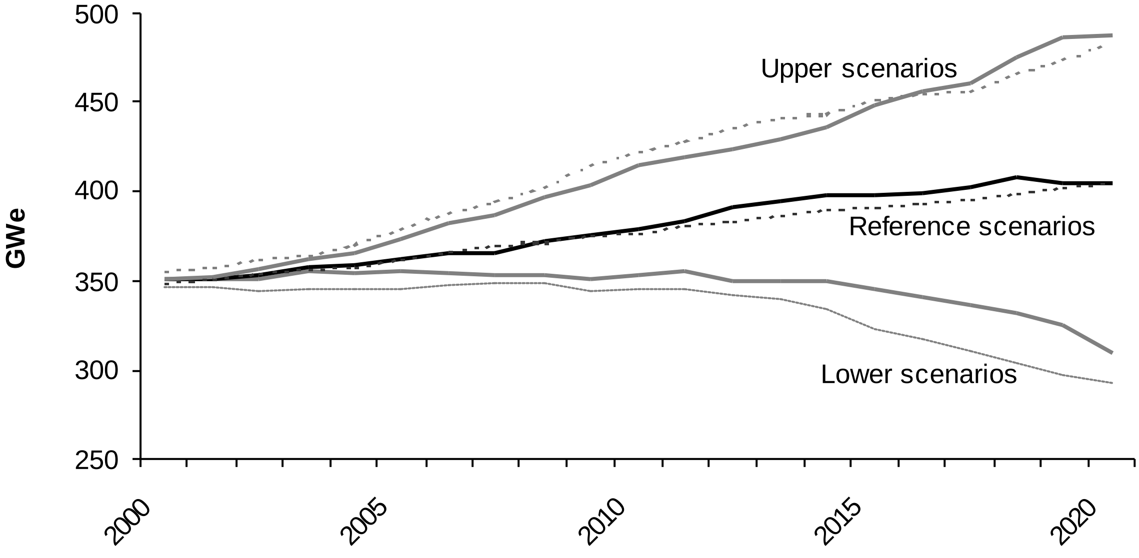

Figure 3 Comparison of 2001 nuclear generating capacity forecast (solid lines) with 1998 forecast (dashed lines).

The results of the WNA's nuclear generating capacity forecast for each scenario are shown in Figure 3, together with the forecasts of the 1998 report. At the end of 2000, world nuclear capacity was 350 GWe. In the reference scenario, this capacity is expected to grow to 379 GWe and 405 GWe by 2010 and 2020 respectively, representing an annual average growth rate of about 0.7%. In the upper scenario, the figures are 414 GWe in 2010 and 487 GWe in 2020. In the lower scenario they are 353 GWe and 309 GWe respectively.

Nuclear Reactor Requirements

Nuclear reactor requirements are the key demand indicator for nuclear fuel. The demand forecasts of the WNA have been derived from both the answers provided by utilities to the questionnaires and from a model developed at the WNA over several years. The model incorporates, on a reactor by reactor basis, the key reactor operating parameters, such as enrichment levels, fuel burn-up and load factors. Figure 4 gives the results of this review for the three scenarios mentioned earlier, and compares them with those in the 1998 demand forecasts.

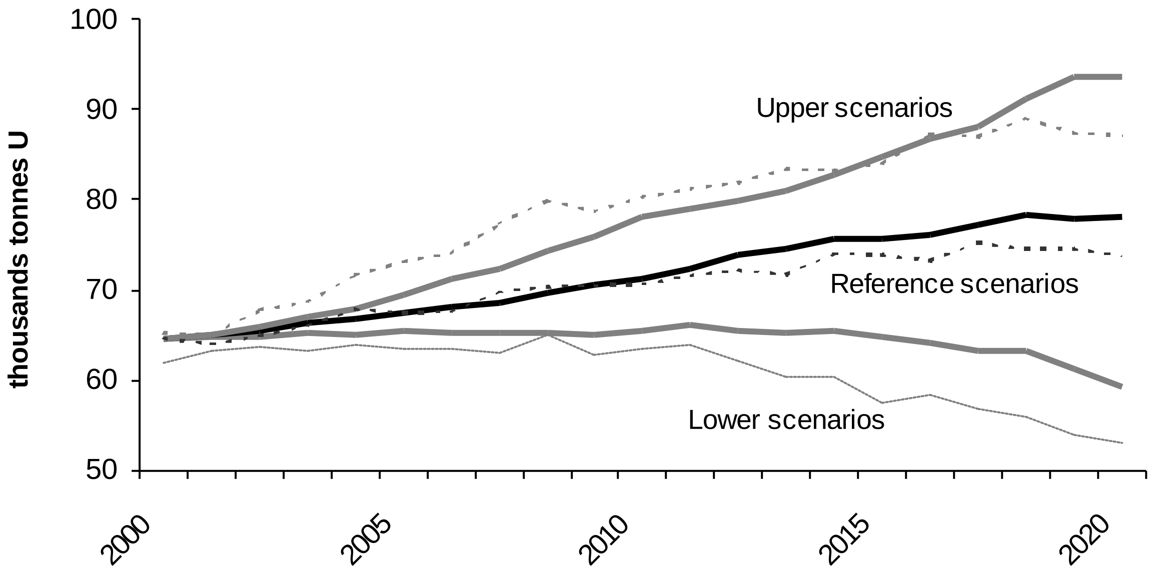

Figure 4 Comparison of 2001 nuclear uranium requirements forecast (solid lines) with 1998 forecast (dashed lines).

The results predicted by previous model forecasts were compared to the specific requirements (in tU/TWh) calculated from historical loadings, showing both regional variations and an estimation of the accuracy of the model. The model's forecast of specific requirements appears to be overestimated by about 5%, when compared with those calculated from historical reactor fuel loading.

Uranium Supply

The demand for nuclear fuel is satisfied either through primary production or through the use of secondary sources. The secondary sources include inventory reductions, recycling of fissile material derived from the reprocessing of spent fuel, the re-enrichment of tails or from military stockpiles.

Primary Production

Uranium production rose by about 12% in 2000 to 34 700 tU, reversing the downward trend experienced since 1998. This increase reflected the changeover to new mines in Canada, with McArthur River and McClean Lake, and the first full year of expansion at Olympic Dam in Australia. Output in the NIS (former USSR) countries has been increasing slowly over the past couple of years after falling dramatically over most of the past decade. World production in 2000 still represents only about 55% of world reactor requirements.

Western production has continued to be concentrated in a small number of large mines in the major producing nations, namely Canada, Australia, Niger and Namibia. The development of smaller in-situ leach mines in a number of countries including Kazakhstan, Uzbekistan and Russia are the only source of diversification currently (Figure 5). Further, the production is increasingly being concentrated in a small number of companies, with the share of production by the five leading mining companies [Rio Tinto includes both ERA and Rossing] increasing from 62% in 1997 to 70% in 2000 (Table 1).

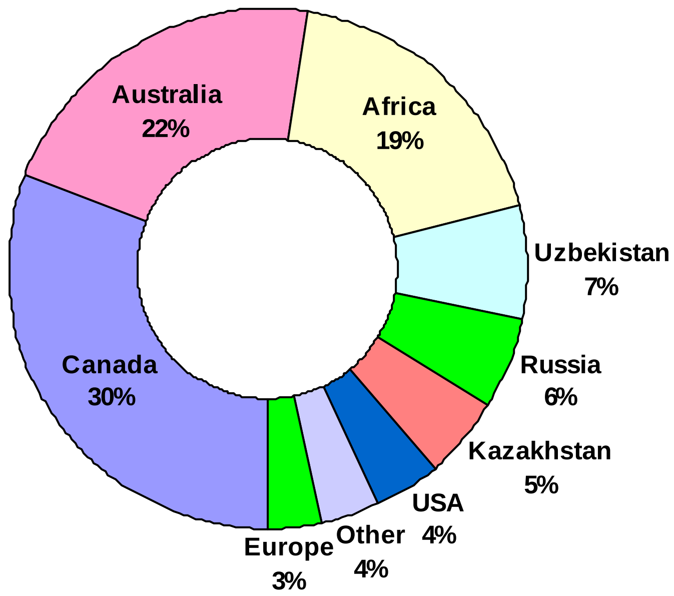

Figure 5 World uranium production by region, 2000 (%).

Table 1: Leading world uranium mining companies in 2000

	Production 2000 (Tu)	World share (%)
Cameco	6 757	19
Cogema	5 159	15
WMC	3 816	11
ERA	3 762	11
Rossing	2 714	8
Navoi	2 350	7
Priargunsky	2 000	6
KAZATOMPROM	1 740	5
Sub total	**28 298**	**81**
World total	**34 734**	**100**

Note: Figures reflect equity interest in production

Known world reserves of uranium are more than adequate to satisfy reactor requirements to well beyond 2020, the period covered by this report. The WNA has not conducted its own survey of reserves since 1997. The 1999 joint OECD Nuclear Energy Agency (NEA) and International Atomic Energy Agency (IAEA) "Red Book" indicates reserves of over 1.2 million tU recoverable at less than US $40 per kg U and over 3 million tU at less than US $80 per kgU. At current rates of consumption, assuming constant secondary supplies, this would represent nearly 100 years' supply. Further, based on forecasted requirements over the next 20 years of between 60 000 to

80 000 tonnes per year, this represents over 40 years of supply. There has been little exploration in recent years. Experience in other commodities would suggest that spending on exploration will lead to the discovery of additional reserves.

Secondary Supply

Essential to an understanding of the volume of material available for recycling and inventories is an appreciation of the extent of uranium production and its utilization from the beginning of the nuclear age to the present. Cumulative world production since 1945 is estimated at about 2 million tU, and can be roughly split into 1.2 million tU from Western mines and 800 000 tU from the NIS, Eastern Europe and China. Table 2 shows that, of the estimated world production, a little more than 1.1 million tU has been used in civil power reactors. The roughly 860 000 tU not used by civil reactors has either gone into military programmes or remains in inventory. On the basis of estimated military use of a little over 720 000 tU, the level of world inventory of natural uranium may be estimated to be about 140 000 tU.

Table 2: Estimated uranium production and consumption 1945-2000 (tonnes U)

	West	East	World
Production	1 245 000	754 000	1 999 000
Reactor requirement	-1 008 000	-130 000	-1 138 000
Military use	-264 000	-457 000	-721 000
Net imports/exports	+144 000	-144 000	-
Remaining inventories	177 000	23 000	140 000

The WNA questionnaires sought information on commercial inventories held by the industry by asking the participants for the amounts of material they owned. In addition, publicly available information was used where questionnaire results were either not available or insufficient to provide accurate results. There has been a small decrease in utility inventories since the last report, still collectively holding about two years of annual requirements. Inventories held by others appear to have grown slightly, but this is after a significant increase in commercial inventory was transferred from the US government to USEC at privatization. Nevertheless, it is evident that Western industry inventories have not made up the entire shortfall between reactor requirements and primary production over this period.

Another secondary source of supply is the recycling of reprocessed fissile materials. Historically, their impact has been limited to a few thousand tonnes of uranium equivalent per year.

Former military material, in the form of low enriched uranium derived from former military weapons high enriched uranium (HEU), has become available under the disarmament agreements entered into by the US and Russia. Up to 9000 tU per year is to be delivered under the agreement between the US and Russia until 2013. This material can be sold in the US under a quota that rises from 3077 tonnes U in 2001 to a maximum of 7690 tonnes per year from 2009.

Under an agreement entered into in 1999, the western companies (Cameco, Cogema and Nukem) have an option to purchase about 67% of the uranium to be delivered, with the balance available to Tenex. Any balance not purchased must be returned to Russia. Russia may use a limited quantity for HEU blend stock, with the balance to be placed in a monitored stockpile.

The US military material declared excess and expected to be available to the market is more limited and it is estimated that the equivalent natural uranium is roughly 1000 tU per year over the forecast period

The ex-military HEU from both Russia and to a lesser extent the United States is expected to be a critical factor in the market in the period to 2020, with ex-military plutonium having only a limited impact. The WNA has developed two scenarios covering the range of possibilities that could be expected (Table 3).

Table 3: Impact of HEU on the uranium market (tonnes U)

	2001	2005	2010	2015	2020
Upper Case	9000	9000	9000	9000	9000
Lower Case	3077	6154	7690	7690	7690

The next source of material is depleted uranium. This material displaces natural uranium in the market when it is re-enriched to the level of natural uranium, i.e. it is enriched so that the U-235 content is the same as natural uranium. There are accumulated inventories of depleted uranium worldwide that have been estimated to exceed 1.3 million tonnes. The economics of re-enrichment depend upon the U-235 content of the depleted uranium in stockpiles (tails assay), and the cost relationship between natural uranium and enrichment services.

Russia has surplus enrichment capacity and has been re-enriching depleted uranium for many years. Russia has been re-enriching depleted uranium from other countries, primarily from the EU to take advantage of this surplus capacity. The uncertainties associated with the amount of available surplus capacity and the tails assay of the depleted uranium being re-enriched make it difficult to assess the current capacity of Russia to supply markets with this material, but it is certainly considerable. On the assumption that the material with the highest assay has been utilized first, there are doubts about the ability of Russia to supply at high levels into the longer term.

Russian inventory supply is the last source of secondary supply. In addition to the low enriched uranium (“LEU”) supplied to the West in accordance with the HEU agreement between the governments of Russia and the United States, Russia supplies LEU under long term enrichment contracts with Western utilities and intermediaries. For many years, no significant amount of natural uranium (as U_3O_8 or UF_6) has been physically shipped from Russia to the West. Therefore, Russia must also be exporting most, if not all, of the uranium feed contained in the LEU it supplies. The uranium feed in this LEU is estimated at around 8000 tU per annum.

Fuel Cycle Services

Conversion, enrichment and fuel fabrication services have separate markets in their own area of the fuel cycle. Demand for conversion and enrichments services are directly linked to demand for uranium and to each other service. The secondary supplies described above also impact the individual markets for conversion and enrichment services.

The fuel fabrication market differs in that it supplies a highly technical differentiated product.

Conclusions

The WNA developed four cases, bringing together the three demand scenarios and compared them with the range of primary and secondary supply sources discussed above, to come to some conclusions on the possible development of the uranium market for the 20-year period to 2020.

There are limitations to this kind of analysis. Obviously, the analysis is static in nature, and no account has been taken of the way in which market participants will react to price levels or to potential shortages or surpluses. In any one year, available supply and demand is balanced through movements in inventory, with companies reacting to market signals, and with price being one of these signals. However, price consideration is outside the scope of this market report.

Figure 6 presents a maximum supply case, taking the highest primary and secondary supply scenarios, while Figure 7 is the opposite, taking low supply scenarios. Both of these extreme cases are clearly unsustainable and one or more of the factors in the market would adjust over time to achieve market balance. In the first case, the market is over supplied. In this case costs of production may determine which supply source is reduced. New mine development might be deferred, potentially even beyond that assumed in the lower case as inventories and military stockpiles, where costs may largely be considered sunk, enter the market.

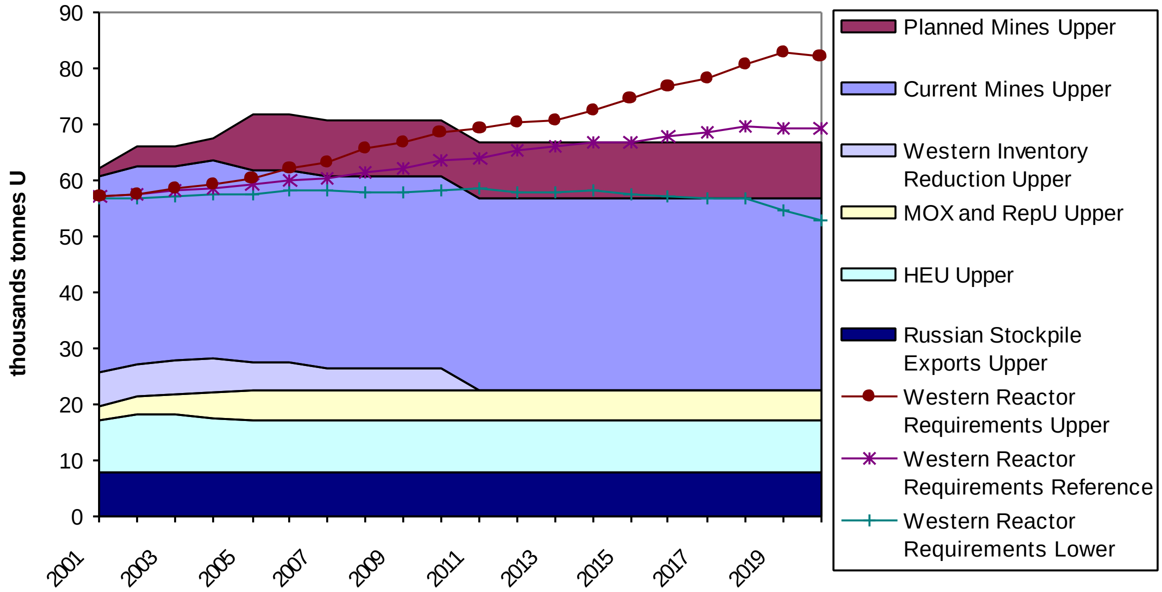

Figure 6 Case A Maximum supply case.

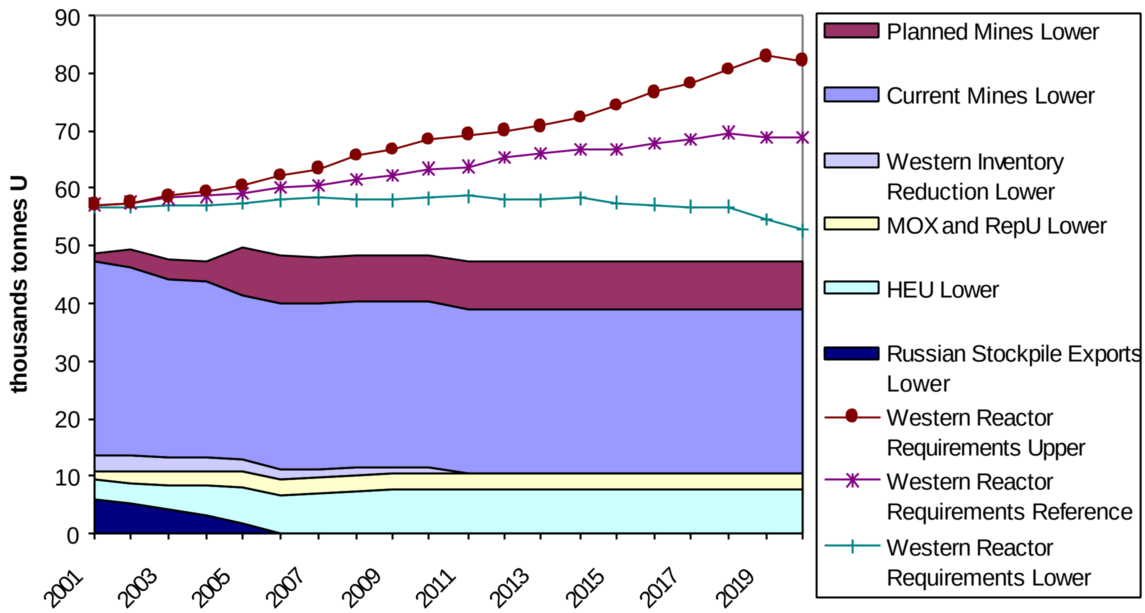

Figure 7 Case B Low supply case.

In the low supply case, utility inventories are likely to be drawn down further until the market balance is achieved through the introduction of new production. This would likely mean that the existing mines would operate at higher capacity utilization rates, as in the maximum case, but that new mine production would also start up. It is possible that until new production was achieved there could be localized disruption as inventories are not evenly distributed or available to all market participants.

Many different scenarios could be contemplated based on varying the key supply sources, and the readers of the report are encouraged to do so, based on the analysis in the report. One possible variation is shown in Figure 8. This is, however, not to be taken as the "most realistic case", but simply as an illustration of one of many possible cases that could be constructed. The supply conditions assumed for this case include the reference case for production from both existing and planned mines, lower western inventory drawdown, the lower scenario for use of MOX and reprocessed uranium, and the upper scenario for HEU supply. In this case a lower scenario is assumed for Russian stockpile supply, gradually reducing to zero after 2015.

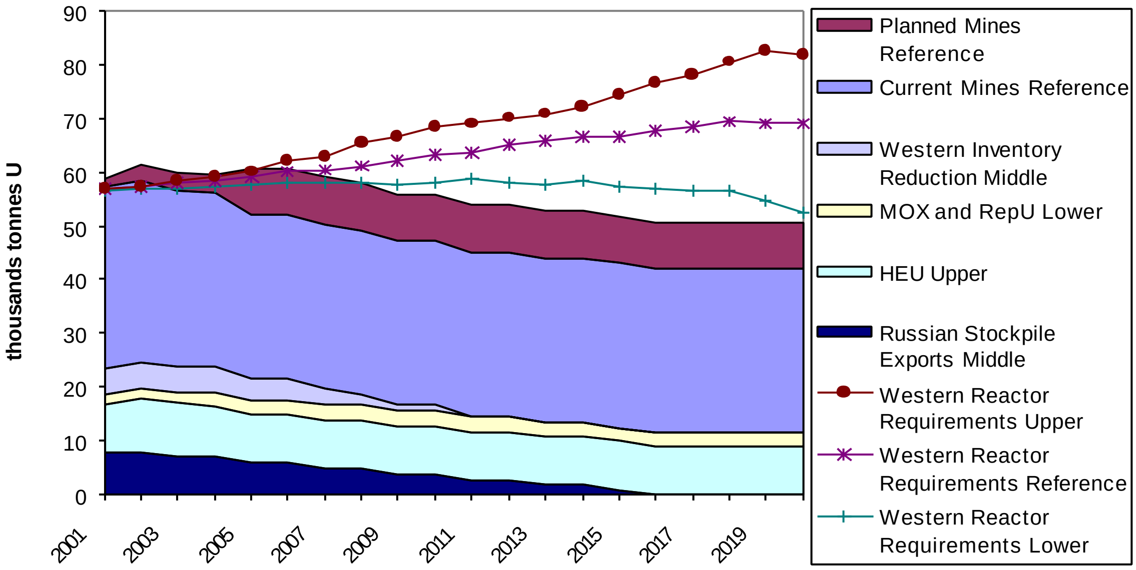

Figure 8 Case C.

This case shows a much greater degree of market balance in the short term, but supply falls below demand in all cases around 2009, as the secondary supplies to the market fall away.

In conclusion, combining all primary and secondary supply sources suggests that the nuclear fuel market will be adequately supplied for most of the next twenty years. New primary supply will be required and will be developed in the proper investment climate, but timing will depend on licensing and construction lead times. The above cases all show that a key feature of the uranium market over the coming period is likely to be the continued dependence on secondary supplies, the bulk of which will be from stockpiles associated in one way or another with de-militarized material in Russia and the United States. The greater the presence of secondary supplies the less need for primary production and therefore, the less likely there is any new investment.

There is an obvious benefit for the world and indeed for the nuclear industry in reduction of military nuclear material stockpiles. However, for the nuclear power industry, there are risks associated with relying to a great extent on supplies from a single source to provide its fuel requirements, particularly when much of the material is in secondary supplies where the availability is driven by politics and not economics. Should supplies from that source be curtailed, for whatever reason, supply disruptions could result. Holders of commercial inventories might be reluctant to trade them in times of apparent or perceived supply shortage. It takes years to bring new primary production facilities into operation.