URANIUM RESOURCES, PRODUCTION AND DEMAND IN SOUTH AFRICA

H J Brynard* and L C Ainslie**
* Ph.D(Pretoria), **M.Sc.(Rhodes)
Atomic Energy Corporation of South Africa Ltd.
P O Box 582, PRETORIA, 0001

SUMMARY

This paper provides a review of the historical development of the South African uranium market and the current status of uranium exploration, resources and production. A prognosticated view of possible future demand for uranium in South Africa is attempted, taking cogniscance of the finite nature of the country's coal resources and estimated world uranium demand. Although well endowed with uranium resources, South Africa could face a shortage of this commodity in the next century, should the predicted electricity growth materialise.

OPSOMMING

Hierdie referaat verskaf 'n oorsig van die historiese ontwikkeling van die Suid Afrikaanse uraanmark en die huidige status van uraaneksplorasie, -hulpbronne en -produksie. 'n Vooruitskatting van die moontlike toekomstige vraag na uraan in Suid Afrika word gemaak, met inagneming van die eindige aard van steenkoolhulpbronne in die land en geraamde wêreld-uraanaanvraag. Alhoewel Suid Afrika goed bedeel is met uraanhulpbronne kan die land in die volgende eeu 'n tekort aan hierdie kommoditeit ondervind as die voorspelde elektrisiteitsgroei realiseer.

INTRODUCTION

The Atomic Energy Corporation of South Africa Limited customarily undertakes the assessment of South Africa's uranium resources and future production capabilities. These assessments are carried out in close collaboration with the mining industry and other Government organisations with the prime objective of monitoring the South African uranium supply. This information also provides the policy makers with an overview of the nuclear resources available for electrical energy generation.

Increasing exploitation costs, inflation and the fluctuation in resources due to uranium exports on the one hand and new discoveries on the other hand continuously change the resource situation, necessitating the reappraisal of the resources on a continuous basis.

HISTORICAL REVIEW OF URANIUM IN SOUTH AFRICA

The first clues regarding the presence of uranium in South Africa were uncovered late in the last century when the green fluoresscence of minute diamonds recovered from gold ores of the Witwatersrand was shown to be caused by radioactivity. Some years later uraninite was identified in heavy mineral concentrates from the City Deep Gold Mine, but because of its lack of commercial value, this raised little interest.

The South African mining industry responded promptly when called upon in 1945 by Field Marshall J C Smuts, then Prime Minister, to assist in acquiring uranium for the "Manhattan Project". The subsequent history of uranium production in the RSA is shown in Figure 1. The mining industry moved quickly to erect uranium plants, and in October 1952 the first uranium plant was opened at West Rand Consolidated Mines. By March 1955 sixteen mines had been authorised to produce uranium. Production accelerated rapidly until 1959 when 26 mines were feeding 17 plants for a total production of 4 954 tonnes U. In the early years South Africa's entire output was committed to supplying the Western World's nuclear armaments program. After 1959 the needs of these programs declined and uranium production in South Africa followed suit reaching a nadir of 2 262 tonnes U in 1965.

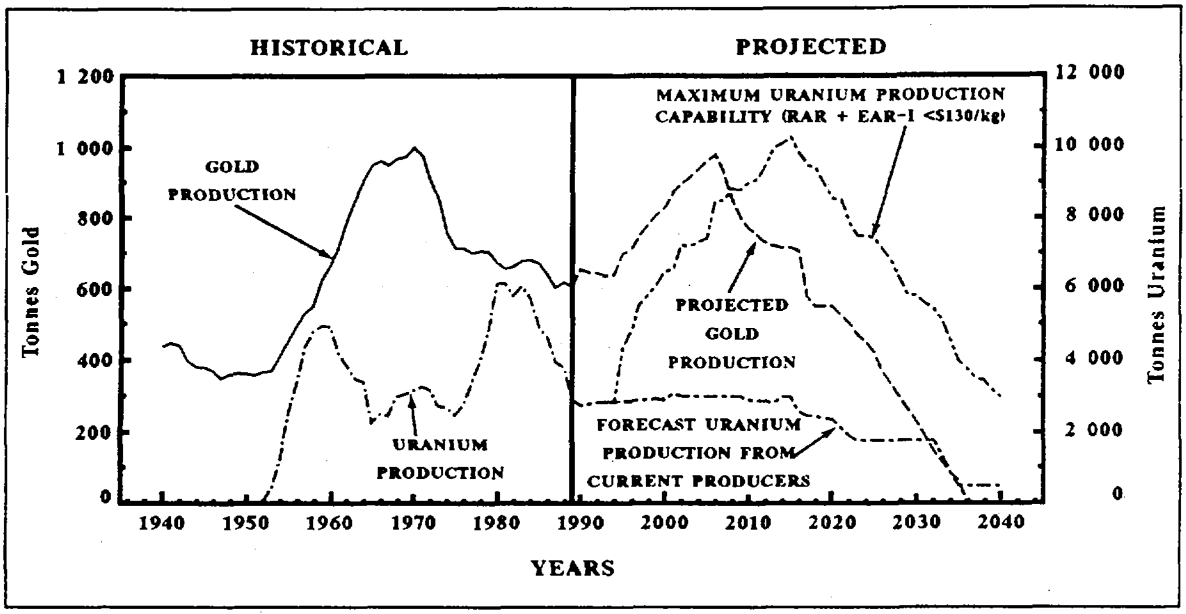

Figure 1 Historical and projected uranium and gold production for the RSA.

At this time the relative abundance and cheapness of fossil fuels did little to encourage development of the embryonic nuclear power industry. The situation changed drastically in the 1970's with the advent of the world oil crisis and demand for uranium rose rapidly. The resultant steep rise in price stimulated South Africa's uranium industry to the extent that by 1980 it had almost trebled its production to 6 143 tonnes U.

Many decades of gold mining activities gave rise to vast uraniferous tailings deposits which, coupled with the favourable uranium price lead to the initiation of three large tailings treatment operations in the East Rand, Klerksdorp and Welkom areas. In 1982 South Africa's first primary uranium producing mine, the Beisa Mine, was brought on stream.

The boom in the nuclear power industry received a severe blow in 1979 when the Three Mile Island incident triggered an anti-nuclear backlash. In the wake of this the growth of the nuclear power industry declined, with a number of planned nuclear plants being cancelled in various parts of the world. Demand for uranium dropped and consequently so did its price, which, by the end of 1984, had fallen to about a third of its peak level, attained in 1978. At the end of 1989 nine uranium plants were in operation and produced 2 943 tonnes U.

URANIUM PROVINCES

Uranium mineralization is present in rocks which encompass almost the whole of the geological history of South Africa, however, significant mineralization is restricted to five fairly well-defined time periods. Each period is characterised by a distinct type or combination of types of mineralization. The oldest type is that hosted by quartz-pebble conglomerates which fall in the time range from 2 900 Ma to 2 400 Ma. Uranium-bearing alkaline complexes cover a wide time scale from 2 000 Ma (Phalaborwa) to 1 400 Ma (Pilanesberg). Uranium is also found in granite-gneisses which span a similarly large time period from 1950 Ma to 1 000 Ma.

A hiatus in the occurrence of uranium in South Africa exists between 1 000 Ma and 300 Ma. It is only with the onset of Karoo sedimentation that uranium mineralization reappears in the South African stratigraphic column. Uranium occurs both in coal seams and sandstones of the Karoo Sequence. The youngest uranium mineralization occurs in a variety of Tertiary to Recent sediments which include calcretes, peaty diatomaceous earths, beach sands and phosphates.

URANIUM EXPLORATION

Uranium has always been of secondary importance to gold as a target commodity in the exploration of the quartz-pebble conglomerates of the Witwatersrand Supergroup, Dominion Group, Mozaan Group and Black Reef Formation. A marked increase in the price of uranium in the late 1970s brought the metal into greater prominence and led to the establishment of two primary uranium producers, Afrikander Lease Limited and the Beisa Section of St. Helena Gold Mines Limited. The subsequent slump in the uranium price caused the untimely closure of both these operations in 1982 and 1984 respectively. The very favourable gold price in rand terms of a year ago has stimulated extensive exploration in various parts of the Witwatersrand Basin but the uranium potential is of little importance in determining target areas and levels of expenditure. A significant factor in determining target areas is the advances in deep-mining technology, making deeper reefs accessible for exploitation. A result of this is the rapid escalation of the costs of exploring these deep reefs and recently companies have been making extensive use of the sophisticated vibroseismic technique to define targets more accurately prior to drilling. Twelve companies are currently active within the Witwatersrand Basin. The success of these activities is attested to by the initiation of ten major mining ventures during the past decade, either as new mines or as extensions to existing mines, with more believed to be imminent.

The presence of uranium in Karoo sediments was first noted in 1967 during the oil search. In 1968 exploration started in the southern Karoo and rapidly spread to other parts of the Karoo Basin. A number of deposits were identified but the drastic slump in the uranium market in the early 1980s led to a decline in exploration with all work terminating in early 1985. A similar fate overtook the uraniferous coal deposits of the Springbok Flats.

The cost of exploration is escalating continuously, both because of inflation and the increasing difficulty in finding new orebodies. In the Witwatersrand Basin alone it is estimated that in the vicinity of R400 million was spent on gold exploration during 1989 and as a result new uranium resources were discovered concurrently with those of gold. Any significant improvement in the uranium market will be followed closely by a resurgence in exploration for uranium as a primary commodity.

URANIUM RESOURCES

Resource estimates are reported in terms of recoverable metric tons of uranium metal (tU) after deduction of expected mining and ore processing losses. These estimates are divided into separate categories reflecting different levels of confidence in the quantities reported and are further divided into categories based on the cost of production. To facilitate reporting to international agencies South Africa conforms in broad terms to the terminology and definitions recommended by the NEA/IAEA.

A major part (79%) of South Africa's uranium resources is present as a by-product of gold in the quartz-pebble conglomerates of the Witwatersrand Basin. The price of gold is thus of importance in categorising these uranium resources, as is the dollar/rand exchange rate. On 1 January 1989 the South African uranium resources in the reasonably assured (RAR) and estimated additional (EAR-1) categories, recoverable at costs less than $130/kg U, were 432 493 t U from sources indicated in Table I.

TABLE I Known uranium resources as at 1 January 1989

PRINCIPAL DEPOSITS OR DISTRICTS	TONNES U				
	REASONABLY ASSURED RESOURCES (RAR)		ESTIMATED ADDITIONAL RESOURCES CATEGORY I (EAR-I)		TOTALS
	Recoverable at costs less than $80/kg U	Recoverable at costs between $80 - $130/kg U	Recoverable at costs less than $80/kg U	Recoverable at costs] between $80 - $130/kg U	
Witwatersrand					
- Conglomerates	184 169	49 743	42 615	25 116	301 643
- Tailings	21 940	18 732			40 672
Phalaborwa	3 343				3 343
Karoo Sequence	43 581	27 666	9 137	5 254	85 638
Surficial		721		405	1 126
TOTAL	253 034	96 862	51 752	30 775	432 422

Estimates are usually also made of the resources in the RAR and EAR-I categories recoverable at costs between $130 and $260/kg U. The exploitation of these resources are, however, inconceivable under present uranium market conditions or even in the long term. Substantial resources in the EAR-II and SR categories are believed to be present in other geological environments in South Africa, but possible resources in these environments are generally believed to fall in the higher cost categories and these are by definition very speculative and should be viewed with circumspection.

The Dominion and Witwatersrand Basins are the most likely environments for the discovery of further resources in the cost categories below $130/kg U and the Karoo still remains to be fully explored.

URANIUM PRODUCTION

All of South Africa's uranium is produced as a by-product; the majority from the Witwatersrand gold mines and a small proportion from the open-pit copper mine at Phalaborwa. As a result the level of production is not entirely dependent on uranium market forces as is that from primary uranium producers. This, coupled with the fact that the majority of production is committed to long-term contracts, cushions the South African uranium industry from fluctuations in the uranium market.

Uranium production has been declining since 1980 to reach the level of 2 943 tU in 1989. The anticipated upturn in the uranium market and the changing political climate in South Africa may change the situation favourably, but, as will be indicated later this may ultimately be to the detriment of the country.

SOUTH AFRICA'S INTERNATIONAL POSITION

South Africa has been a major participant in the international uranium market since its early days, both in terms of resources and production. It has consistently maintained its resources at about 14% of WOCA'S known resources, and as of the beginning of 1989 it ranked third after Australia and Niger with 13,6% of the total Reasonably Assured Resources exploitable at costs of less than $80/kg U.

Weakness in the uranium market over the last few years, allied with escalating working costs in the gold industry, and political factors have resulted in rationalisation within the South African uranium mining industry. This has lead to the closure of a number of uranium plants which has adversely affected the country's international position with regard to production. In 1985 South Africa was ranked second after Canada, but by 1989 its contribution to the WOCA total had fallen from 13% to 9%, and its ranking from second to seventh. It is still a reliable uranium producer and has the capacity to increase its output if the market improves.

URANIUM MARKET CONDITIONS

To estimate the possible future uranium market under the present depressed market conditions is fraught with uncertainties.

The Western World's natural uranium demand to fuel reactors reached 41 800 tonnes U in 1987, and is projected to increase to 55 000 tonnes U by the year 2000. The total uranium production remained below demand for the third consecutive year and during 1987 amounted to 37 800 tonnes U. The gap between production and demand is projected to increase in the years from 1988 to 2000, but demand can be met by inventory draw-down and reprocessing till the mid- to late-1990's, if the expected increase of production to 42 000 tonnes U per year as seen by NUKEM in 1989 materializes.

It seems that the uranium market is moving into a more stable situation and as NUKEM puts it, panic sales of excess inventories carried by utilities with cancelled reactor projects no longer exist. Producers with uncommitted excess production no longer have to compete with inventory sellers and low-price uranium purchases by producers who had to close their high-cost operations and fullfil their delivery obligations have diminished.

Although a production level peaking at over 10 000 t U is theoretically attainable by South African producers (Fig. 1), it is considered unlikely to be achieved in practice from market projections.

URANIUM DEMAND IN SOUTH AFRICA

In the RSA the major sources for electricity generation are coal, nuclear power, pump storage, hydro-power and gas turbines in order of importance. The most significant is coal which contributed 87,5 per cent to the total installed electrical capacity of 34 141 MW in 1989, while the Koeberg nuclear power station contributed 5,7%[1].

Unfortunately, however, coal is a non-renewable energy source and has a finite life time in the RSA. Present estimates point to the fact that the last coal fired power plant in the RSA may be commissioned in the period 2035 to 2050[2]. Thereafter, the only presently known realistic alternative for base load generation in the RSA is nuclear power. This form of power generation, however, requires a sophisticated technology which must be supported by a specific expertise and infrastructure before being able to contribute in any significant way to the RSA's power requirements. The lead time from the decision to install a new power station to final operation is at least 10 years. It is, therefore, neccesary to accurately predict the demand 10 years ahead while ignoring largely short term fluctuations. It also makes sound sense to phase in any nuclear capacity at a suitably early time well before the last coal fired power station is commissioned. One scenario investigated in a joint ESKOM/AEC study[3] in 1987 is shown in Figure 2.

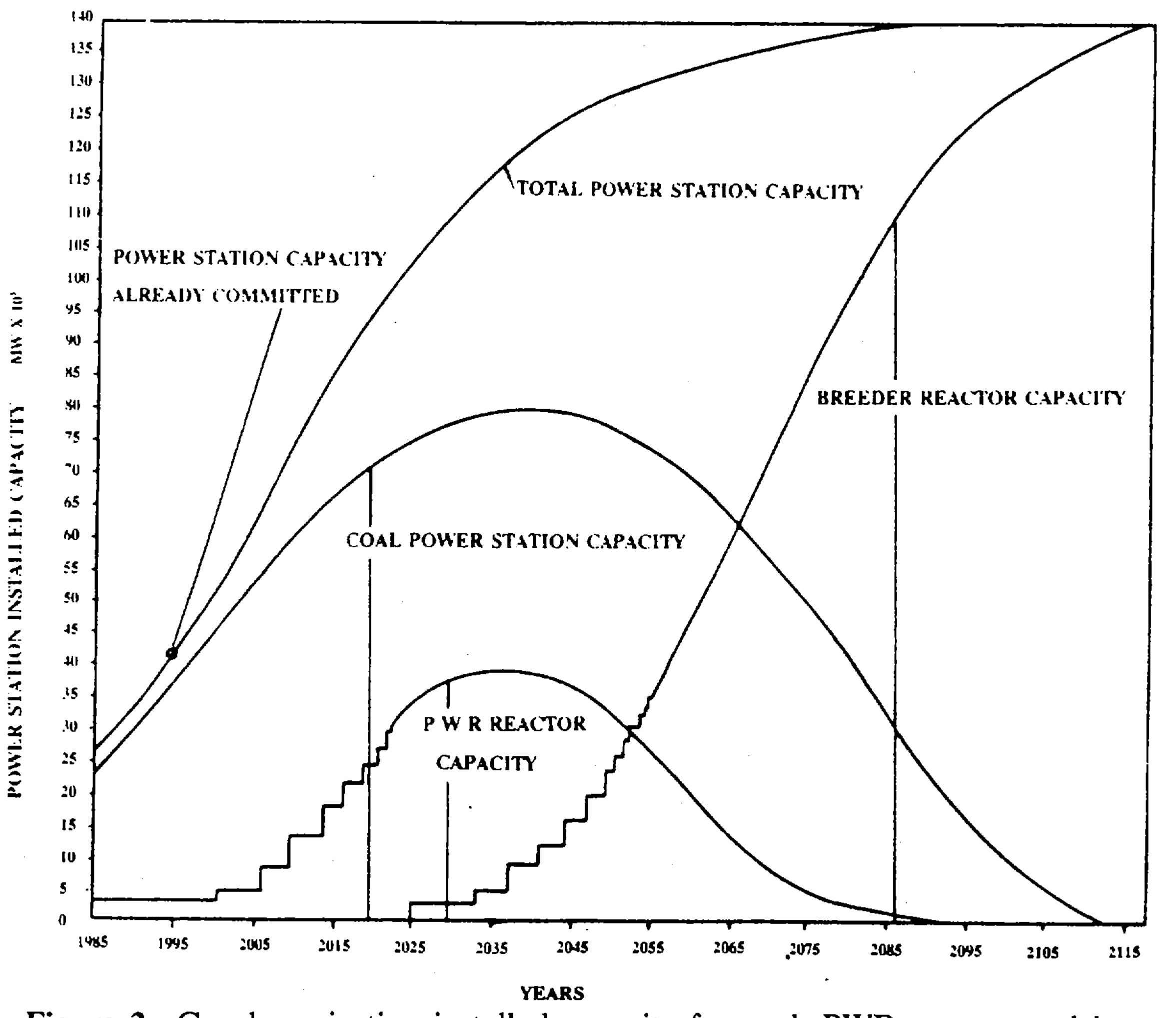

Figure 2 Graph projecting installed capacity for coal, PWR reactor and breeder reactor power stations.

H J BRYNARD

It should be noted that time scales and growth curves on this figure should be treated with some caution as many of the assumptions that were made in 1987 are no longer valid and could result in a shift of the respective curves in the short and intermediate term. From Figure 2 it becomes apparent that coal and nuclear generated electric power should be seen as complementary in the future electric energy strategy of the RSA with a well planned transition from one to the other. The timely development of the nuclear capacity requires careful strategic planning as a number of strengths, but also significant constraints in the RSA, should be taken into account.

The electrical energy equivalence of the RSA uranium resources (RAR + EAR-1 <$13O/kg U) of approximately 432 500 tU when used in a once-through cycle in light water rectors such as Koeberg, is approximately equal to 8 140 Mt of coal. However, in breeder reactors these uranium resources could be the electrical energy equivalent of 490 000 Mt of coal in which case energy supply problems would almost certainly not arise within the next century.

The current RSA uranium production, which is virtually all exported and currently runs at a few thousand tons per annum, should not have a major impact on the total reserves available for nuclear power in the RSA unless a significant price increase materialises. In such an event the continued export of RSA uranium may become a significant constraint as has been pointed out earlier. Should future technological advances prove the use of thorium viable as a nuclear fuel, it is estimated that South Africa could contribute 130 000 tons of ThO_2 from known deposits to the international inventory of which about 38% is in the reasonably assured category. However, it must be stressed that exploration for this commodity has never been undertaken on an extensive scale in South Africa and that the technology for utilising this energy source for power generation on an industrial scale is largely still unproven. The fact that uranium in the RSA is largely associated with gold occurrences has been, and probably will remain a significant blessing in the near future, but as the RSA gold production declines, the coupling of uranium production to gold production will become a very severe constraint, as shown graphically in Figure 1.

H J BRYNARD

The focus of interest from Figure 1 is on the decades 2020 to 2040, during which the local demand for uranium will increase dramatically. This period of maximum demand coincides with the time during which gold production from South African mines will decline to negligible levels[4], according to Figure 1. This means that much of the uranium associated with the gold in the Witwatersrand reefs will have been mined out, but not necessarily recovered. In addition 21% of current resources, constituting 90 200 tU, are located outside the Witwatersrand Basin. The cost of recovering this uranium would, therefore, have a profound influence on the eventual cost of electricity.

Although the RSA has considerable uranium resources in the lowest cost category (about 167 000 tons RAR<$8O/kg U), a significant portion of these may become unexploitable for various reasons. Some uraniferous reefs of the Witwatersrand Basin in current mining lease areas may remain unmined for the life of the mine because of low associated gold grades. Closure of the mine would effectively sterilise these resources. A substantial increase in the uranium price could permit the mining of these reefs for uranium with gold as an important by-product. Of more immediate concern are those mines which have shut down their uranium plants. If no planned stockpiling policy has been implemented the uraniferous tailings will be diluted in the main tailings stream. This dilution could render it uneconomic to recover the uranium as a primary product when it is needed. Further plant closures could aggravate the situation. In addition, a further loss in uraniferous tailings as a result of mining back-fill schemes, could ensue. It is estimated that 42% of the RAR<$8O/kg U resources in current mining lease areas could be affected by these factors. This represents about 16 GW(e) of future PWR nuclear capacity and 960 GW(e) of fast breeder nuclear capacity which may be lost. An incentive to persuade the mines to conserve the uraniferous tailings for later extraction and to reconsider back-fill schemes should be investigated.

The future supply of uranium in South Africa should also be viewed in the global context of resources available to the world's nuclear industry. This shows that the alternative of purchasing uranium from sources outside South Africa should be regarded with circumspection. Current world (WOCA - World Outside Centrally Planned Economies) forward coverage, based on the current consumption rate of low cost resources (RAR($8O/kg U) is about 37 years[5]. For the intermediate term, assuming a 3,5% mean growth rate in consumption and no additional discoveries, current resources would leave a forward coverage of 25 years i.e. until 2015, present inventories excluded. These projections are based on the assumption that the uranium resources of South Africa and Australia, which together account for 44% of the world's RAR < $8O/kg U resources, would be available to the world's nuclear industry. Should this not be the case the coverage period reduces to only 15 years, which is close to the lead time to construct a nuclear power station. This indicates that there could be little readily available uranium on the world market at the time when South Africa's requirements are at their peak.

CONCLUSIONS

Although well endowed with uranium resources, South Africa could face a shortage of this commodity in the next century, should the predicted electricity growth materialise. Irrespective of whether this will be the case or not, all our current energy resources should be conserved in the most cost-effective way.

REFERENCES

1 ESKOM Annual Report, 1989.

2 De Villiers, J W L, Elektrisiteitsvoorsiening in Suid Afrika. S A Tydskrif vir Natuurwetenskap en Tegnologie. Vol. 5 No. 1, 1986, pp.9-17.

3 A study of future power generation in South Africa. A combined ESKOM/AEC Study, June, 1987.

4 Krige, D G, Elementary geostatistical models aplied in forecasting South Africa's long-term gold production. Mining Engineering, June, 1987, pp. 427-432.

5 Nuexco, Uranium resources: Are they adequate? August, 1989. pp. 22-30.

H J BRYNARD