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URANIUM AND THE GENERATION OF POWER - THE SOUTH AFRICAN PERSPECTIVE

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1. INTRODUCTION

The subject of my address to you tonight is: URANIUM AND THE GENERATION OF POWER - THE SOUTH AFRICAN PERSPECTIVE.

I have subdivided my talk into three main parts:- Firstly I am going to look at uranium requirements, uranium production capability and uranium reserves in the light of estimated energy forecasts for South Africa and the western world. Mention will also be made of the impact of breeder reactors, of plutonium and of uranium enrichment.

The second part of my address deals with the South African uranium situation, exploration currently underway and some recommendations.

The last part of my address deals with characteristics and criteria that have a bearing on uranium mineralisation in various formations in South Africa.

Unless otherwise stated, the statements, text figures and interpretations which follow reflect my own personal views, which are not necessarily those of my employers or of any other authoritative body mentioned in my address.

Over the last two decades (1950 - 1970), total world energy consumption rose at an overall rate of 5,2 per cent. Figure 1 is a representation of demand and projected demand for different types of fuel-past and present. It is based on correlation of energy consumption, with relatively modest per capita increases in gross domestic-product (GDP) and indicates the possibility of the quadrupling of energy demand by the year 2000 when it would reach a level of 29 billion tons of coal equivalent (TCE). Solid fuels, natural gas and hydro-use increase pari passu with the population growth, with liquid fuels and nuclear power projecting way above it.

Figure 2 illustrates the radical changes in the relative shares of the different primary fuels over the last 70 years. Whilst solid fuel accounted for more than 90 per cent of total energy consumption in 1900 and still amounted to 60 per cent in 1950, the trend was reversed by 1970, when petroleum and natural gas replaced solid fuel due mainly to the low prices made possible by the development and exploitation of the extremely large low cost reserves in the Middle East and in North Africa.

Because of the lead times involved for the development and commercialization of radically new sources of power, major changes in the market shares of different fuels cannot be expected to occur over the next decade (figure 2). The share of nuclear power which is expected to increase from 4 to 14 per cent of total primary energy by 1985, indicates that its role as a potential short-term substitute is relatively limited.

This, however, does not imply that its future prospects would not influence prices of fossil fuels. Pricing policies for oil and gas will take into account not only existing nuclear power plants, but also the size and credibility of future programs so that medium term prospects may influence the actual prices of energy in the short-term.

As seen from figure 2, nuclear fuels are still not expected to be the major source of energy by the year 2000, when they will represent less than 28 per cent of the total, while natural gas and oil would still account for more than 48 per cent.

A very general estimate of world energy resources is given in figure 3. Although it is realized that without a clear indication of costs of exploration and recovery of ores the results should be viewed with caution, it clearly points out the importance of breeder reactors. If known low-cost uranium were used in present light water reactors only, it might meet the requirements of the present programs for nuclear power roughly to the end of the century. If used in breeders uranium resources would be multiplied by two or three orders of magnitude and exceed those of all fossil fuels combined.

Reserves of coal, oil and natural gas will be increasingly depleted over the next few decades and uranium and other nuclear fuels will increasingly be employed.

One of the unique properties of nuclear fuels is the extraordinary amount of heat which can be released from a very small amount of material. The theoretical advantage of nuclear fuels over coal for example, in terms of potential energy per unit of mass is about 3 million to one. In today's nuclear power systems, up to about 2 per cent of this potential may be realized eventually with plutonium recycle. Breeder reactor systems are expected to increase this figure to 60 per cent or more. Current commercial light water nuclear reactors, even without plutonium recycle, produce energy from each kilogram of uranium equivalent to that available from about 25 tons of coal.

This characteristic of a highly concentrated energy source in turn has two implications which have a special significance. First, as nuclear power takes on a larger share of the electric generating market, regional differences in power generation costs will tend to disappear. Second, nuclear fuels are considerably less affected by price escalation attributable to rising transportation costs. In South Africa the coal fields are concentrated in Northern Natal and Northern and Eastern Transvaal and transportation is responsible for a factor 4 to 5 increase in costs at centres such as Cape Town and Windhoek.

Although capital costs of nuclear plants are higher than those of fossil fuelled plants, once the capital investments is made, the cost of producing nuclear power from a particular plant tends to be stable.

2. ENERGY FORECAST FOR SOUTH AFRICA

The industries which concern themselves with the supply of energy are all capital-intensive and need a considerable lead-time in order to plan their operations. It has been estimated by the Department of Planning that in South Africa useful energy consumption will increase more than five-fold between 1970 - 2000, whereas the population is expected to double over the same period.

South Africa obtains four fifths of its energy from locally mined coal, and though not large by world standards, our coal reserves represent about 84 per cent of the grand total for Africa. The history of electricity in South Africa goes back as far as 1882 when Kimberley received street lighting - three years before London and only three years after Edison opened New York's first power station.

Escom, constituted in 1922 started with a modest hydro plant at Sabie in 1925. Between 1950 and 1960 Escom's installed capacity increased from 1 514 MW to 3 487 MW. Today it is 10 301 MW, and when present projects have been completed, by the end of the decade, it will total 15 381 MW - ten times the 1950 figure. Escom has estimated that by the year 2000, requirements will be 79 000 MW. This is six times the present day figure.

Growth in electricity demand in South Africa during the sixties rose by a yearly average of 8 per cent. In 1972, it increased by 10 per cent, and in 1973 by almost 12 per cent. Now the gold boom promises a further surge. With increased mining activity more power is needed throughout the industry to increase the capacity of systems needed for ventilation, refrigeration, haulages, extraction etc.

Other mining activities, in the Northwest Cape Province and in South West Africa, especially of copper, asbestos, manganese, diamonds and uranium, have to be provided for, as well as one or more envisaged electrolytic refineries, the first of which is planned for 1981.

In 1974 coal still accounted for more than 75 per cent of the total demand for energy in South Africa and in the process more than 65 million metric tons were consumed. It is practically the sole source of electricity generation in South Africa and alone accounted for more than 33 million, of the abovementioned 65 million tons. Coal will still account for more than half of the energy consumed by the year 2000 in South Africa.

It is no easy matter to accurately assess the size of South Africa's coal reserves. Apart from the fact that opinions differ as to what constitutes reserves, it is very difficult to calculate the actual amounts of coal in known deposits that will eventually be extractable. The Petrick Commission I understand should report shortly on this very important matter.

The fact is that South Africa's deposits of cheap coal are not inexhaustible and, since coal is a very valuable raw material for the chemical industry, it would not be sensible to rely exclusively on coal for the generation of power - particularly not since South Africa has extensive resources of cheap uranium. In these circumstances, the country is obliged to organise its power supplies and the exploitation of its raw material resources on a long-term basis.

Should the declared objective of a continued economic rate of growth of 5,5 per cent be maintained, an alternative for coal will have to be harnessed for energy production. In the light of the world short= age of crude oil, nuclear power is the only other technology suffi= ciently advanced to add significantly to the energy budget on the short and medium term, even if we have to pay a modest premium over the cost of conventional power. It takes six or seven years to build a nuclear power station even with enhanced reactor construction capability. In South Africa the first nuclear power reactor of the twin unit station is planned for on-line service in 1983, with the second unit in 1984 at Duinefontein, across the Bay from Cape Town. Escom forecasts for nuclear and fossil fuel are given in Table 1. And this leads me naturally to a consideration of the estimates of the present and future demand, reserves and availability of nuclear fuel, measured against forecasts of energy demand in the western world.

3. URANIUM RESERVES

The free world had at its command (August 1973) as shown in Table 2 reasonably assured resources of 1 126 thousand tons uranium concen= trate (U_3O_8) that can be mined at a cost of less than $10 per pound ($22 per kg), In the category estimated additional resources there is a further one million tons which can possibly also be made available at a cost of less than $10 per pound.

As a matter of interest details of South Africa's uranium reserves are shown in Table 3.

These figures, although the latest available, are very dated already. There is no $10 per pound uranium available on the market any longer. The Secretariat of the International Atomic Energy Agency, Vienna, has convened a Joint meeting with the Nuclear Energy Agency, Paris in June 1975 in Vienna of its member States to prepare new estimates in the light of the new energy situation. The new report shall aim to be as comprehensive, authorative and broadly based as possible. World resources of uranium shall be estimated in the cost ranges 15 US $/lb and 15 - 30 US $/lb U_3O_8 for the categories Reasonably Assured and Estimated Additional. Of the existing $10 reserves the USA with 29,9 %, South Africa with 23,3 % and Canada with 21,4 % have led the world. Since the last estimates were made, however, Australia has announced reserves of approximately the same order.

Although South Africa with its large coal and uranium reserves commands a strong position in the marketting arena, there is no room for complacency. The demand for both fuels promises to rise sharply and we should prepare now to meet that demand.

4. WORLD ENERGY FORECAST

In a world-wide context it would appear that in the short term (i.e. until 1985 ±), the share of electrical energy from nuclear sources will remain modest, but that the prospects of development after that time could have a significant effect on the prices of conventional fuels. Competition would therefore continue between nuclear energy and the other forms of energy currently produced.

The most reliable forecast of nuclear electric generating capacity required by the western world, which is based on conservative assumptions of population growth and energy consumption by the ERDA, is shown in Figure 4.

Table 4 illustrates the relatively small role of nuclear generated electric power up to 1980.

The status of the nuclear power industry in the United States of America on 24 January 1975 was:

	MWe
56 plants with operating licences	37,536
63 plants with construction permits	64,369
100 plants on order	112,186
17 letters of intent/options	19,082
	233,173 MWe

A total of 233 gigawatt.

5. URANIUM REQUIREMENTS

A nuclear plant can be expected to operate for at least 30 years and the life time requirements of a 1 000 megawatt reactor will range between 4 000 to 6 000 short tons U_3O_8 depending on the type of reactor. The United States alone would require a lifetime uranium requirement of between 900 000 and 1 344 000 short tons U_3O_8. The rest of the Free World combined would require about as much. A total amount therefore of between one billion 800 thousand and two billion 688 thousand short tons U_3O_8. This is more than twice the existing world reserves of uranium. Since this estimate does not allow for future growth and is based only on plant capacity already committed it stands to reason that estimates of total uranium re= quirements would be very much higher.

Accepting that the uranium industry, on a world basis, should main= tain an eight year forward reserve, it is estimated that cumulative requirements will exceed assured uranium reserves, by around 1979. As the forecasts of uranium requirements until the end of the present century show, very large and increasing annual demand for uranium are expected from the mid-1970's onwards. Owing to an overly optimistic projection of the completion dates of nuclear power plants, uranium production has exceed demand and heavy stocks, estimated at around 100 000 short U_3O_8 have been accumulated by both producer and consumer. In spite of this and of significant new discoveries in South West Africa and Australia the oversupply situation of uranium started to change dramatically in October 1973 and uranium prices have since more than doubled.

A 1973 World Survey by the Joint NEA/IAEA Working Party on "Uranium Resources, Production and Demand" Figure 5, indicates that from a present production level of just over 19 000 tonnes uranium per year the demand will rise to be equivalent of an annual production re= quirement of 50 000 tonnes uranium by 1980, 100 000 by 1985 and 180 000 by 1990. New reserves of over one and a half million tonnes of low cost uranium should be proven before 1992 to satisfy consumer demands up to the end of the century, i.e. more than 75,000 t. per year over next 20 years. Measured in terms of rands (an estimated three to four thousand million), the exploration challenge is staggering. In view of the lead-times associated with exploration and development of new reserves, the fact that renewed effords to intensify exploration rates should be made very soon cannot be over emphasized. Indeed few, if any, mineral pro= duction industries have been called upon to plan for a near tenfold in= crease in production in a space of about 15 years as these forecasts imply. This might possibly mean that, perhaps, ten times the present number of uranium mines will have to be planned and engineered by 1990.

Other projections are even higher and for the 21st century nuclear power requirements of 3,5 million tons uranium for the year 2000 and as much as 10 - 12 million tons by the years 2020/2030 are forecast.

The question is how to achieve the required increase in the rate of discovery of uranium to satisfy the most likely demand forecasts. The present exploration effort throughout the world is not increasing suf= ficiently to attain this objective.

6. URANIUM PRODUCTION CAPABILITY

The availability of uranium resources is dependent on exploration effort, development and mill capacity.

6.1 South Africa

Production of uranium in South Africa is limited to the Republic. There are approx. 50 gold mines within the Witwatersrand Supergroup, of which at least 17 are thought capable of supporting uranium production, but of which only 7 are producing uranium at present.

The approximate capacity of existing extraction plants on the Witwatersrand amounts to 3 550 metric tons U_3O_8 per annum.

The refining capacity of the plant of the Nuclear Fuels Corporation is approximately 6 000 tonnes U_3O_8 per annum and the current production rate is approximately 3 100 tonnes U_3O_8 per annum.

As U_3O_8 is produced as a by-product of gold, limiting factors are the price of gold and the attendant production-rate of gold. The industry is, however, poised for a rapid expansion of production whenever prospects improve. The new plant at President Brand is ready to commence production at short notice. Certain gold mines have also been planning to erect plants and start production as soon as it becomes economically feasible. In the meantime residual slimes from the gold-producing plants are continuously sampled, and those with the higher U_3O_8 content are stored on separate slimes dams in such a way as to facilitate reclamation for treatment at some future date. Furthermore, research is being directed into improved methods of extracting low-grade uranium from newly mined ores, and possibly even from tailing dumps and slimes dams. The latter possibility may well prove economical within a few years, but firm assumptions of future production rates, based on this contingency, are at present not possible as a great deal depends on rising price trends.

The Palabora Mining Company has installed a plant to extract small tonnages of uranium and badeleyite from the final concentrator tailings at its copper mining complex in Transvaal. Estimated production is of the order of 100 tons uranium annually.

Exploitation of the large low-grade uranium deposit at Rössing in South West Africa is planned to commence in 1978.

6.2 Free World

As shown in Figure 6 actual production of uranium in the Free World in 1972 was of the order of 25 000 short tons U_3O_8. Capacity now is estimated at 40 000 short tons.

It is expected that demand will catch up with supply around 1978 and that to meet the estimated subsequent increased demand it has already became necessary to construct additional mill capacities for 10 000 to 14 000 tons of uranium to be commissioned in 1976 to 1978, when demand will exceed supply. Uranium has and will almost certainly continue to have the fastest demand growth rate of any mineral commodity.

The total potential production capability of currently operating mines and new deposits now being developed towards production is estimated to range between 45 000 and 60 000 tons a year. This total is fairly definite and could not be easily increased, yet the yearly increase of the various demand estimates falls somewhere between 17 and 22 % for at least the next 15 years.

Although the free world is evidently heading for a uranium shortage the uncertain element in this field is the production that is possible from the known but undeveloped occurrences. The tendency here is usually to over-estimate the possible production capability and underestimate the time it takes to achieve production. To get new capacity on stream is not a simple matter but experience has shown it takes about eight years from the start of a successful exploration program to get a new uranium mine and mill into production.

Naturally, South Africa's large uranium reserves place the country in a strong position in the uranium market, but there is certainly no room for complacency. In view of the fact that the demand for uranium has already increased sharply, the South African industry, which has been built up on a sound foundation over the years, will have to make a concerted effort to ensure that no single kilogram of uranium goes to waste in such a manner that its recovery at a later date would prove uneconomical. Furthermore, South Africa must intensify its program of exploration and must give far greater definition to this program than is at present the case. It may be of interest to know that of the 12 companies now prospecting for uranium in the Karoo only three are South African.

Two technological developments tend to limit the increasing demand in the course of time. The one concerns the recycling of the synthetically produced nuclear fuel plutonium and the other the development of fast breeder reactors.

7. IMPACT OF BREEDER REACTORS AND OF PLUTONIUM

7.1 Breeder Reactors

It is important to note that the concept of the breeder is not new and has been nurtured from the early formative experimental period in the 1940's on a limited scale, sufficient to demonstrate its technology and basic safety characteristics. Several factors, however, reduced the early prospects of commercial introduction, the foremost of which was the impact of the general acceptance of the light water reactor. Furthermore, the level of breeder development was such as to preclude immediate commercial introduction.

In Europe the United States of America and Russia a lot of work is underway on fast breeders which ultimately is bound to meet with some success. Owing to inherent difficulties of materials and safety, together with reprocessing which may raise serious environmental difficulties, fast breeders will find very stiff competition from the almost universally accepted light water type reactors.

Why then bother with fast breeders? If you do develop fast breeding, you can burn more than one-half of all uranium and thorium found in nature, perhaps something like 80 per cent (against the present burn-up of around 2 per cent). It would then pay to extract uranium from the cheapest source material found at the surface - 'burning the rocks' as stated by Weinberg. Fast breeders can utilize nuclear fuel more efficiently and has the potential of breeding more fuel than it uses. It uses U^{238} as fuel, which is contained in much larger quantities in natural uranium than its fissionable component U^{235}, on which the present day thermal reactors are based.

There is little doubt within the nuclear industry that the breeder reactors will ultimately penetrate and take over the major portion of the heat source market for the generation of electricity. The date of major market penetration is uncertain although it is generally concluded that a significant beginning will occur in the mid-eighties. Studies indicate that by 1990 some 20 to 30 gigawatts of breeder capacity will be available. By the year 2000, this would have increased to several hundred gigawatts.

It remains to be seen whether the fast breeders can be introduced in the above period to exercise a suppressing influence on the increasing demand for uranium for the nuclear power program of the world. The new and involved technology and experience gained from the development of thermal reactors tends to show that the perfecting of the fast breeder technology will in all probability take longer than the enthusiastic nuclear scientists and engineers expect. For this reason lower estimates for the demand for uranium after 1985 remain questionable, since demands for a number of years will probably be higher than indicated by present estimates.

6.2 Plutonium

Plutonium is formed in nuclear power reactors principally through the neutron bombardment of uranium-238. Since most of the commercial nuclear power reactors are fueled with uranium with a low enrichment in uranium-235, the bulk of the uranium contained in the fuel is U-238. The principal plutonium isotope produced is Pu-239, though a number of the other plutonium isotopes are also produced.

Plutonium is useful both as a fuel for current light water reactors and in particular as a fuel for breeder reactors, which are expected to be in commercial use by 1990. Since significant quantities are produced in light water reactors, its use, after recycling, as fuel in light water reactors can have a profound effect on their fuel costs.

One reactor can be refueled exclusively with the plutonium produced each year by about four reactors of the same size. New reactors, however, require more fuel initially - 3 to 4 times the annual replacement requirement.

The recycling of plutonium in the fuel of commercial nuclear power reactors may and probably will have a significant impact upon the future needs for uranium raw material and enrichment services. While the impact of plutonium recycle is very small at the present and will continue to be rather small in the next few years, the recycling of plutonium a decade from now will reduce the amount of uranium and its required separative work by about 14 to 15 per cent. This will enable us to satisfy the expected demand for nuclear fuel while conserving a valuable natural resource and minimizing the amount of expensive separative work capacity required - and it will enable us to do so at reasonable cost.

As far as South Africa is concerned according to the present calculations our predicted reactor installation program will produce only 4,36 tonnes of plutonium by the year 2000 which would be insufficient to fuel a breeder reactor.

7. URANIUM ENRICHMENT

Today enriched uranium is the cornerstone of the peaceful application of nuclear energy in the world. Enriched uranium is the fuel for most nuclear power stations - in the same way as coal, oil and natural gas are the fuels for most of the conventional power stations.

The provision of adequate power is indispensable for the preservation and further improvement of mankind's standard of living, and nuclear energy will play an increasing part in meeting the ever-expanding demand for electricity. For this reason there will be a growing demand for enriched uranium and it is self evident that South Africa, as a large uranium producing country, has a strongly motivated interest in the production of enriched uranium.

In addition it must be taken into account that South Africa is standing on the threshold of a fairly large power program of her own - some 10 gigawatt up to the end of the century. If this program could in part be based on enriched uranium it would effect tremendous capital savings, but only if South Africa is assured of a guaranteed availability of enriched uranium which implies local production.

It is well known that a number of countries are carrying out research and development work in the field of uranium enrichment, i.e. to process uranium to its most sophisticated form. In many countries this work is being done without their having the motivation of an own uranium production, which South Africa has in no small measure. It is therefore obvious that we should concern ourselves with this subject since South Africa, as one of the largest uranium producing countries in the world, would find it in its own interest to market uranium in the enriched form.

The Prime Minister announced on 20 July 1970 that South Africa had developed a new process for the enrichment of uranium and was busy building a pilot plant. It was at that time the fourth country in the western world, next to the USA, England and France, that had lauched such an undertaking. The country undertook this work to pave the way for the ultimate marketing of its large uranium sources in a refined form and to contribute towards the scientific and technological developments of the world, particularly since South Africa had received so much from the world in this connection.

You are all aware of the pilot plant now in the course of erection at Pelindaba. The Government has approved funds for the necessary preparatory design and feasibility study (technical and economic) of a commercial scale plant based on the South African process.

The importance of this can be judged when we refer back to Figure 4 giving the forecast by the USAEC for nuclear generated electricity to the year 2000. On the conservative assumption that ninety per cent of this nuclear power capacity will be based on enriched uranium it means that the requirements for enriched uranium for power generating purposes alone will increase from 2 500 tons separative work for the year 1970 to 44 000 tons for 1980 and 300 000 tons for 1990. The cumulative demand for enriched uranium alone up to the end of 1980 is estimated at 220 000 tons of separative work.

8. EXPLORATION

I now come to the second part of my address which deals with the South African uranium situation, exploration currently underway and some recommendations.

There is only one conceivable and practical way out of our energy delemma - make the greatest use of what we have the most of, uranium and coal. We have to use what we have; we don't have time to rely on things that are yet to be proved such as fusion, solar energy, wind, etc.

A fundamental requirement to any exploration effort is the knowledge and understanding of how uranium ore deposits are formed. Greater knowledge of the chemical, mineralogical and geological controls and of the concepts of regional, tectonic, lithological and geochemical distribution of uranium, which contribute to the genesis and formation of ore deposits would be a bsic contribution to exploration planning.

As there may already be some geological limitations to further extensive discoveries in the current principal uranium producing countries, future exploration may turn more and more to developing countries, where many potentially favourable areas remain to be explored. It should be borne in mind, however, that unit power cost in nuclear systems is not very sensitive to nuclear fuel costs in any significant degree, with the result that exploitation of uranium in the higher price ranges could become a feasible proposition. We would do well in the present circumstances to look carefully at any deposit, no matter how low the grade and determine whether it could have future potential at a much higher cost.

In South Africa over the past decade prospecting operations largely centred about the following three areas:-

1. Quartz-pebble conglomerates contained within the Witwatersrand Supergroup

2. The Beaufort Group of the Karoo Supergroup

3. The western part of the Damara Orogenic Belt in South West Africa east of Swakopmund

8.1 Quartz-pebble Conglomerates

Uranium is a by-product of gold mining and it stands to reason that the entire industry is geared to the maximum production of its principal product - gold. Conglomerate reefs selected for development are those with the highest gold values, with uranium content scarcely being taken into account, especially over the past decade when there was practically no demand for it and the price of gold sky high.

Viewed in the context of the large number of quartz-pebble conglomerate reefs present in the Witwatersrand Supergroup, there is a distinct possibility that potentially viable uranium-rich reefs may exist in present-day and/or abandoned gold mines, which have been overlooked because emphasis for so many years has been on maximum gold production and extraction.

In the exploration for gold, many thousands of boreholes have been drilled in the course of time, many of which are still in existence. A limited number of these boreholes were logged radiometrically, either by the mining companies concerned (the minority) or the Geological Unit of the Atomic Energy Board which was in existence from 1952 to 1958. These logs are filed with the Geological Survey in Pretoria. They are in the form of analogs, and a computer program has been developed, whereby they can be evaluated to give printouts in the form of uranium values. Information derived from such boreholes, grouped on a regional or mine-to-mine basis, should also be taken into account by the new computer program now being developed to assess the uranium reserves of the Witwatersrand Supergroup.

If this data proves to be of value, consideration should be given to radiometrical logging of the large number of boreholes not yet probed on the many existing and abandoned gold-mines within the Witwatersrand Supergroup.

8.2 <u>Karoo Supergroup</u>

Over the past three years a considerable number of occurrences of uranium mineralisation of variable grades have been discovered in the area around Beaufort West, Cape Province. Since the original discovery, similar-type uranium mineralisation has been discovered in the lower members of the Karoo Supergroup as far afield as Marble Hall, the Waterberg coal-field, northern Natal and the Orange-Fish tunnel in South Africa; the Kaokoveld and Gibeon districts in South West Africa and also Angola.

Up to the present these new discoveries of uranium mineralisation are confined to the Lower Formation of the Beaufort Group, which is formed by a succession of alternating sandstone, shale, and mudstone over the next few decades and uranium and other nuclear fuels will increasingly be employed.

beds with cherty lenses aligned along certain zones. A striking feature is the irregularities in the bedding with the result that a particular lithological unit can seldom be traced for more than a few kilometres. Uranium mineralisation is most often associated with deposits formed along erosion channels and washouts. Clay pellet conglomerate lenses, fragments of clay, rolled pieces of bone and major carbon trash accumulations are common. This may be either fossil flora, fossilised bones or carbonaceous material. No known geological reasons exist, however, why similar discoveries should not also be made in some of the other members.

No attempt was made to evaluate the resources of the newly discovered uranium deposits in the Karoo Supergroup since the exploration and investigations undertaken to date are still regarded as inadequate and it is too early to predict their significance and true potential. Drilling programmes are in progress and from the limited information available, it would appear that they are mainly shallow, flat lying deposits.

Our geologic knowledge tells us that there is good reason to expect we will find like deposits in those areas similar to those already discovered, but any attempt to quantify the potential of these undiscovered resources on the basis of the extent of unexplored but favourable ground will at this stage amount to guesswork. Also, our ideas of what is conceivably discoverable and producible will surely change with development of new knowledge about the origin and occurrence of uranium in the Karoo, and advances in mineral recovery, extraction metallurgy and use technology.

Airborne radiometric surveys proved the presence of a large number of individual anomalies. Many of these have been actively explored on the ground by trenching and drilling. Although close to the surface (within 30 m) deposits are relatively small and not individually viable; however, collectively they could perhaps eventually be exploited from a centrally situated plants, provided there are enough to them within a given area.

8.3 <u>Western Part of the Damara Orogenic Belt</u>

The western part of the Damara Orogenic Belt is built by highly folded, metamorphosed and partially granitized Precambrian rocks and is characterized by an extremely variable stratigraphy. It of electricity in South Africa goes back as far as 1882 when Kimberley received street lighting - three years before London and only three years after Edison opened New York's first power station.

comprises a large number of geological formations belonging to the Khomas and Hakos Groups of the Damara Supergroup, the Nosib Group and the Abbabis Group. The most common rocks are different types of quartz and feldspar-rich biotite-bearing metasediments (schists and gneisses), crystalline marble, calc-silicate rocks and quartzite.

One of the most outstanding features of the area is the abundance of pegmatites in certain formations although some more homogeneous rocks units are largely devoid of them. The pegmatites containing uranium occur in a high grade metamorphic environment, where they have intruded gneisses, migmatites, amphibolites, limestones and various reconstituted sedimentary rocks. In certain areas such as Rössing these rocks have been so intensively intruded by pegmatite that they now occur as xenoliths of varying size scattered throughout the intrusive pegmatite. As the latter is predominantly a quartz, alkali-feldspar rock it has locally been termed alaskite.

Very large grant areas have been under active investigation over the past two years and extensive geological and radiometric surveys, coupled with wagon drilling were undertaken in a number of selected target areas. Investigations covered uranium mineralisation both in surficial calcrete deposits and in alaskitic-type rocks similar to those of Rössing. Although some promising areas which appear to have potential are under active investigation, information of the investigation available at this stage is insufficient to permit an assessment of the real economic potential of the respective areas to be made.

As an aerial gamma-ray spectrometric survey remains the most powerful tool for tracing new deposits of radioactive material, an area of approximately 25 000 km^2 north and east of Rössing was covered at a line spacing of 1 000 m and a ground clearance of 150 m. The survey revealed a number of new radioactivity anomalies. On the ground, the origin of the radioactivity was traced to the presence of different secondary uranium minerals in various types of host rock such as calcrete, recemented surface material and the weathered zone of different basement rocks. The uranium occurs as easily leachable secondary uranium minerals such as beta-uranophane, metatorbernite, carnotite and gummite, derived from primary uraninite associated with intrusive alaskite present in the different types of country rocks.

country is obliged to organise its power supplies and the exploitation of its raw material resources on a long-term basis.

Evaluation of the available data indicated that the maximum of useful information had not been extracted from the recorded information. Following digitisation and computer processing of airborne radiometric data, additional uranium anomalies were identified.

9. CHARACTERISTICS AND CRITERIA THAT HAVE A BEARING ON URANIUM MINERALISATION IN VARIOUS FORMATIONS IN SOUTH AFRICA

I come now to the final part of my address in which certain characteristics and criteria that have a bearing on uranium mineralisation and exploration in rocks of the Witwatersrand, the Ventersdorp, and the Transvaal Supergroups, are reviewed.

I am going to be very brief and list only some of these criteria. Those of you interested enough may refer to the published address for further details.

9.1 The Witwatersrand Supergroup

There is a readily available and extensive literature extent on the Witwatersrand Supergroup. The gold-bearing formations of this Supergroup have in addition been sampled for gold and uranium more fully and systematically than any other group of mineral deposits in the world. That being the case this description confines itself to a statement of approximately 25 characteristics and criteria which may have a bearing on and which could possibly be applied to help locate further deposits of uranium in the Witwatersrand Supergroup. Some of these criteria are:-

1. The ratio of uranium to gold
2. Implications of cogenetic relationship of uranium to gold
3. Distribution of payable concentrations of gold and uranium
4. Form of ore bodies
5. Confines of mineralisation
6. Relationship to sedimentary features
7. Effects of disconformities and weathering of bed rocks
8. Faulting
9. Uranium cycles
10. Average uranium content of the Witwatersrand Supergroup and of source rocks

Australia has announced reserves of approximately the same order.

Likewise some observations on the possibilities of uranium mineralisation in the Ventersdorp Contact Reef are recorded; consideration is given to the uranium mineralisation in pebble conglomerates in the Black Reef Group in the Kaapse Hoop and Northam areas; and the possibilities of uranium in intrusive pipes other than Palabora such as Tweerivier, Glenover, Pilanesberg and Ondurakorume are reviewed.

10. CONCLUSION

In the time at my disposal I have attempted to sketch a picture of nuclear energy in terms of a few important developments as it affects South Africa and its possible future as a supplier of uranium fuel to the western world.

In spite of increased exploration activity, increases in proven reserves of uranium have been modest (except in Australia) and no important new regions of potential uranium production have came to light.

Long-term planning has become a matter of the greatest importance with regard to uranium exploration, exploitation and recovery, and this to a far greater degree than ever before.

existing world reserves of uranium. Since this estimate does not

TABLE 1

INSTALLED ELECTRICAL (MW) CAPACITY FORECASTS

YEAR	APPROXIMATE INSTALLED CAPACITY - MW	NUCLEAR INSTALLED CAPACITY	
		MW	Percentage of total
1985	25 000	2 000	8
1990	37 000	3 000	8
1995	54 000	5 000	9
2000	79 000	10 000	13

TABLE 2

ESTIMATED WORLD RESOURCES OF URANIUM
(DATA AVAILABLE 1 JAN. 1973)
(X 10^3)

Type of Resources / Country	PRICE RANGE <$10/lb U_3O_8				PRICE RANGE $10-15/lb U_3O_8			
	Reasonably Assured		Estimated Additional		Reasonably Assured		Estimated Additional	
	Tonnes U	S. tons U_3O_8	Tonnes U	S. tons U_3O_8	Tonnes U	S. tons U_3O_8	Tonnes U	S. tons U_3O_8
U.S.A.	259	337	538	700	141	183	231	300
SOUTH AFRICA	202	263	8	10,4	62	80,6	26	33,8
CANADA	185	241	190	247	122	158	219	284
AUSTRALIA	71	92	78,5	102	29,5	38,3	29	38
OTHERS	149	193	104,5	131,6	325,5	424,1	127	165,2
TOTAL (ROUNDED)	866	1126	916	1191	680	884	632	621

TABLE 3

SUMMARY: ESTIMATED RESOURCES OF URANIUM ($\times 10^3$)

	Tonnes U		Total	Sh. tons U_3O_8		Total
	< $10	$10 - 15		< $10	$10 - 15	
Reasonably Assured	202	62	264	262.6	80.6	343.2
Estimated Additional	8	26	34	10.4	33.8	44.2
Total	210	88	298	273	114.4	387.4

TABLE 4

ELECTRIC GENERATING CAPACITY
(Gigawatt)

YEAR	U S A		FREE WORLD		T O T A L		COMMUNIST
	Installed	Nuclear	Installed	Nuclear	Installed	Nuclear	Nuclear
1972	398	14,7 (3,7%)	452	18 (4%)	850	32,7 (3,85%)	2,5
1980	1 158	132 (11,4%)	942	140 (14,8%)	2 100	272 (13,1%)	
1985		280	2	303		583	
2000		1 200		1 460		2 660	600

have to make a concerted effort to ensure that no single kilogram of uranium goes to waste in such a manner that its recovery at a later date would prove uneconomical. Furthermore, South Africa must intensify its program of exploration and must give far greater

There is little doubt within the nuclear industry that the breeder reactors will ultimately penetrate and take over the major portion of the heat source market for the generation of electricity. The

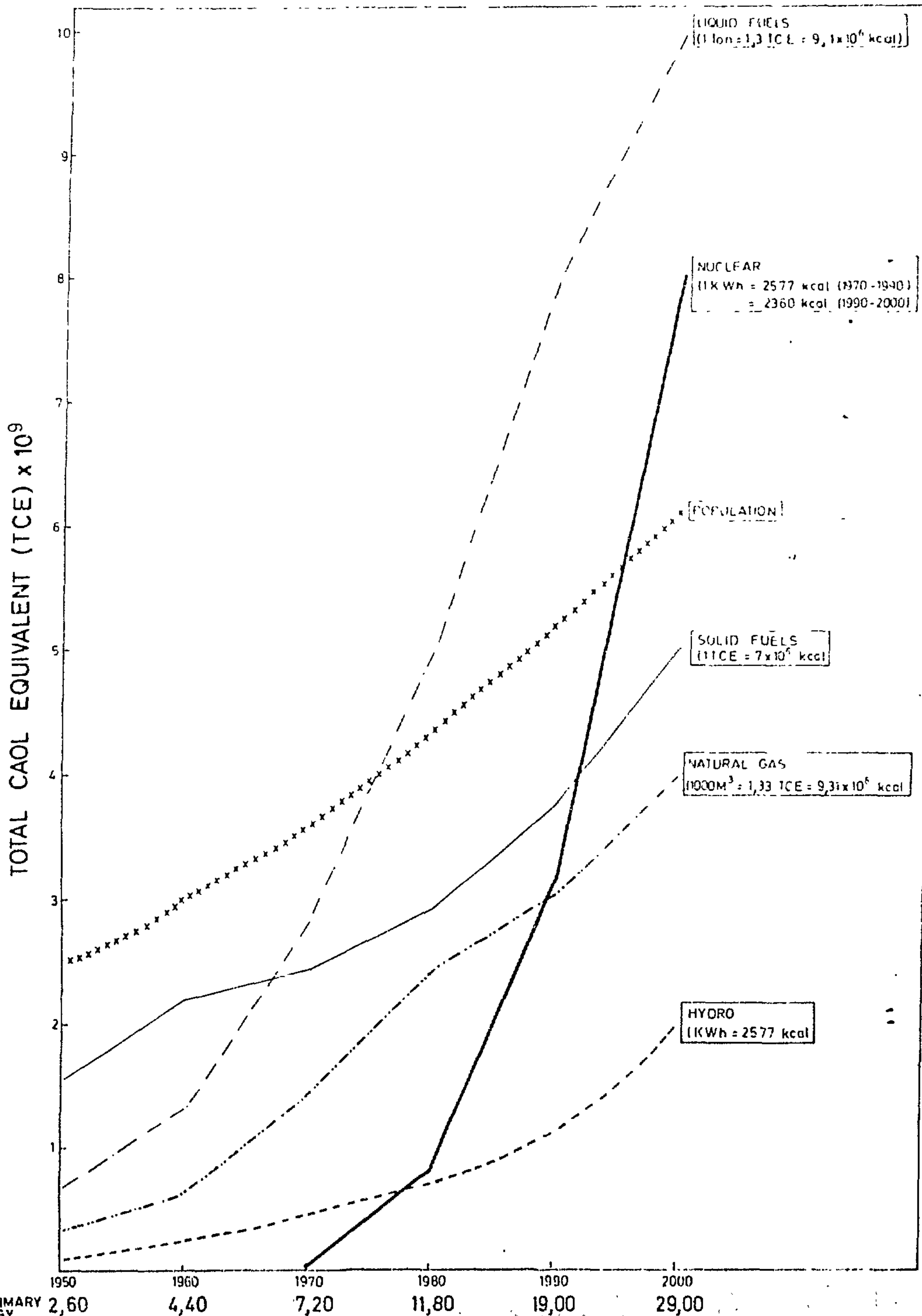

FIG. 1. POPULATION AND USE OF PRIMARY ENERGY - PAST AND PRESENT

future needs for uranium raw material and ...

While the impact of plutonium recycle is very small at the present and will continue to be rather small in the next few years, the

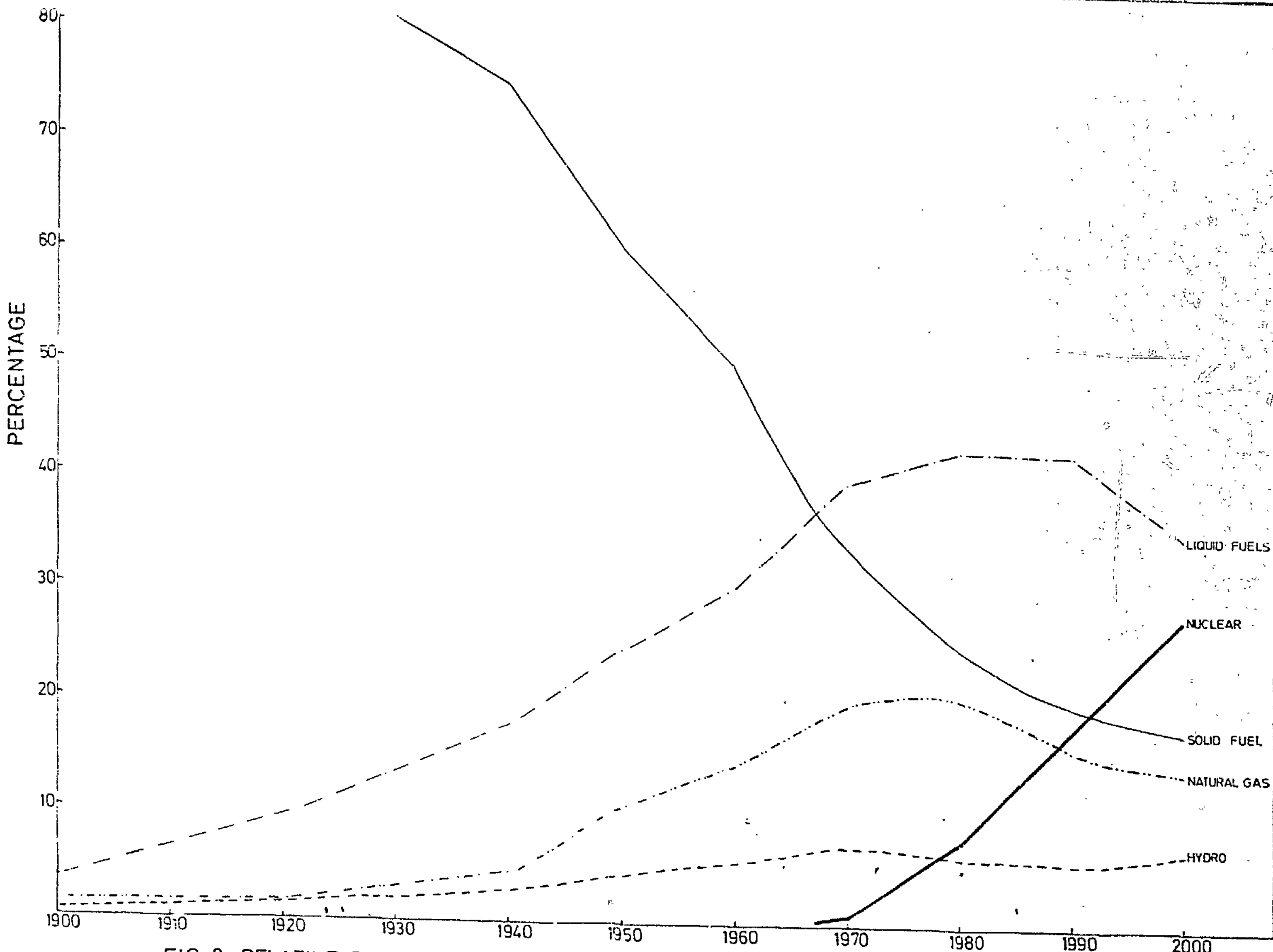

FIG 2 RELATIVE SHARE (IN PERCENTAGE) OF PRIMARY FUELS - ACTUAL AND PROJECTED

vation of an own uranium production, which South Africa has in no
small measure. It is therefore obvious that we should concern-
ourselves with this subject since South Africa, as one of the

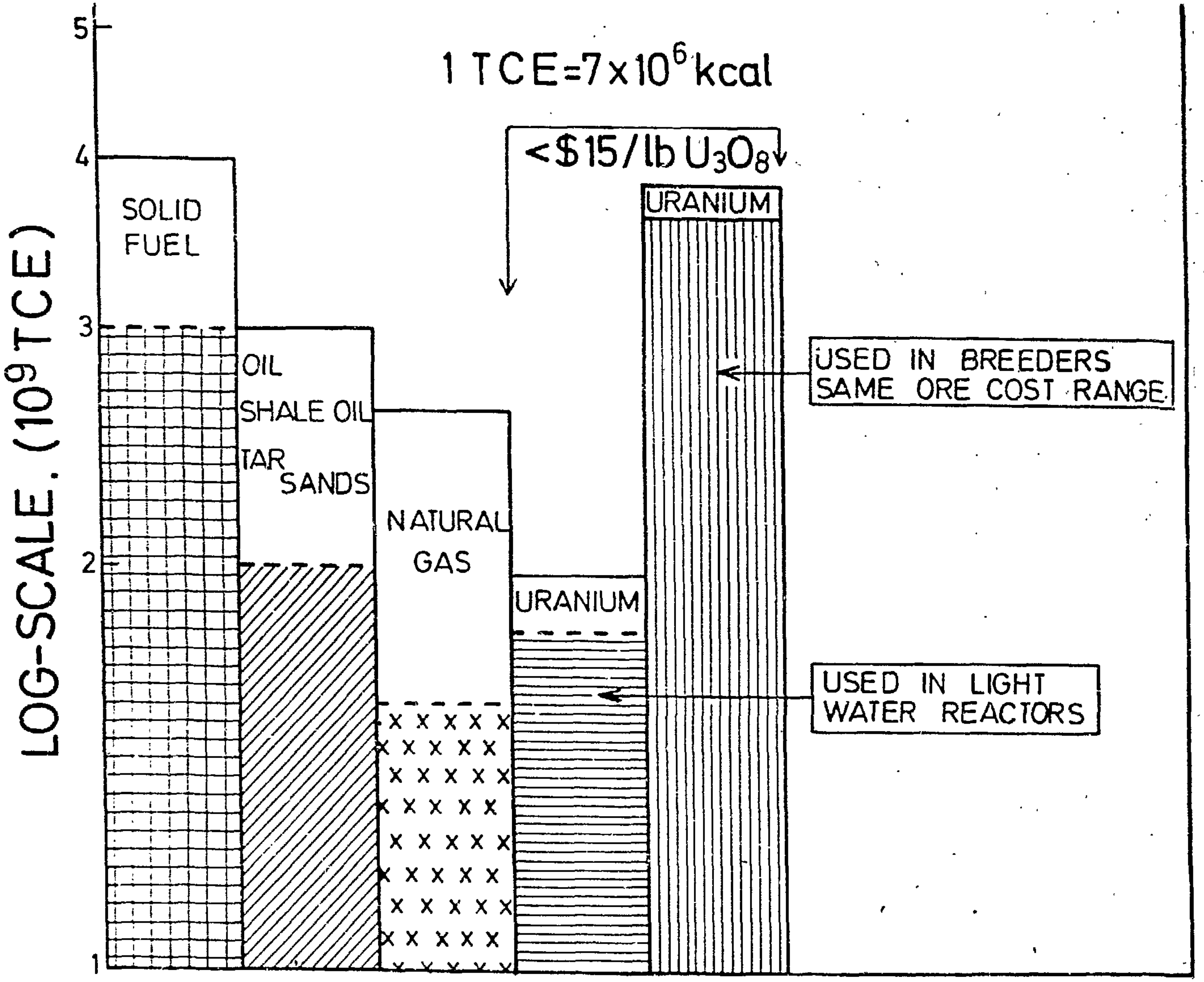

FIG. 3. ESTIMATES OF WORLD ENERGY RESOURCES

wind, etc.

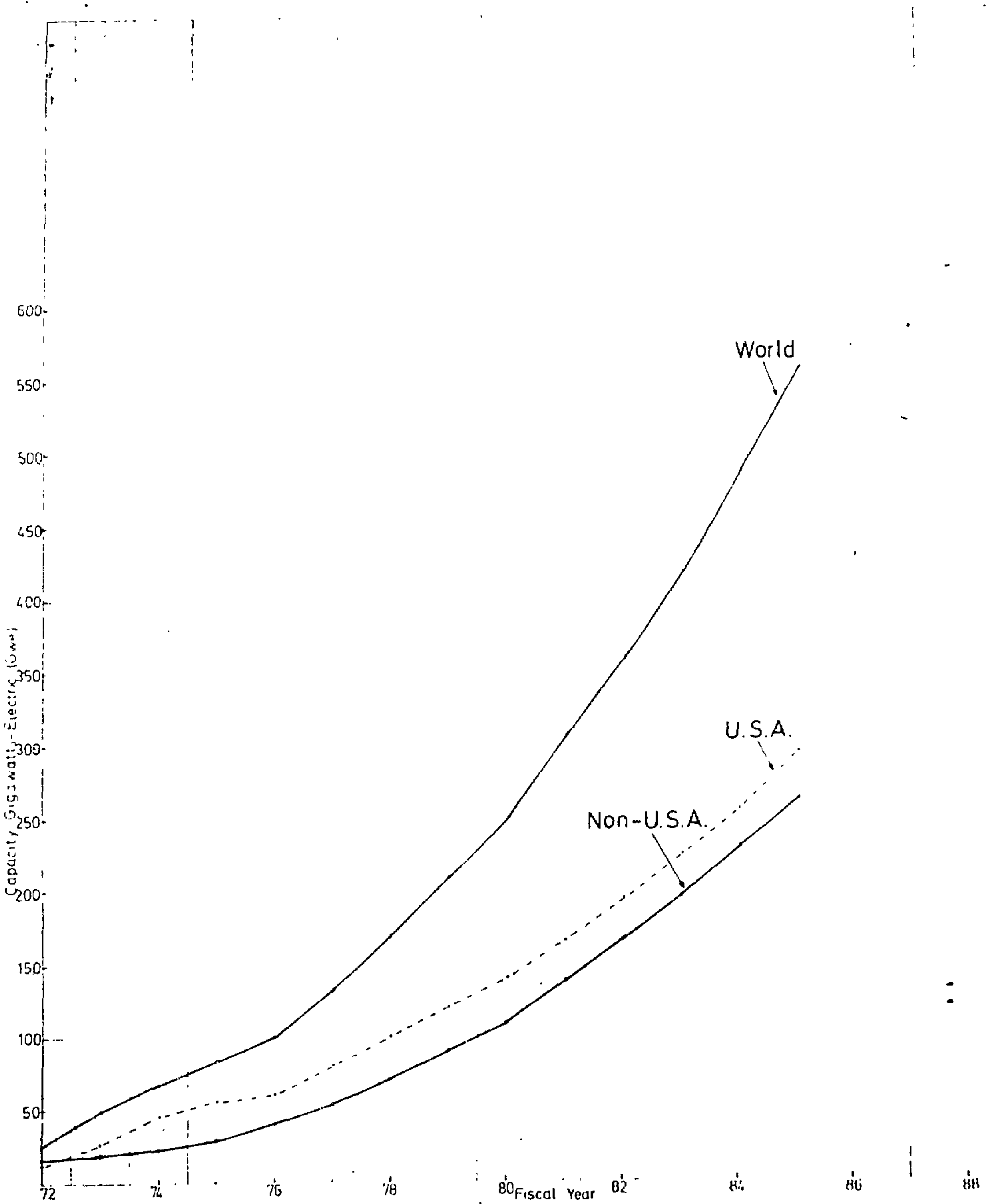

FIGURE 4: Forecast of Nuclear Capacity

sky high.

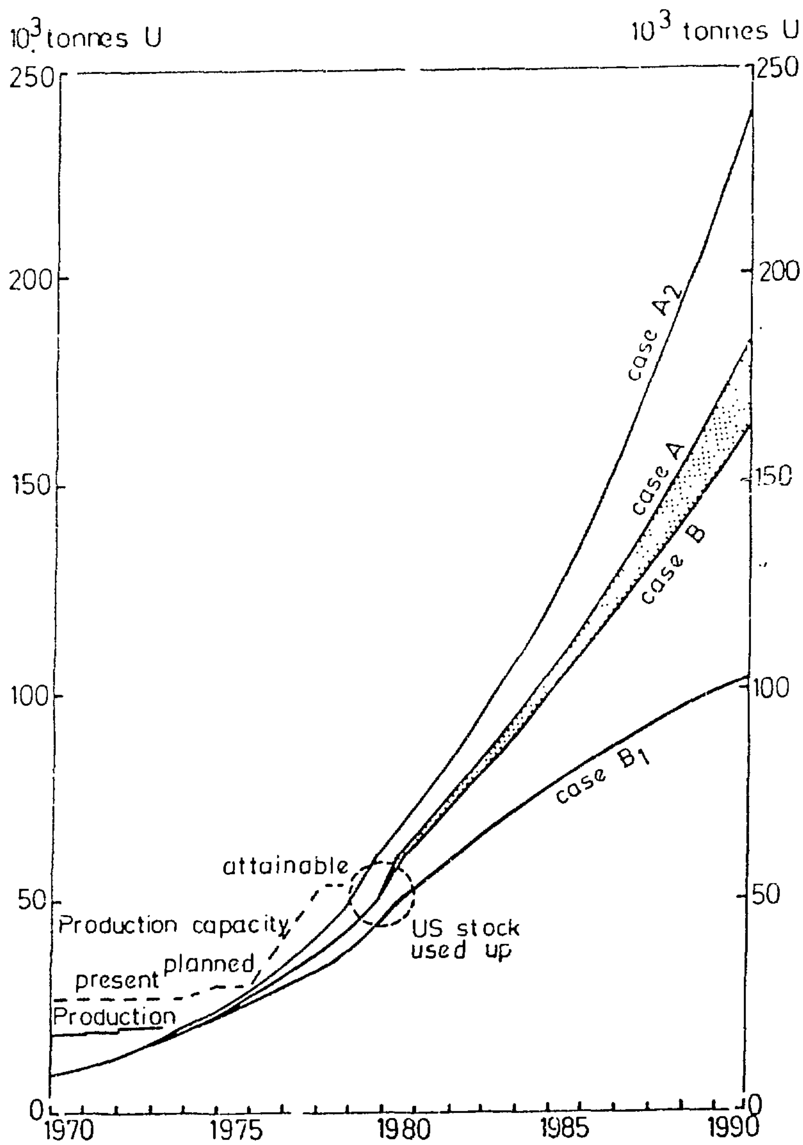

FIG. 5. ANNUAL WORLD URANIUM REQUIREMENTS

formed by a succession of alternating sandstone, shale, and mudstone

FIGURE 6

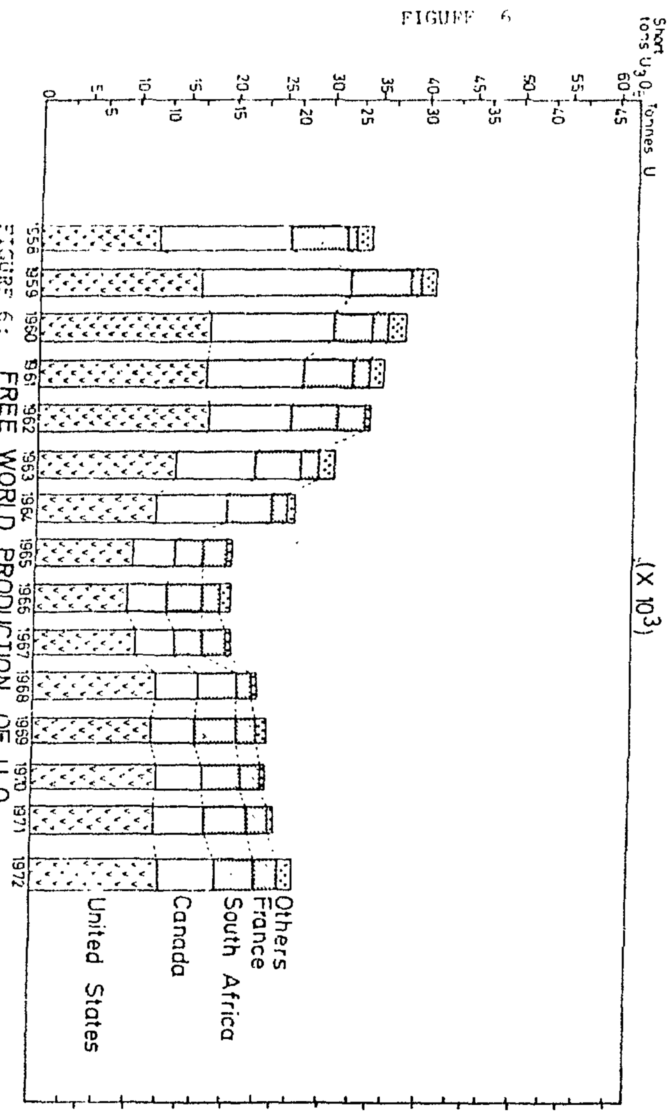

FIGURE 6 : FREE WORLD PRODUCTION OF U_3O_8