URANIUM RESOURCES, DEMAND AND PRODUCTION

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I. OVERVIEW

The industrialized countries presently consume 80% of the world's oil production and yet they possess only 20% of its proven reserves. Due to the oil crisis of the '70s, it has been demonstrated that the economies of these countries are vulnerable to increases in price, or reduction in supply of the oil they import. Many countries have already recognized, for their own energy security and sustained economic growth, the need to replaced imported oil by other energy sources. Nuclear power is economically and strategically an attractive option, especially in countries without significant domestic energy resources.

Following the Venice Summit in June 1980, leaders of the seven major industrial countries of the WOCA(1) area, agreed on the need "to break the link between oil consumption and economic growth". The agreed target was the relative reduction in contribution of the oil component to total energy consumption. This would be achieved by increasing the consumption of coal, expanding the role of nuclear energy, and accelerating the development of synthetic fuels and other alternative energy sources. This policy has since been embraced by many other goverments, outside the seven major WOCA's industrilized countries.

In this regard, in the present speech emphasis has been placed on the resource aspects of uranium supply, although attention has also been devoted on projection of production capabilities from resources in the principal resource categories. In lesser detail, demand projections should also be considered.

The immediate outlook for the uranium industry is one of oversupply rather than of potential shortage. Following the oil crisis of the early '70s, utilities and their agents contracted for greatly increased uranium supplies to meet the needs of nuclear programmes then envisaged. For a number of reasons, principally the world-wide slowdown of economic growth, this demand has failed to materialize. As a result, more uranium is being

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(1)WOCA = World Outside the Centrally Planned Economic Area.

produced than is being consumed and this situation may continue for some time.

The uranium industry is reacting to the present situation in seve ral ways. In the absence of a market for their product, some mines (mainly those with higher cost of production) have been closed down, particulary in the USA. Some other producers are reducing their output and reducing their production costs by increasing their cut-off grade, by selectively mining the higher grade parts of their deposits, or by producing from their ore stockpiles. These measures will help to bring supply and demand into balance, which is in the long term interest of both sides of the industry. One possible consequence of these trends, however, is that resources left in the ground now, during the extraction of the higher-grade material, may not be recoverable in the future because they could become too costly to exploit.

Another reaction to the over-supply situation is goverment industry cut-backs in uranium prospecting and exploration programmes, which could have a significant effect on the rate of addition to RAR (Reasonable Assured Resources) in the near future. However, this may be partly offset by continued commitment to exploration on the part of consumers seeking to ensure that their longer term requirements are met.

II. URANIUM RESOURCES

II.1. URANIUM RESOURCE BASIC-DATA

Estimations of the WOCA uranium resources are periodically analysed (normaly every two years) by a joint "NEA/IAEA Working Party on Uranium Resources" and the corresponding results are published by the OECD (Organization for Economic Co-operation and Development) in the well known "Uranium Resources, Production and Demand", commonly known as the "Red Book", with editions in 1965, 1967, 1969, 1970, 1973, 1975, 1977, 1982 and 1983.

The aforesaid analysis is performed on the basis of data provided by national authorities in a special questionaire sent to all member-states of the two involved organizations (OECD and IAEA).

II.2. URANIUM RESOURCE CATEGORIES

Resource estimates are divided into separate categories reflecting different levels of confidence in the quantities reported. The resources are further separated into categories based on the cost of production (TABLE I). Resources estimates in the "Red Book" are presently expressed only in terms of metric tons (tonnes) of uranium (U), but some years ago they were also indicated in short tons or U_3O_8 (see point II.3.)

II.2.1. Definition of Resource Categories

II.2.1.1. Reasonably Assured Resources (RAR), refers to uranium that occurs in known mineral deposits of such size, grade and configuration that it could be recovered within the given production cost ranges, with currently proven mining and processing technology. Estimates of tonnage and grade are based on specific sample data and measurements of the deposits, and on knowledge of deposit characteristics. Reasonably Assured Resources have a high assurance of existence and in the cost category below U$S 80/kg U are considered as reserves.

II.2.1.2. Estimates Additional Resources-Category I (EAR-I), refers to uranium in addition to RAR that is expected to occur, mostly on the basis of direct geological evidence, in extensions of well-explored deposits, and in in which geological continuity has been established but where specific data and measurements of the deposits and knowledge of the deposits characteristics are considered to be inadequate to classify the resource as RAR. Such deposits can be delineated and the uranium subsequently recovered, all within the given cost ranges. Estimates of tonnage and grade are based on sampling as in available and on knowledge of the deposit characteristics as determined in the best known parts of the deposit or in similar deposits. Less reliance can be placed on the estimates in this category than on those for RAR.

II.2.1.3. Estimated Additional Resources-Category II (AER-II), refers to uranium in addition to EAR-I that is expected to occur in deposits believed to exist in well-defined geological trends or areas of mineralization with known deposits. Such deposits can be discovered, delineated and the uranium subsequently recovered, all within the given cost ranges. Estimates of tonnage and grade are based primarily on knowledge of deposit characteristics in known deposits within the respective trends or areas and on such sampling, geological, geophysical or geochemical evidence as may be available. Much less reliance can be placed on the estimateds in this category than those for AER-I.

TABLE I

NEA/IAEA CLASSIFICATION SCHEME FOR URANIUM RESOURCES

EXPLOITABLE AT COSTS				
$ 130 to $ 260 / kg U	REASONABLY ASSURED RESOURCES	ESTIMATED ADDITIONAL RESOURCES I	ESTIMATED ADDITIONAL RESOURCES II	SPECULATIVE RESOURCES
$ 80 - $ 130 / kg U	REASONABLY ASSURED RESOURCES	ESTIMATED ADDITIONAL RESOURCES I	ESTIMATED ADDITIONAL RESOURCES II	SPECULATIVE RESOURCES
up to $ 80 / kg U	REASONABLY ASSURED RESOURCES RESERVES	ESTIMATED ADDITIONAL RESOURCES I	ESTIMATED ADDITIONAL RESOURCES II	

DECREASING CONFIDENCE IN ESTIMATES →

II.2.1.4. Speculative Resources (SR), refers to uranium, in addition to Estimated Additional Resources-Category II, that is though to exist mostly on the basis of indirect evidence and geological extrapolations, in deposits discoverable with existing exploration techniques. The location of deposits envisaged in this category could generally be specified only as being somewhere within a given region or geological trend. As the term implies, the existence and size of such resources are highly speculative but not objective.

II.2.1.5. Correlation between the resource categories defined above and those used in other major resource mineral classification system is shown in TABLE II.

II.2.2. Cost Categories

Three categories of cost of production have been accepted (all of them in terms of U$S of 1st January, 1983):

- less than U$S 80/kg U
- between U$S 80 and U$S 130/kg U
- between U$S 130 and U$S 260/kg U

When estimating the cost of production for assigning resources within these cost categories, it was suggested or mentioned that account has been taken on the following partial cost:

a) The direct costs of mining, transporting and processing the uranium ore;
b) the costs of associated environmental and waste management;
c) the costs of maintaining non-operating production units where applicable;
d) The capital cost of finance, including any unamortised costs where applicable;
e) indirect costs such as office overheads, taxes and royalties where applicable;
f) future exploration and development costs wherever required for further ore delineation to the stage where it is ready to be mined.

In spite of the aforesaid, it should be mentioned that not always

TABLE II

APPROXIMATE CORRELATIONS OF TERMS USED IN MAJOR RESOURCE CLASSIFICATION SYSTEMS

NEA / IAEA	REASONABLY ASSURED		ESTIMATED ADDITIONAL I	ESTIMATED ADDITIONAL II	SPECULATIVE
Australia	REASONABLY ASSURED		ESTIMATED ADDITIONAL I	UNDISCOVERED	
Energy, Mines and Resources Canada	MEASURED	INDICATED	INFERRED	PROGNOSTICATED	SPECULATIVE
France	RESERVES I	RESERVES II	PERSPECTIVES I	PERSPEC-TIVES II	
South Africa	REASONABLY ASSURED		ESTIMATED ADDITIONAL I	ESTIMATED ADDITIONAL II	SPECULATIVE
United States DOE	RESERVES		PROBABLE POTENTIAL RESOURCES		POSSIBLE AND SPECULATIVE POTENTIAL RESOURCES

«The terms illustrated are not strictly comparable as the *criteria used in the various systems are not identical.* «Grey zones» in correlation are therefore unavoidable, particularly as the resources become less assured. Nonetheless, based on the principal criterion of *geological assurance of existence,* the chart presents a reasonable approximation of the comparability of terms».

all the partial costs above mentioned are taken into account for the estimation of final costs. This is especially valid for items b) and c) but also, in many cases, as in USA, Canada, South Africa, Brazil, Spain, Argentina, etc., large regional exploration programmes are supported by the concerned goverments and results are in some cases offered free of cost to private companies.

II.2.3. Relationship between categories

TABLE I illustrates the inter-relationship between the different categories. The horizontal axis expresses the level of assurance about the actual existence of given tonnages based on varying degrees of geologic knowledge, while the vertical axis expresses the economic feasibility of exploitation by the division into cost categories.

The dashed lines between RAR, EAR-I, EAR-II and SR in the highest cost category indicate that the distinctions of level of confidence are not always applied. The shaded area indicates that because of the degree of confidence in their existence, RAR and EAR-I recoverable at less than US$ 130/kg U are distinctly important, they are reffered to as "known resources".

Because resources in EAR-II and SR categories are essentially undiscovered, the informatión on them is such that it has not always been possible to divide them into different cost categories, and this is indicated by horizontal dashed lines between cost categories.

II.3. UNITS

Metric units are presently used in all international tabulations regarding uranium resources. Resources and production quantities are expressed in terms of metric tons (tonnes) contained uranium (U) rather U_3O_8. Ore grades are expressed in % of U or in kg of uranium per tonne of ore. Unfortunately, in USA papers figures are expressed in short tons of U_3O_8 (and pounds of U_3O_8).

Conversion of units are the following:

1 short ton U_3O_8 = 0.769 tonnes U

US$ 1/lb U_3O_8 = US$ 2.6/kg U

II.4. THE WOCA's URANIUM RESOURCES

The WOCA's uranium resources that are known to exist are contained in deposits of the conventional type from which uranium could be recoverable at costs of US$ 130/kg U or less. These resources are integrated with the Reasonable Assured Resources (RAR) and the Estimated Additional Resources of Category I (AER-I). In addition to these resources, other conventional but improperly called "resources" are thought to occur which, if discovered, could also be recovered at costs of below US$ 130/kg U. These are the Estimated Additional Resources of Category II (AER-II) and the Sepculative Resources (SR). Finally, other resources should be considered, such as those recoverable at costs higher than US$ 130/kg U.

At the present there is a reduced interest in unconventional sources of uranium, although such sources may be of increasing importance in the long term.

II.4.1. Uranium resources from conventional deposits

The uranium resources have been assigned, on the basis of their conventional geological setting, to the following types:

1. Proterozoic quartz-pebble conglomerate deposits.
2. Proterozoic unconformity-related deposits.
3. Disseminated magmatic, pegmatitic and contact deposits in igneous and metamorphic rocks.
4. Vein-type and similar deposits.
5. Sandstone deposits.
6. Surficial deposits.

Non conventional uranium sources are included in another category:

7. Other type of deposits

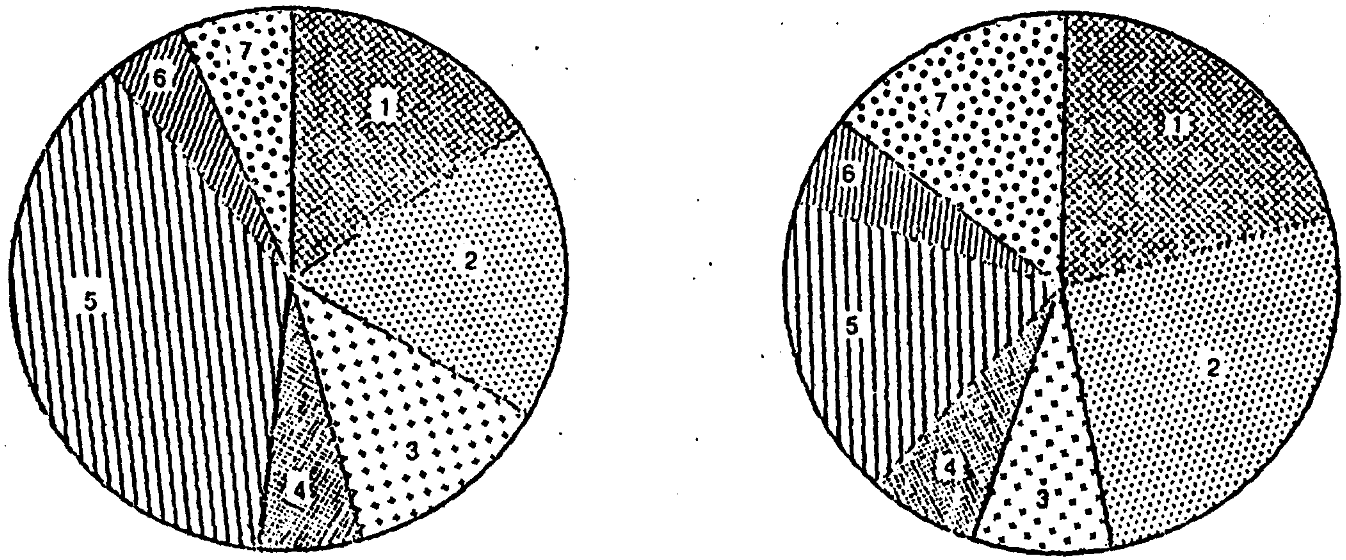
The distribution of uranium resources by deposit-type is shown in Fig. 1. For RAR the main participation corresponds to sandstone-type, but quartz-pebble conglomerate, unconformably-related and disseminated magmatic deposits have also a good incidence.

For AER-I, the major component corresponds to quartz-pebble conglomerate, unconformity-related and sandstone-type deposits.

Sandstone uranium deposits are well represented, especially in the USA and Niger, but they also occur in Argentina, Australia, Brazil, France, Pakistan, etc. Quartz-pebble conglomerate deposits are frequent in Canada and South Africa, but also in Brazil. Unconformably-related deposits, which interest in growing rapidly, are well represented in Canada, Australia and

Figure 1

DISTRIBUTION OF URANIUM RESOURCES BY DEPOSIT TYPE



Reasonably Assured Resources

(< $ 130 / kg U)

Estimated Additional Resources
Category I
(< $ 130 / kg U)

1. Quartz-Pebble Conglomerate Deposits.
2. Unconformity-Related Deposits.
3. Disseminated Magmatic, Pegmatitic and Contact Deposits in Igneous and Metamorphic Rocks.
4. Vein Deposits.
5. Sandstone Deposits.
6. Surficial Deposits.
7. Other Types of Deposits.

Brazil, with some examples in the USA. Among the disseminated magmatic, pegmatitic and contact deposits, the most representative ones are located in Namibia, Canada, Australia, Brazil and Greenland. The major vein-type and similar uranium deposits are known in France, Spain, Portugal, USA, Czechoslovakia, Canada, etc. Surficial deposits, especially those of calcrete type, are known in several countries, as Somalia, Mauritania, Namibia, etc., but the most important accumulations are recorded in Australia. No more details on the conventional-type of uranium deposits should be given now, because the subject will be discussed in other speeches.

II.4.2. Unconventional and by-product resources

In some countries, unconventional and by-product sources of uranium could already have economic significance. In other cases the grades are too low for economic recovery at the present time.

The more interesting resources of this nature are the following:

a) Marine phosphate

This is probably the most important source of production from this category, and uranium is already being obtained in significant quantities as a by-product of phosphoric acid production in the USA. The largest deposit of this type is located in Morocco, where over 6 million tonnes of uranium content was reported, but also Syria, Brazil, Spain, etc., have significant resources of this type.

b) Black-shales

Many marine black-shales, rich in organic matter, contain uranium at grades of 0.001 to 0.008%. Occasionally they can exceed 0.03% as in Sweeden and the USA, and their exploitation, attempted in the first country, was not satisfactory.

c) Coals and lignites

Although most coals contain less than 0.001% U, some low rank impure coals may contain as much as 1%. In USA, certain lignites have between 0.1 and 0.4% U and Tertiary lignites of Spain contain 40,000 t U in the RAR category and another 63,000 t U as AER.

d) Monazite

Uranium is a minor constituentin monazite which is mined for its thorium and rare earth content, but only small uranium quantities are recovered as by-product in Brazil from the monazite treatment.

e) Seawater and marine bottom muds

It has been estimated that the world's oceans contain about 4,000 million tonnes of uranium. Recent studies indicate that the possible cost of recovering uranium from seawater could be between U$S 500 and U$S 1000 per kg U.

More favourable perspectives for uranium recovery seem to be offered by some black muds rich in organic matter of low energy bottom basin of some seas, as those of the Baltic and Black seas, where the uranium contents in the muds are over 10 times higher than the U content in the sea water (adsorption by organic matter).

f) Tailings

In South Africa some 51,000 t U contained in the tailings of gold mines are included in estimates of RAR and AER recoverable at less than U$S 130/kg U.

g) By-product of copper mining

Uranium is being recovered as a by-product of the mining of copper in the USA. South Africa produces uranium as a by-product fo recovery of copper and other metals from the Phalaborwa carbonatite complex.

h) Igneous rocks

Large amounts of low grade uranium are contained in some igneous complexes of Greenland, USA, etc., but their exploitation is considered too costly.

II.4.3. Resource estimates

II.4.3.1. The RAR for costs lower than U$S 130/kg U

The WOCA RAR for costs lower than U$S 130/kg U are indicated in TABLE III and they amount to around of 2,000,000 t U divided in

1,425,000 t U for costs lower than U$S 80/kg U.
575,000 t U for costs between U$S 80 and U$S 130/kg U.

Regarding the aforesaid resources, some aspects should be pointed out as follows:

a) 83% of the RAR, that is to say, around 1,700,000 t U are located in only

TABLE III

REASONABLY ASSURED RESOURCES
(1,000 Tonnes U)

Data available 1st January, 1983

COUNTRIES / COST RANGE	$80/kg U (reserves)	$80-130/kg U	TOTAL
Algeria[2,5]	26	---	26
Argentina[2]	18.8	4.5	23.3
Australia	314	22	336
Austria[5]	0	0.3	0.3
Brazil[1]	163.3	---	163.3
Cameroon, Republic of	0	0	0
Canada	176	9	185
Central African Republic[1,4]	18	---	18
Chile*[1]	0	2.3	2.3
Denmark	0	27	27
Egypt	0	0	0
Finland[1]	0	3.4	3.4
France	56.2	11.3	67.5
Gabon	18.7	4.7	23.3
Germany, Federal Republic of	0.9	4.2	5.1
Greece	0.4	0	0.4
India	31.7	10.9	42.6
Italy	2.9	---	2.9
Japan	7.7	---	7.7
Korea, Republic of	0	10	10
Mexico[1]	2.9	---	2.9
Namibia[5]	119	16	135
Niger[2,3]	160	---	160
Peru[1]	0.5	---	0.5
Portugal[1]	6.7	1.5	8.2
Somalia[1,4]	0	6.6	6.6
South Africa	191	122	313
Spain	15.7	4.5	20.2
Sweden[6]	2	37	39
Turkey[1]	2.5	2.1	4.6
United States of America	131.3	275.9	407.2
Zaire[2,3]	1.8	---	1.8
TOTAL (rounded)	1,468	575	2,043
TOTAL (adjusted)[7]	1,425	575	2,000

Reported tonnages refer to quantities of uranium recoverable from mineable ore, except were noted.

* Assigned to cost category by Secretariat.

1 Uranium contained in-situ.

2 Uranium contained in mineable ore.

3 OECD(NEA)/IAEA: "Uranium Resources, Production and Demand", Paris, 1977.

4 OECD(NEA)/IAEA: "Uranium Resources, Production and Demand", Paris, 1979.

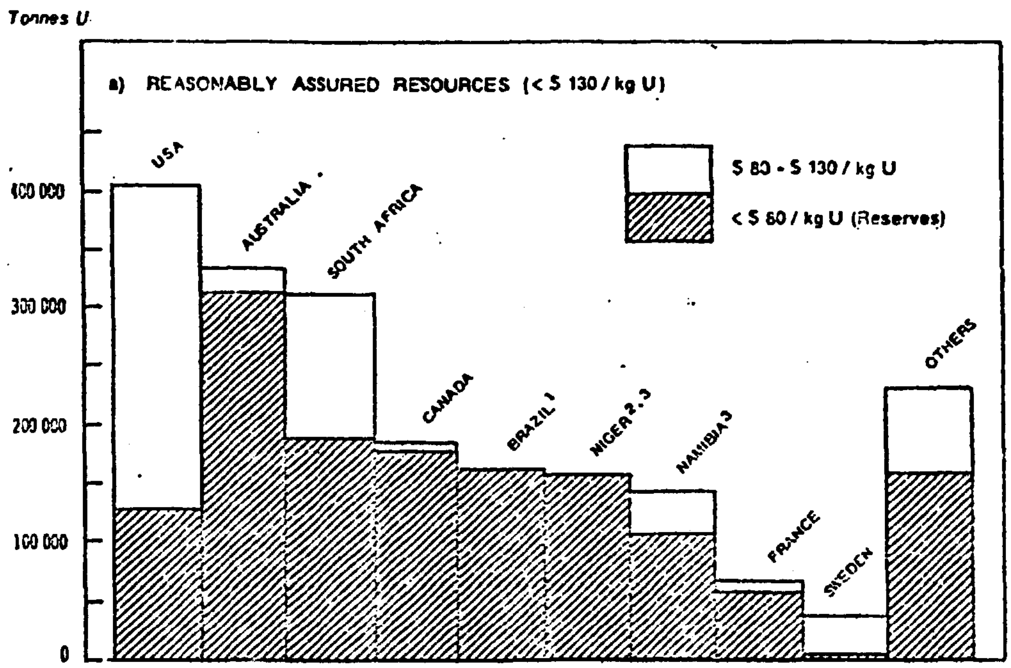
5 OECD(NEA)/IAEA: "Uranium Resources, Production and Demand", Paris, 1982.

6 Includes 35,000 tonnes U in the Ranstad deposit from which no uranium production is allowed due to a veto by local authorities for environmental reasons.

7 Adjusted by the Working Party to account for mining and milling losses not incorporated in certain estimates.

TABLE IV

GEOGRAPHICAL DISTRIBUTION OF URANIUM RESOURCES



7 countries: Australia, Brazil, Canada, Namibia, Niger, South Africa and USA, which means an average for each country of around 240,000 t U. TABLE IV.

b) Another 14% of the RAR (c.a. 290,000 t U) belong to 9 countries, with an individual average resource of around 30,000 t U, that is to say, in a ratio of 1 to 8 regarding the large uraniferous countries. The mentioned 9 countries are Algeria, Argentina, Central African Republic, Denmark, France, Gabon, India, Spain and Sweden.

II.4.3.2. The AER-I for costs lower than U$S 130/kg U

The AER-I of this category of cost are indicated in TABLE V and they account for around 1,200,000 t U, divided in

855,000 t U for costs lower than U$S 80/kg U
305,000 t U for costs between U$S 80 and U$S 130/kg U

Regarding the geographic distribution of the AER-I, it could be mentioned that:

a) 77% of this category of resources, amounting to 945,000 t U (of a total of around 1,200,000 t U) are located in only 5 countries (Australia, Brazil, Canada, South Africa and USA). representing an average distribution of around 190,000 t U of each country.

b) Another 19% of the AER-I, amounting 235,000 t U, are known in 8 countries (sometines with not strong credibility), giving an average availability of around 30,000 t U for each one of them (Denmark, France, Gabon, Western Germany, India, Namibia, Niger and Sweden). The ratio between b) and a) is of around 1/6.

II.4.3.3. Countries with the main uranium resources in the RAR and AER-I categories for costs of less than U$S 130/kg U

TABLE VI illustrates the ranking of the countries having the main WOCA's uranium resources for categories RAR and AER-I.

II.4.3.4. EAR-II

As its was mentioned above, the Estimated Additional Resources of Category II are highly speculative and not too much data on the matter have been provided by the consulted countries. Over a total of more than 100 countries to which the concerned questionnaires were by the IAEA and OECD,

TABLE V

ESTIMATED ADDITIONAL RESOURCES - CATEGORY I
(1,000 Tonnes U)

Data available 1st January, 1983

COUNTRIES / COST RANGE	$80/kg U	$80-130/kg U	TOTAL
Algeria	---	---	---
Argentina[2]	7	---	7
Australia	369	25	394
Austria[5]	0.7	1.0	1.7
Brazil[1]	92.4	---	92.4
Cameroon, Republic of	0	1.2	1.2
Canada	181	48	229
Central African Republic	---	---	---
Chile[*,1]	0	2.3	2.3
Denmark	0	16	16
Egypt[2,4]	0	5	5
Finland[1]	---	---	---
France	26.6	6.25	32.9
Gabon	1.3	8.3	9.6
Germany, Federal Republic of	1.3	6.9	8.2
Greece	6	0	6
India	4.8	14.6	19.3
Italy	---	1	1
Mexico[1]	3.5	2.6	6.1
Namibia[5]	30	23	53
Niger[2,3]	53	---	53
Peru	---	---	---
Portugal	1	---	1
Somalia[1,4]	0	3.4	3.4
South Africa	99	48	147
Spain	5	---	5
Sweden[6]	0.3	43	43.3
Turkey	---	---	---
United States of America	30.4	52.2	82.6
Zaire[2,3]	1.7	---	1.7
TOTAL (rounded)	914	308	1,222
TOTAL (adjusted)[7]	835	305	1,190

Reported tonnages refer to quantities of uranium recoverable from mineable ore, except were noted.

- * Assigned to cost category by Secretariat.
- 1 Uranium contained in-situ.
- 2 Uranium contained in mineable ore.
- 3 OECD(NEA)/IAEA: "Uranium Resources, Production and Demand", Paris, 1977.
- 4 OECD(NEA)/IAEA: "Uranium Resources, Production and Demand", Paris, 1979.
- 5 OECD(NEA)/IAEA: "Uranium Resources, Production and Demand", Paris, 1982.
- 6 Includes 40,000 tonnes U in the Ranstad deposit from which no uranium production is allowed due to a veto by local authorities for environmental reasons.
- 7 Adjusted by Working Party to account for mining and milling losses not incorporated in certain estimates.

COUNTRIES WITH THE MAIN URAMIUM RESOURCES

(RAR and AER-I US$ 130/kg U)

TABLE VI

1.	AUSTRALIA	730,000 t U
2.	USA	490,000 "
3.	SOUTH AFRICA	460,000 "
4.	CANADA	414,000 "
5.	BRAZIL	255,000 "
6.	NIGER	213,000 "
7.	NAMIBIA	188,000 "
8.	FRANCE	100,000 "

only 9 have informed on the subject. Of them, only two countries include significative figures: Canada 280,000 and USA 810,000 t U, for costs of less than U$S 130/kg U.

II.4.3.4. Speculative resources for costs of less than U$S 130/kg U

Still more subjective are the estimates of this category, achieved by two different sources.

According to national data, the WOCA Speculative Resources for costs less than U$S 130/kg U could be in the orden of 6 to 7.7 million tonnes of uranium, but IUREP estimation increases the figures up to 9.6 to 12 million tonnes of U.

II.4.3.5. Resources outside the WOCA

Very little information is available on the uranium resources of the Centrally Planned Economic Area (CPEA). Estimates made for the 11th World Energy Conference(1980) had indicated around 500,000 t U for the low cost category, and 1.5 million tonnes for the AER category, with the majority in the Union of Sovietic Socialist Republic and German Democratic Republic.

The IUREP estimates on Speculative Resources for the CPEA arrives to figures comprised between 3.4 and 8.3 million tonnes of uranium, for all cost categories.

II.4.3.6. Uranium stocks

In the period since 1965 up to 1983, uranium production has totalled close to 500,000 t U. During the same period, reactor requirements have been less than 300,000 t U. Much of the difference between these two amounts is being held by customers or producers in stockpiles. In addition, some of the pre-1965 production (245,000 t U), not used for defense purposes, could also be included in the stockpiles. Total uranium stocks are estimated to be the equivalent of between the next four to five years of reactor uranium requirements.

Few countries have provided detailed information on the size of the uranium stocks which are held by producers, consumers or governmental agencies, and in this regard, TABLE VII only descibes a portion of the total stocks, which surely are much higher.

TABLE VII. STOCKS

(data available 1 January 1983)

(in tonnes natural U equivalent, rounded figures)

COUNTRIES	NATURAL	ENRICHED	DEPLETED
ARGENTINA	50 (1)	-	-
AUSTRALIA	1,750 (1)	-	-
BRAZIL	50 (1)	-	-
FINLAND	600 (3)	710 (3)	-
W GERMANY	150 (1) 6,800 (3)	2,700 (1) 4,500 (3)	- 2,750 (3)
ITALY	2,200 (2)	1,400 (2) 3,750 (3)	- -
KOREA	1,520 (3)	100 (3)	-
THE NETHERLANDS	800 (3)	900 (3)	1,450 (3)
PORTUGAL	500 (1) 130 (2)	- -	- -
UK	no data	no data	5,000 (3)
USA	37,300 (1) 5,400 (2) 35,600 (3)	34,000 (1) - 8,600 (3)	4,400 (1) 7,600 (2) -
TOTALS	92,350	56,660	21,200

(1) Government stocks
(2) Producer stocks
(3) User stocks

II.4.3.7. Economic constraints

With increasing costs of exploration and production the uranium industry will need incentives to delineate and develop new resources.

The risks of no return on investments are greater for exploration than for other parts of the nuclear fuel cycle, especially as much of the future exploration will need to take place in areas with difficult access or in countries which can offer little logistical support for exploration.

Assurance of demand is an important factor affecting future uranium production and availability. At the present time, with a soft market, the incentive to explore for, and to produce uranium is less than it has been for some time.

If both demand and price increase, then the incentive will return. However, with the long lead times from start of exploration to first production from a successfull discovery, which have gradually lengthened from an average of 8 to 10 years to something in the order of 15 years for many deposits, there is the possibility that, without timely exploration and development works, increased production could lay behind demand.

b) Physical constraints

Several physical factors can limit the rate of discovery and production of uranium. With some exceptions, uranium ore bodies are becoming increasingly difficult to discover and, although some may be discovered with existing exploration techniques, improved techniques will probably be required to discover many of the hidden deposits.

Another fact that can limit the rate of production from an orebody is the physical nature of the orebody itself, which in turn determines the methods that are used to mine it. The possible rate of development of shallow high grade deposits amenable to open-cut methods contrast markedly with the development of deeper underground deposits. In other cases, the uranium is a by-product and hence the production rates depend on the output of the main product.

c) Political, ecological and other contraints

Non favourable government policies on foreign investment can act to discourage the exploration for, and production of uranium in some countries.

Ecological and/or political groups of opinion can also disturb the development of the uranium industry in some countries and there are several examples on the matter. 35,000 t U of the Ranstad deposit in Sweden will not be mined due to a veto by local authorities for invoked environmental reasons.

Difficulties created by aborigins' claims have delayed for several years the uranium exploration and the subsequent production in some areas of Canada and Australia.

III. URANIUM REQUIREMENTS (DEMAND)

Uranium requirements will depend not only on the nuclear growth projections but also on the types of reactors operated over the next 50 years.

Important analyses on the subject have been prepared by international or multinational organizations, but their results were not always coincident for estimations beyond the year 2000. On the other hand, such projections only correspond to the WOCA's countries and do not include countries or the CPEA (Centrally Planned Economic Area).

An interesting exercise was presented in 1977 by the Workshop on Alternative Energy Strategies (WAES) with projections until de year 2000, and in the same year, another valuable exercise was prepared for the World Energy Conference (WEC). An exhaustive study has been implemented by the Workshop I of the International Nuclear Fuel Cycle Evaluation (INFCE), the results of which have been published in 1980 by the IAEA.

Periodically (commonly every two years), the Nuclear Energy Agency (NEA) of the Organization for Economic Co-operation and Development (OECD) performs analyses on the WOCA nuclear growth projections, and the corresponding results are jointly published by OECD and IAEA in the well known "Red Book" (Uranium. Resources Production and Demand). All member states of both organizations (more than 100) are asked to supply the concerned data on the matter and the last issue of the "Red Book" correspond to 1983.

In spite of the high qualifications of the members of the mentioned group of experts, their respective conclusions are very different for projections beyond the year 2000, as is illustrated in Fig. 2.

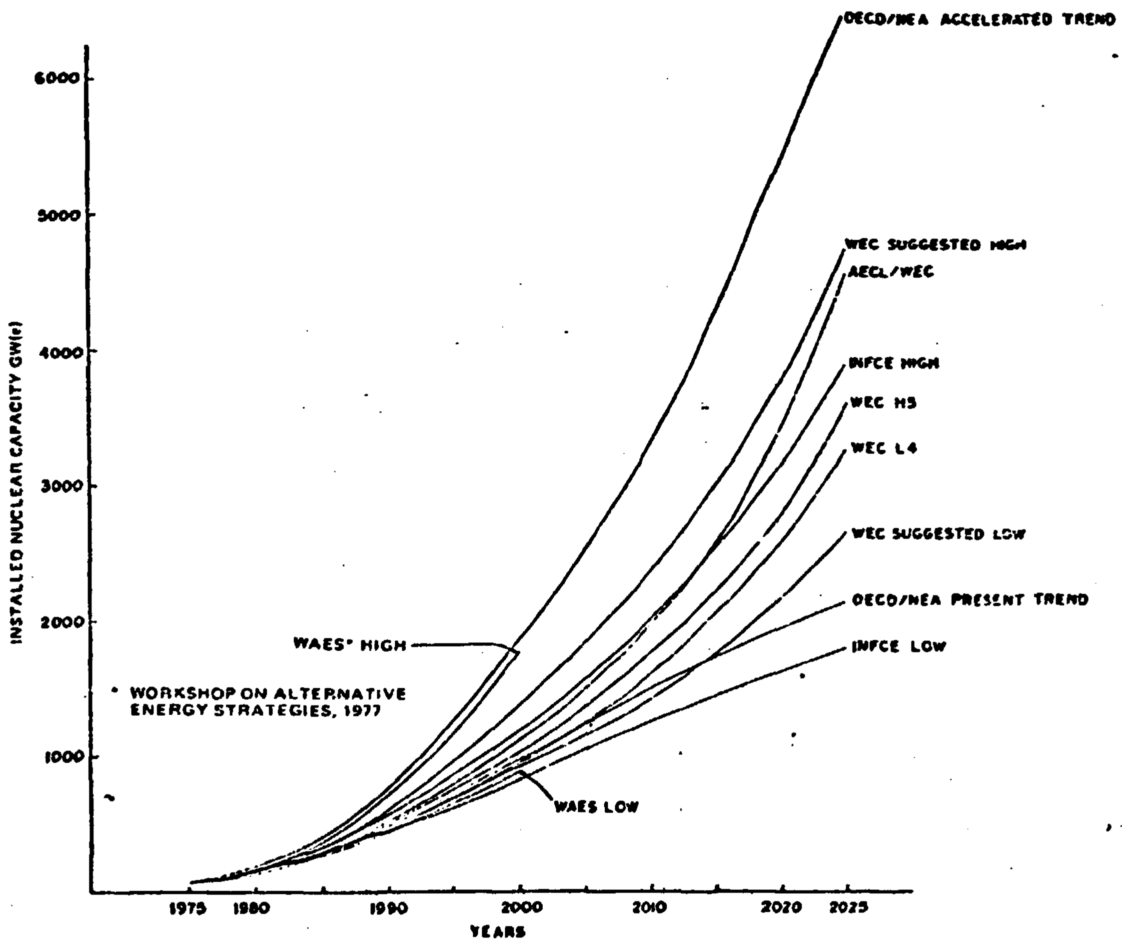


Fig.2 *Projections of installed nuclear capacity in WOCA.*

For the period up to the year 1995, uranium reactor requirements are those provided by national authorities in response to questionnaires. These estimations are well defined, being mainly based on reactors already built or under construction. For the period beyond 1995 the uranium requirements were calculated from projections of nuclear power growth computed by the NEA Secretariat. These projections were based upon revised national nuclear capacity projections to the year 2000 and earlier projections to the year 2025 developed by the Working Party on Nuclear Fuel Cycle Requirements. In brief, the method used for the long term projections was to take projections of per capita electricity demand and population, and to convert these into total electricity demand and then to estimate the nuclear share using logistic "S" curves.

In setting parameters for nuclear penetration after the year 2000, implicit account was taken of relative generating costs, the availability of renewables, hydropower and load profiles. Because of different factors, it was assumed that the nuclear share of electricity production would ultimately reach between 35-50% in Canada-USA; between 50-75% in the rest of countries of OECD and between 25% and 50% in developing countries. By this method, a "higher" and a "lower" projection were made.

On the other hand, four illustrative strategies related to different types of reactors to be used after the year 2000 were selected:

- Extreme strategies dominated by single types of reactors

  (this is to give an idea of the maximum range of possible uranium requirements for the post-2000 period)

  1. LWR-Once-through reference. All LWR's built in 1991-2000 are 15% improved type. After 2000 improved LWR's installed exclusively.

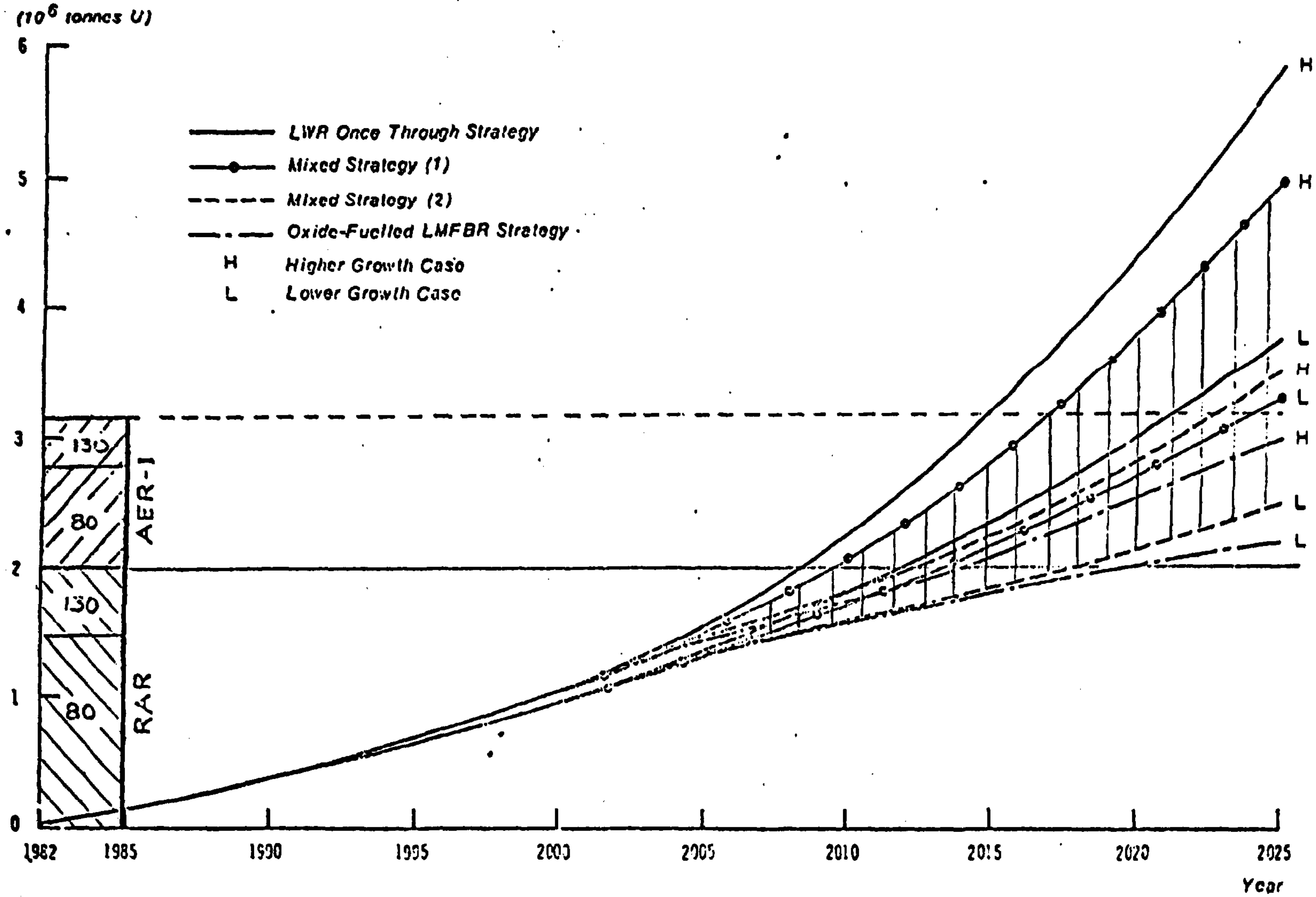
  2. Uranium/plutonium fuelled LMFBR reference. Oxide-fuelled LMFBR's installed for 2001 at rate determined by plutonium availability, growth in nuclear demand and substitution model such that all new reactors in 2001-2010 are current technology LWR's with once-through operation.

- Mixed reactor strategies

  3. Mixed reactor strategy (1). An important improved LWR strategy is followed in North America while the remainer of the OECD countries continue

Figure 3

CUMULATIVE URANIUM REQUIREMENTS FOR ILLUSTRATIVE FUEL CYCLE STRATEGIES FOR WOCA



to rely mainly on LWR with some LMFBR's.

4. Mixed reactor strategy (2). All OECD countries (except Canada) follow the LMFBR strategy.

In both of the last two strategies, HWRs are used in Canada and also in some developing countries.

Fig. 3 illustrates the cumulative uranium requirements estimated for the four above mentioned reactor-type strategies and for the two estimations of nuclear power growth: "higher" and "lower" cases.

In one extreme, using only LWR-Once-through strategy, the RAR will be enough to meet the reactor requirements until the years 2008 and 2012, for "higher" and "lower" growth estimations (respectively). If AER-I are certificated, uranium supply could be extended until 2015 and 2021 (respectively).

The extreme example in the other sense, for lowest uranium consumption, is given by the exclusive use of the oxide-fuelled LMFBR strategy. In this case, the RAR will be able to meet the demand until 2013 and 2020 (higher and lower growth, respectively), but in case the AER-I could be used, supplies would be extended to 2026 and 2050 (approximately).

But obviously, nuclear power will grow in different ways in different countries, so that the single type strategies are not expected to be realistic projections, and in this regard, the most plausible range of demand will be given by Mixed-strategies (1) and (2), and the corresponding cumulative uranium requirements are illustrated in the shaded areas of Fig. 3.

In this case, RAR will be enough to satisfy the demand until c.a. 2009 and 2013 (high and low) for Mixed Strategy (1), but dates will be extended to 2017 and 2024 if AER-I are incorporated.

For Mixed Strategy (2), dates are 2012 and 2018 (high and low) for RAR, and 2023 and 2033 (respectively) with the use of AER-I.

IV. URANIUM PRODUCTION CAPABILITY

IV.1. FOREWORD

The projections of uranium production capabilities are the maximum levels of production that could be practically and realistically achieved under favourable circumstances from the plants and facilities at specific production centres within the involved countries.

In this regard, four types of centres were defined:

- Existing: Are those that currently exist in operational conditions and include those plants which could be rapidly brought back into operation.

- Committed: Are those that are either under construction or are firmly committed for construction.

- Planned: Are those that are planned, based on feasibility studies, but for which constructions commitments have not yet been made. This class also includes those plants which would require substantial expenditures to bring them into operational conditions.

- Prospective: Are those that could be supported by tributary RAR and EAR-I, i.e. "known resources", but for which construction plants have not yet been made.

For the projection of the short term production capability only the first two types of centres are used.

For the long term the projections were based on all types of centres. In both cases the projection assumed that the production centres would be supported only by known resources: RAR and AER-I recoverable at costs of US$ 130/kg U or less.

IV.2. THE PRESENT SITUATION

For many years, uranium production has significantly exceeded reactor requirements, and inventories are still increasing and the level of stocks is still sufficient to cover reactor requirements for between four to five years.

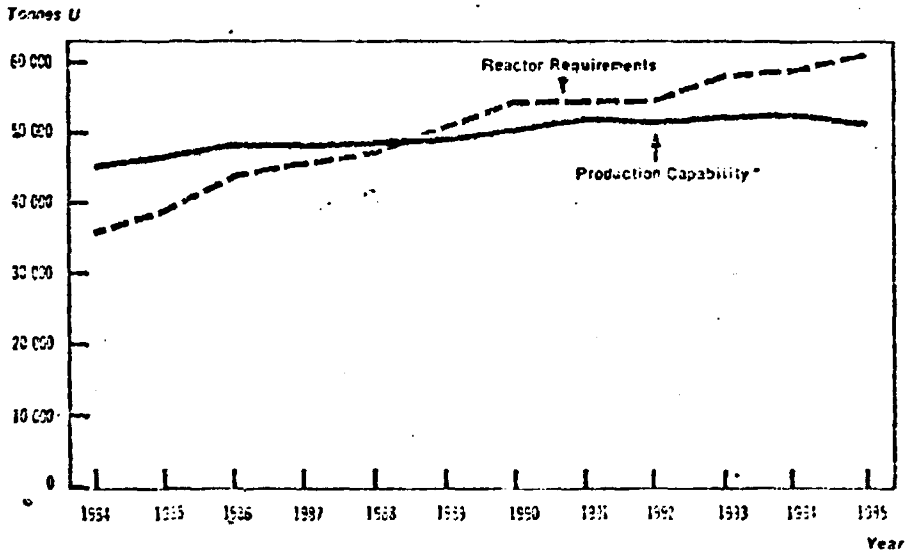
IV.3. THE SHORT TERM (1985-1995)

The projection of production capability for short term is shown in Fig. 4.

A comparison between short term production capability and reactor

Figure 4

ANNUAL REACTOR URANIUM REQUIREMENTS AND URANIUM PRODUCTION CAPABILITY - 1984-1995



* Based on existing and committed production centres supported by known resources (RAR and EAR-I) recoverable at cost of $ 130 / kg U or less.

requirements indicates that the production from existing and committed facilities could continue to meet reactor requirements until the end of this decade. After that time some production may be required from facilities which are now only in the planning stage or from other mills, particulary in the USA, which are now on standby status.

The present level of stocks is however equivalent to the next four-five years demand, so that the need for new production facilities draw down their stocks.

IV.4. THE LONGER TERM (post-1995)

In Chapeter III, projections for nuclear power growth in WOCA for the period to 2025 have been discussed, but it must be remembered that such long term projections are highly speculative.

The two different strategies mentioned above are intended to show the extreme range of uranium requirements that could be expected if a particular growth in nuclear power occurs. The mixed strategies are included to illustrate other possible and more realistic annual uranium requirements.

Fig. 5 presents a comparison of the long term projections of requirements taking into account the different scenarios. This figure shows that production from existing and committed production centres could not be expected to cover the requirements beyong the end of this decade.

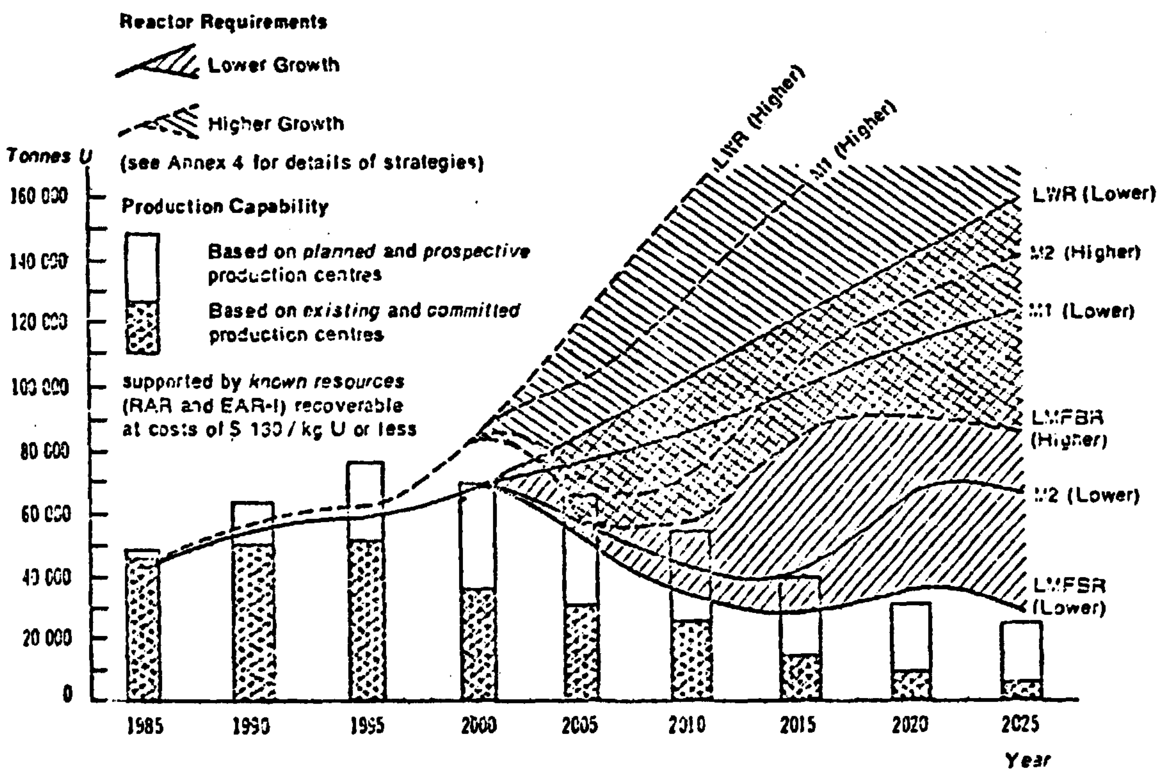
Beyond that time, production would be required from now only planned or prospective centres of production, and such centres could be called upon to meet as much as half of the supply by the end of the century.

On the other hand, it is also likely that in the years between now and the end of this century, the supply will be augmented by the development of new resources in the less than U$S 80/kg U category.

However, in spite of this, production from all these centres may be not able to fully cover annual uranium requirements much beyond the end of the century. Additional production would then be required to be drawn from presently undiscovered resources (AER-II and SR), higher costs (U$S 130 - U$S 260/kg U) known resources and/or unconventional sources.

Figure 5

ANNUAL REACTOR URANIUM REQUIREMENTS AND URANIUM PRODUCTION CAPABILITY FROM KNOWN RESOURCES (< $ 130 / kg U) 1985 - 2025



V. CONCLUSIONS

The OECD/IAEA Red Book conclusions could be summarized as follows:

1. In spite of the present uranium over-supply situation, over the coming decades a substantial effort will have to be put into exploration and the establishment of production facilities to ensure the supply of uranium is adequate to meet long term requirements.

2. In this connection, it is important to emphasize the length of time it takes from commencement of an exploration programme to first production from a successful discovery. Presently this lead time could be of around 15 years.

3. Political, ecological and other constraints also appear to have had a marked influence on lead time. On example of the influence of one of such factors is the pause in the development of Australian uranium resources during the period 1972-77 until the Ranger Uranium Environmental Inquiry was completed. Canadian examples are the seven-years moratorium placed on uranium exploration and mining in British Columbia.

4. Although lead times can vary from country to country, a comparison of recent experience with that of the early development of the uranium industry serves to illustrate the trend to longer times. In Canada, during the late '40s and the '50s, lead times from commencement of exploration to first production varied from 3 to a maximum of 10 years. In the case of three more recent Canadian examples, the lead times varied from 11 to 16 years.

5. Probably the gratest influence on lead times is the market factor. Uranium at the present time continues to be over-supply in spite of increases on lead times, and while this situation continues there is not reason to expect a lead time decrease. This is especially valid for the absolutely free uranium market, described in our first speech as Market Nº 3, but for the second type of uranium market the possibilities seen to be more optimistic.

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