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George A. Mackay

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Uranium Mining in Australia

GEORGE A. MACKAY

Managing Director, Electrolytic Zinc Co. of Australasia Limited

ABSTRACT

Australia had an active uranium mining industry in the 1950s with uranium oxide being supplied under contract to the atomic energy authorities of the U.K. and U.S.A. In the 1960s, when these contracts concluded, domestic production ceased, apart from Rum Jungle, whose production until 1971 was stockpiled.

By the 1970s, the demand for uranium from the electrical utility industry had risen sharply and the effects on Australia were notable. The Mary Kathleen mine re-opened in 1976 but, more significantly, exploration activity suddenly expanded with the result that several world-standard deposits were located.

Western world requirements for uranium based on increasing energy consumption and a changing energy mix, will warrant the development of Australia's resources. By 1985 our mines could be producing 9,500 tonnes of uranium oxide yearly and by 1995 the export value from uranium could reach that from wool.

In terms of benefit to the community the economic rewards are considerable but, in terms of providing energy to the world, Australia's uranium is vital.

WORLD ELECTRICITY DEMAND

The major use for uranium is as a fuel in the generation of electricity and consequently, the future demand for uranium will be determined by the rate of electricity consumption.

The main factors influencing growth rate of energy are per capita consumption and population increase. The per capita consumption of electricity in turn depends on a number of factors: the economic ones such as personal incomes and the price of electricity as well as the technical ones such as energy use efficiency, conservation, climate, environmental requirements, and chosen life style.

Energy use efficiency is a measure of the energy needed to do a job. These efficiencies change as technologies improve and as better devices are more widely used, e.g. fuel needed to heat a building can be reduced by insulation and design. On the other hand, energy consumption can also increase through changing technology, especially of a labour-saving nature. The latter aspect has been observed in Japan where the amount of energy to produce a unit of gross domestic product in 1970 was nearly 8 per cent more than the energy required in 1960.

In predicting the future demand for energy, including electricity, a country may equate the increase in energy use with the increase in gross national product. As a rule of thumb, in Western countries at least, there has been a 1:1 ratio of increased energy consumption for increased real income. Since the oil crisis in 1973 this ratio has declined in the U.S. to 0.9:1, a trend expected to prevail in other industrialized countries and to reach about 0.8:1 by the year 2000. Declining energy consumption in the OECD countries has been noted by the United States Central Intelligence Agency (1977). The C.I.A. estimated that OECD energy demand will approach 85 million bbl/day oil equivalent in 1980 rising to about 100 million bbl/day in 1985. The 1985 demand is about 40 million bbl/day lower than it would have been had the oil crisis not occurred. Of that reduced demand, 30 million bbl/day is due to slower growth now envisaged and 10 million bbl/day due to price effects and conservation. OECD energy demand will now grow by 4 per cent per year, rather than 5 per cent per year if the pre-1973 trend had been maintained.

Sir Willis Connolly (1976) has claimed that the primary energy consumption of the world has recently been increasing exponentially at about 5 per cent a year (3 per cent due to per capita consumption and 2 per cent to population growth) and that this growth rate could probably be maintained to the year 2000. Most signifi-

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cantly though, he has said that electricity consumption has been increasing at 7 to 8 per cent a year. At this rate electricity consumption doubles every 10 years.

At the 1977 World Energy Conference in Istanbul, a demand projection for electricity to the year 2020—about 40 years from now—was given as between six and seven times the present value in a report by the Energy Research Group (1977). At that rate, electricity will require nearly 40 per cent of all primary energy. The Workshop on Alternative Energy Strategies (1977) confirms this by estimating that electricity demand by the year 2000—about 20 years from now—could be triple today's annual level which is approximately 8×10^{12} kWh.

With the natural aspiration of people for higher standards of living there are good reasons to believe that the existing pattern of economic development will continue, but with a lower energy growth in the developed countries and higher energy growth in the developing countries.

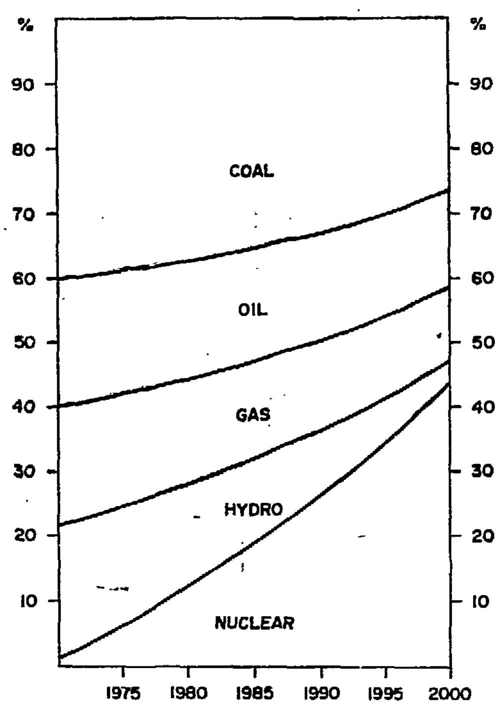

FIG. 1—Primary energy input for electrical generation.

After considering the various estimates that have been made of future demand, and taking into account the effects of conservation, higher-priced energy and increased environmental standards, it would seem that the long-term world energy demand will probably increase annually by a rate of 4.5 per cent. At the same time electricity demand should increase by 6 per cent per year at least to the end of this century and probably well into the next.

Growth in electricity demand in the future will see a change in the make-up of the primary energy sources used in world electrical generation. Nuclear power will make a major contribution, rising from about 5 per cent now to about 45 per cent in the year 2000. Coal's proportion of the primary fuel input will decline from 40 per cent to about 26 per cent, but in absolute terms coal supply will still increase by 3 per cent per year. Furthermore, oil and gas production will be unable to match the continued growth of electricity consumption and their relative shares of total demand will decline comparatively, while the share held by hydroelectric power will decline even more severely. Fig. 1 shows the estimated proportions of primary energy input for electrical generation to the year 2000.

ENERGY SOURCES

Nuclear power is seen as an energy source for the production of electricity. With world electricity consumption predicted on a 6 per cent per year growth path, the probability of being able to meet future demand from fossil fuels is doubtful. Certainly it is unlikely that hydro power can be expanded to any significant extent. There is every potential that a prospective gap will occur from the demand for electricity exceeding supply if nuclear power is not expanded.

A knowledge of the primary fuels availability is essential in understanding the constraints to future electricity production.

Coal

On paper, coal has the resources capable of sustaining energy growth well into the future. However, until the year 2000 there may be reluctance by many countries—producers and importers—to increase their dependence on this fuel. Compared to other fossil fuels, coal has pollution and environmental effects in its mining, its transport, its use, and ultimately its waste.

Coal's value in electricity production has not diminished but its use in developed countries as a primary fuel has comparatively levelled off. One of the great hopes for coal, however, is in the production of synthetic fuels. It is difficult to give credence to this concept in economic terms at the present time due to the production cost of such fuels. However, even if these fuels were competitive it is doubtful whether the coal production rate could be lifted, physically, to meet the demand.

Peters and Schilling (1977) revealed that sufficient coal deposits and reserves existed in many countries to meet an increasing conventional demand in the future. Their availability however, will depend on overcoming such obstacles as disposition and physical conditions of deposits, environmental impact, quality, conversion, capital, and labour. Many countries have no coal deposits at all, or, because of recovery problems, must rely on increasing imports.

They estimated that, from a review of coal producing countries accounting for about 95 per cent of the world's reserves, total coal output will exceed 4000 million tonnes annually in the year 2000, about double the present output or 3 per cent per year growth. In 1975 the production and consumption of coal in these countries (million tonnes coal equivalent) is shown in Table 1. On the production side, these figures show a doubling by the end of the century, proportionally less than the expected net increase in energy consumption.

Similarly, the proportion of coal exported decreases in future in most of the countries shown, revealing that the main coal producing countries plan their coal production to match their own requirements. For instance, plans in the U.S.A. are to produce 1341 million tonnes in the year 2000 but export only 91 million tonnes (7 per cent). In 1975 the figures were production 599 million and export 60 million tonnes (10 per cent).

Peters and Schilling (1977) noted the effect of declining exports and concluded that present measures to increase coal outputs will fail to satisfy the future world demand for energy. They showed the present world geological coal resources to be more than 10,000 $\times$ 10^9 tons coal equivalent but the reserves economically recoverable by today's standards to be only 810 $\times$ 10^9 tons. In contrast, the First Report of the Ranger Uranium Environmental Inquiry (1976) has lower estimates with 7300 $\times$ 10^9 tonnes of resources and reserves of 665 $\times$ 10^9 tonnes.

TABLE 1

Coal production and consumption 1975
(million tonnes)

	Production	Consumption
Australia	75	35
Canada	23	13
China, People's Rep.	470	470
Germany, Federal Rep.	126	101
India	98	92
Poland	181	144
South Africa	69	67
U.K.	129	122
U.S.A.	599	515
U.S.S.R.	614	555
Total	2384	2112
Total (1985)	3596	3326
Total (2000)	4000+	

Whilst coal resources would appear adequate to fulfil the increase in world energy consumption, grave doubt has been expresed that the levels of coal production required to meet energy demand could be achieved for the following reasons.

1. The disposition of resources is not favourable and it is apparent that the major coal producers are not inclined to increase their exports.
2. There are real obstacles in obtaining mining workforces and being able to justify the development, or even expansion, of transport networks (usually rail) to move coal from the mines.
3. Constraints will frequently exist on the scope to expand production from existing mines. The alternative to develop new mines may be hampered by environmental constraints and, as an example, there is legislation in a number of American States against the development of strip mining.
4. There is reluctance in the major coal producing countries to expand their dependence on coal, e.g. U.S.A. where coal accounts for 90 per cent of the conventional energy resources but currently supplies only 45 per cent of electrical generation and 18 per cent of total energy consumption. The principal factors for discouraging increased dependence on coal have been the distance of deposits from the major markets, the high levels of sulphur, the inadequacy of transport systems, and environmental factors.

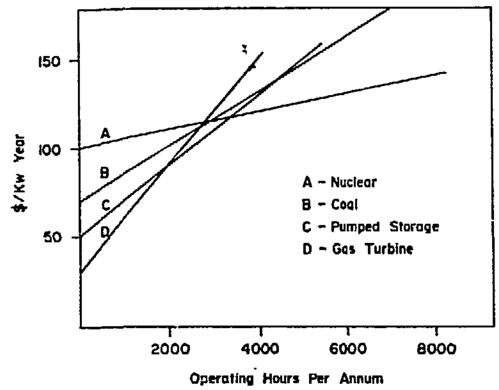

FIG. 2—Electrical generating costs.

Currently coal supplies about 30 per cent of the world's energy and about 40 per cent of electrical generation. About 40 per cent of coal produced is used for electrical generation but, in terms of electrical generating costs, many utilities have found it more economical not to use coal. The Atlantic Council of the United States (1976) estimated costs of generating electricity which showed that nuclear power is favoured for base load generation and gas turbines for peak load generation. The Council interpreted power costs in Fig. 2. More recently, the Atomic Industrial Forum (1977) and the United Kingdom Atomic Energy Authority (1977) have demonstrated that nuclear power plants in the U.S.A. and U.K. (Central Electricity Generating Board) have produced electricity at substantially lower average total cost than coal or oil-burning stations. Comparative costs are shown in Table 2.

Oil

The growth of oil and natural gas as primary energy sources has been dramatic. In 90 years they have become the dominant fuels of today, a position achieved because they have been cheap,

TABLE 2

Electrical generating costs

	U.S.A. (cents per kWh)	U.K. (pence per kWh)
Nuclear	1·5	0·69
Coal	1·8	1·07
Oil	3·5	1·27

TABLE 3

Petroleum: ultimate conventional reserve

	%
Middle East and North Africa	42
USSR, China, and socialist countries	23
North America	11
Latin America	9
South and East Asia	6
Western Europe	4·5
Southern Africa	4·5

multi-purpose, and in plentiful supply. The 1973 crisis changed all that. Price increases have reduced oil's competitiveness, notwithstanding the fact that the prices of all forms of energy have increased in its wake.

The crisis has indicated to all consumers the tenuous position of oil in the future—a future that must rationalize the use of fuels to maximize the life of oil reserves. The preferred use for oil will be in the transport sector and as a feedstock for the petrochemical industry. These uses currently account for about 60 per cent of oil consumption and oil fuels 90 per cent of transport's requirements. Considering there is no substitute for oil in the petrochemical industry and in transport, with the possible exception of gas, a continuing supply to those industries should be ensured. A realization of the dependence on oil by those industries is vital to the total energy equation. With the finite limits to oil reserves becoming more obvious, the continued use of oil in the generation of electricity is wasteful of those reserves when substitute fuels are available. Currently 12 per cent of oil production is used to generate electricity and 20 per cent of electrical generation is fuelled by oil.

From World War II to 1973, demand for oil in the Western world increased at about 6 per cent per year and currently accounts for more than half the primary energy used in those countries.

There is no doubt that the oil crisis put a brake on consumption after 1973. Consumption is now accelerating again and approaching the growth that was experienced in the years up to 1973 and at this pace, world consumption in 1990 will be double the current level. This will cause a serious depletion of oil reserves.

Desprairies (1977) showed our ultimate worldwide conventional petroleum reserves are 250-300 gigatonnes (Gt) located as shown in Table 3, or about three times known present reserves. The gross increase in reserves by the year 2000 will be influenced by an increased oil recovery rate of 40 per cent (at present it is about 25 per cent) which will mean existing oil deposits may be revalued.

Desprairies's figures showed that ultimate production will be reached in 1990 at 4-5 Gt and that the years from 1985 to 1995 would be critical because production capacities are likely to level off and if demand continues to grow there will be an oil shortage. The only possible relief to this shortage, if the world continues to depend so heavily on oil, is for the price of energy to escalate to the point where unconventional sources might be tapped. These include the deep offshore and polar zones which could double reserves at high cost. At present there is no move towards tapping these reserves because of the status of technology and, more importantly, because more than half the conventional reserves can be exploited at costs equal to or less than present selling prices. The same rationale applies to the potential source of oil from shales and tar sands and hydrocarbons from coal.

Natural gas

Natural gas, on a preference scale for fuel usage, would rate second to oil. Reserves of natural gas exceed those of oil in terms of future supply, with Communist countries holding 30 per cent of the reserves and North America and the Middle East 20 per cent each.

According to the First Report of the Ranger Uranium Environmental Inquiry (1976), ultimately recoverable natural gas reserves will yield up to 100 years' supply at 1975 levels of consumption. However, although there is uncertainty about reserves and the time when they are exhausted, the report does say it seems possible that the contributions of oil and natural gas to total energy requirements could be severely diminished by the end of this century.

As with oil, the use of gas needs to be studied closely so that the maximum life of our resources for premium purposes can be guaranteed. The position with gas reserves is not as critical as oil but does need monitoring. At present its use in electricity generation is of the order of 25 per cent of all gas used, and 15 per cent of all electricity produced uses gas as the primary fuel.

Gas is valuable for peak electrical generation and it would seem desirable to keep gas restricted for that purpose and not used for base load generation where the demands would be much greater, price permitting. The other major use for natural gas is heating, which accounts for about half total consumption. There is an increasing use for gas as a transport fuel and as this would be a premium requirement (no substitute other than oil) world supplies must be rationalized to future transport demands.

Gas reserves are predominantly located in the hands of a few, which will always impose potential limitations on worldwide unrestricted use.

Nuclear power

Uranium is the most recent of the developed viable energy sources and, to date, the least utilized. Commercially, nuclear powered electricity generation has been in operation for twenty-two years. Reserves of uranium, in energy terms, would be many times more than the reserves of oil and natural gas put together if the breeder reactor becomes a reality. The reason is that breeders exceed the present generation of conventional reactors in their fuel efficiency by a factor of perhaps 70:1.

Today 20 countries have nuclear power stations and the total installed capacity of these installations is close to 100 GWe. The growth in nuclear capacity and its rising importance to electricity production is shown in Table 4. U.N. published statistics have been taken to 1974 and then extrapolated according to growth for the 10 years to 1974 which was 7 per cent per year for total electricity generated and 31 per cent per year for electricity generated from nuclear plants.

TABLE 4

World generation of electricity (10^9 kWh)

Year	Total all sources	Nuclear
1955	1544	—
1960	2300	2
1965	3380	24
1970	4908	78
1971	5227	106
1972	5639	143
1973	6073	190
1974	6245	233
1975	6682	305
1976	7150	400
1977	7650	524

On the basis of an 8-13 year lead time, it would be expected that the growth of capacity would accelerate in the 1980s in response to the fourfold increase in oil prices in 1973. However, many expectations of new plants are not materializing due to an economic downturn, or plans have been deferred due to a number of reasons finally reflected in public concern and government caution.

Price (1976) has referred to the effect of a slowdown in energy growth having a profound effect on nuclear growth because nuclear, being a new energy source, is still largely concerned with increments of installed capacity (at least for a time, until the post-war generation of steam plants comes up for renewal). A 1 per cent uncertainty in energy growth—say 3 per cent instead of 4 per cent—then translates into a 25 per cent uncertainty in the rate of nuclear growth, on the basic assumption that all new energy growth is nuclear.

The present nuclear capacity is about 100 GWe. Taking into account reactors being built, and firm orders for reactors to be built, the present known future capacity will be nearly 400 GWe by about 1988 and about 500 GWe by 1990. Decisions for plants starting up in 1990 are being made now. When the full effects of the energy gap from 1985 are realized, the rate of planning of nuclear reactors will increase even more rapidly.

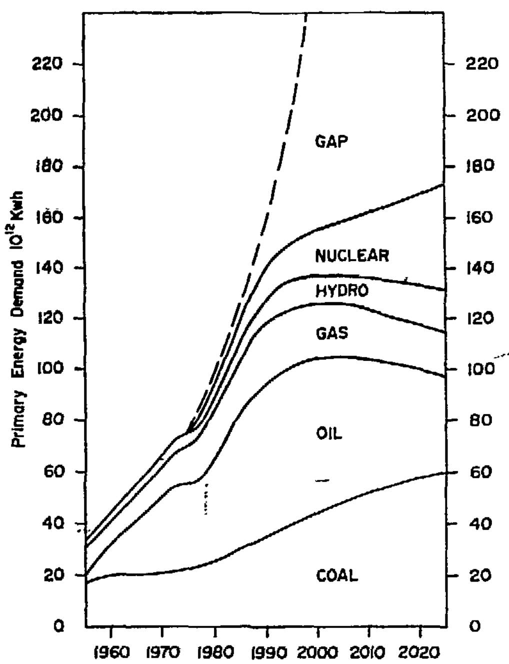

FIG. 3—World energy supply and demand.

The dimension of the energy gap was highlighted in the Royal Commission on Environmental Pollution Sixth Report (1976) and shown in Fig. 3. Based on a 5 per cent per year growth rate, this estimate predicts a gap of as much as one-third of the expected demand. Obviously such a large theoretical gap could call for very substantial readjustments in both supply and demand.

Dr. Symonds (1976) said the 1973 oil crisis did not necessarily herald concern for resource depletion, but highlighted the problem of how to arrange a new balance between resources. The U.S.A., Japan, and countries of Western Europe had seen the shortages of oil-based fuels looming in the 1960s. In these countries nuclear power capacity has been growing steadily and in Belgium, Sweden, and Switzerland the share of electricity produced from nuclear power plants is in the vicinity of 20 per cent.

Table 5 shows various estimates of Western world nuclear capacity by the year 2000. Taken at 1000 GWe and operating plant performance of 75 per cent the electricity produced from nuclear plants in the year 2000 would be 6.6×10^{12} kWh. This would have supplied all the electricity generated in the world in 1974. The proportion of total electricity produced by nuclear power in the world is expected to rise from 5 per cent to at least 40 per cent by the end of this century. By then, for example, the U.K. and U.S.A. should be meeting 50 per cent of their electricity needs from nuclear power and Japan 33 per cent.

Summary

At the present rate of usage of fossil fuels, the world's energy reserves of oil and natural gas would each have less than 50 years' supply and could be severely diminished by the end of this century. Extensions to reserves are possible with new discoveries and improved recovery techniques but regardless of resource sizes there are physical restrictions on the ability to significantly increase production rates of fossil fuels to match potential demand increases.

TABLE 5

1977 estimates of Western world nuclear capacity (GWe)

		1977	1980	1985	1990	1995	2000
Workshop on Alternative Energy Strategies							
	—high			413			1772
	—low			291			913
World Energy Conference				270			1141
International Atomic Energy Agency							
	—high		180	415	740		1900
	—low		150	310	520		1000
Uranium Institute							
	—high	81	166	326			
	—low			264			
OECD							
	—high	87	146	368	700	1220	1890
	—low	87	146	278	504	750	1000

The underlying risk is that by using oil and gas for unlimited purposes, these reserves will soon be depleted. Oil, in particular, should be used sparingly for electricity generation because substitutes are available and oil is vital to the transport and petrochemical industries. On the other hand, natural gas reserves are predominantly located in a small number of countries which might make importing countries doubtful of being able to ensure regular supplies at reasonable prices, a disadvantage in terms of energy planning.

Coal as an energy resource is plentiful, although its disposition, like gas, is unsatisfactory. Major coal reserves are held by a few, and many countries have no coal or very little. Coal also suffers from the disadvantages of pollution, especially the low grade high sulphur coal now available, and there are the physical constraints on production and transportation and the reluctance or difficulty of producing countries to increase exports in the future.

Nuclear power currently stands as the only viable alternative to fossil fuels in the generation of base-load electricity and many countries are becoming committed to nuclear power: currently 20 countries have nuclear power stations and this will increase to 40 known countries by the 1990s.

WESTERN WORLD URANIUM DEMAND

Central to the future requirements of uranium is the likely effect of President Carter's plan to restrict the reprocessing stage of the nuclear fuel cycle. Without reprocessing and recycling of plutonium and uranium and the operation of breeder reactors, the future uranium required increases considerably. It is unlikely however, that the world will respond readily to the proposal. Many countries see breeder reactors as minimizing their fuel import bills and ensuring adequate supplies of uranium being available for a long time. President Carter saw Australia as being vital to his plan. Australia, with its untapped reserves of uranium largely uncommitted, has the capacity to provide reassurances through fuel supply to overseas electric utilities to operate only conventional reactors without recourse to breeder reactors. While it may be wasteful in lost fuel efficiency the Carter plan could satisfy public questioning of the "plutonium economy". The plan would also present to Australia a larger market for the sale of uranium provided no major increases are made to the world's uranium reserves in the meantime.

Opposition to the Carter plan was voiced at the Iran Conference on Transfer of Nuclear Technology held in Persepolis in 1977, when concern was expressed that to defer reprocessing and recycling strikes at the very root of the nuclear choice, i.e. fuel efficiency. It is widely accepted that safeguard proposals as a deterrent to nuclear weapons proliferation will eventually become universally acceptable. There is bound to be widespread recycling of uranium and plutonium after 1985, but it is unlikely to have a strong influence in the market for uranium much before the year 2000.

It could be confidently expected that as the future energy gap becomes realized, the growth of nuclear generating capacity will accelerate and, by allowing up to 13 years lead time, greater growth should be apparent from 1990 onwards. From then on, Australia should be able to sell at full planned capacity which, on our present resources, could be at least 23,000 tonnes U_3O_8 per year.

The industry is now experiencing a downward revision of uranium requirements brought about by the failure of electrical utility plans to materialize for a number of reasons tied to electrical consumer demand, unused capacity, public opposition, licensing delays, environmental constraints, delay in completing the nuclear fuel cycle and escalating construction costs. In the past a nuclear power programme might have been replaced by an incremental increase in fossil fuel power generation. Such an option is not now readily available or realistic.

The demand for uranium will strengthen to the end of the century and beyond and provide sufficient market for the sale of Australia's present reserves. In the years to 1990, however, production could be limited to avoid an over-supply situation arising. Uranium tends to be purchased under contracts with deliveries to be made many years ahead. As a result a large proportion of uranium requirements to 1985 are committed under long term contracts, leaving Australia with restricted opportunities, i.e. the uncommitted demand which is difficult to estimate. The market from 1985 to 1990 is also partly committed but from 1990 is largely uncommitted and it is from 1990 that Australian producers could sell to the full extent of their production plans.

Western world demand for uranium has been estimated by many agencies. A selection of these, for comparative purposes, is shown in Table 6. The best estimate that can be placed on the Western world demand for uranium given the projected electrical generation growth and the proportion to be generated by nuclear power is stated in Table 7. Slippages in nuclear power programmes are not expected to occur after 1990.

WESTERN WORLD URANIUM SUPPLY

Uranium production in 1959 for weapons purposes was about 35,000 tonnes. This level has never been reached since in the Western world, but production for peaceful purposes has been rising from the later 1960s to match the planned increase in nuclear generating capacity and in 1976 was 23,000 tonnes. Last year Western world production was 28,000 tonnes. The major resource countries shown in the First Report of the Ranger Uranium Environmental Enquiry (1976) are listed in Table 8.

To give dimension to these estimates, 4 million tonnes of uranium would produce 30,000 GWe for a year, the same as would be obtained from

TABLE 6

Comparison of Western world uranium requirement estimates ('000 tonnes uranium)

		Uranium Institute (June 1977)		OECD (Dec. 1977)		International Atomic Energy Agency (May 1977)		Workshop on Alternative Energy Studies (1977)		Australian Atomic Energy Commission (June 1977)	Ford Foundation (1977)	
		High	Low	High	Low	High	Low	High	Low		High	Low
1980	per year	34	32	43	41	43	32	48	38	38		
	cumulative	146	141	130	128	175	141			136		
1985	per year			88	65			85	55	70		
	cumulative			477	411					420		
1990	per year	94	74	156	85	146	74	130	80	106		
	cumulative	813	714	1107	796	1115	714			860		
2000	per year	166	110	338	125	339	110	230	118			
	cumulative	2200	1650	3591	1859	3600	1650				3180	2860

TABLE 7

Western world uranium demand 1977-2000 ('000 tonnes uranium)

1977	25
1980	38
1985	72
1990	144
2000	260
cumulative	3031

the burning of 4×10^{11} bbl of oil or 10^{11} tonnes of bituminous coal. Four million tonnes of uranium supplied to the year 2000 would satisfy all cumulative estimates of demand as shown in Table 6. The reasonably assured resources to $US30/lb U_3O_8 are about half this figure, i.e. 2 million tonnes, and this amount does not meet estimated cumulative demand to the year 2000, recycling notwithstanding. It is this gap in low cost potential supply that encourages a continuation of exploration programmes around the world for economic deposits of uranium.

HISTORY OF THE AUSTRALIAN URANIUM INDUSTRY

The commercial development of uranium began during World War II as a result of the military requirement. The U.S.A. which had no domestic uranium industry at the time, imported its requirements from Canada and Zaire. After the war the military requirement continued and the U.S.A. and U.K. procurements were handled by the Combined Development Agency which was

TABLE 8

Western world uranium resources ('000 tonnes uranium)

	Reasonably assured		Estimated additional to $US30 per lb U_3O_8	Total
	to US$15 per lb U_3O_8	$15-$30 per lb U_3O_8		
Canada	145	28	605	778
U.S.A.	331	269	815	1415
South Africa	186	90	74	350
Australia	312	—	41	353
Western Europe	61	426	181	668
Others	116	58	111	285
Total	1151	871	1827	3849

established for that purpose by the governments of the U.S.A., U.K., and Canada.

Subsequently the Australian Government encouraged exploration for uranium, and a guaranteed price schedule for the purchase of uranium ores was implemented. Under the scheme all uranium was sold to the Combined Development Agency through the Atomic Energy Commission, an arrangement which lasted until 1964. Tax-free rewards were also offered for discoveries and something like $225,000 was paid out to 35 prospectors.

Similar schemes operated elsewhere. In the U.K. purchases were guaranteed for 10 years with grants to aid mine development and encourage exploration throughout the British Colonies. Canada and the U.S.A. were also trying to encourage domestic exploration and production and Britain and the U.S.A. made an agreement to receive uranium from South African gold mines.

Mineralization had been discovered at Rum Jungle in 1949 and, in 1953, Territory Enterprises Pty. Ltd. a subsidiary of Consolidated Zinc Pty. Ltd. (now CRA) operated the project on behalf of the Australian Government. It was Australia's first uranium mine. From 1954 to 1971, three orebodies at Rum Jungle were mined by open cut methods and the ore was treated on site to produce yellowcake. Also in the Northern Territory, the Adelaide River mine of Australian Uranium Corporation N.L. operated to 1957 (treatment being carried out at Rum Jungle) and United Uranium N.L. opened the El Sharana mine in 1956 and a plant at Moline in 1959, which treated ore from nine deposits in the South Alligator field until 1964. South Alligator Uranium Ltd. also had a treatment plant at Rockhole Creek from 1959 to 1962.

In South Australia, an underground mine at Radium Hill was developed in 1954 by the Department of Mines and the ore was treated at a plant in Port Pirie which came into operation in 1955 and continued to 1962. The Mary Kathleen mine commenced production in 1958, shutdown in 1963, and re-opened in 1976; it is now Australia's only operating uranium mine.

From $A1.70/lb offered in 1949, guaranteed prices steadily rose and by 1958 ranged up to $A4.50/lb U_3O_8. From July 1958 however, prices paid to domestic mining companies for uranium oxide remained confidential and were subject to negotiation between producer and the Australian Atomic Energy Commission.

Australia ultimately had several mines in operation and six treatment plants. Production reached a peak in 1961 with 1400 tons of uranium oxide, but by then contracts were coming to an end and by 1964 when the U.S.A. and U.K. cut back in purchases from all sources, only Rum Jungle was still in production. Uranium continued to be mined at Rum Jungle until 1971 but all production from 1964 was stockpiled by the Australian Atomic Energy Commission and amounted to 2050 tonnes U_3O_8.

During the period 1954-71, Australian production of U_3O_8 was approximately 9200 tonnes of which the major contributors were Rum Jungle, with 3530 tonnes U_3O_8, Radium Hill/Port Pirie (850), and Mary Kathleen (4080).

AUSTRALIAN RESOURCES

With the withdrawal of the U.S.A. and the U.K. from the market in the early 1960s production in Australia ceased and exploration declined. Final deliveries under Combined Development Agency contracts were made in 1964. The Government had fostered uranium exploration in the 1940s and 1950s and it did so again in the 1960s and 1970s, but for entirely different reasons. The Government was then intent on developing reserves for future needs in Australia and the known low cost reserves were inadequate to support a nuclear power programme. The 1967 export policy emphasized Australia's needs and by 1971, following some outstanding exploration results, the Government announced its intention to maintain a system of export control which would not involve quantitative restrictions. Consequently, Australia's uranium resources now amount to a total that must be close to half a million tonnes of U_3O_8 which stamps Australia potentially as a major world producer. Details of individual deposits are set out in Table 9.

MARKETS FOR AUSTRALIAN PRODUCTION

Australia has no nuclear power industry. Any future industry by the year 2000 is not likely to be significant in terms of demand for domestic uranium in which case, the total Australian production can be taken to be available for export.

Projected increases in world uranium requirements in the late 1980s to 2000 will place heavy demands on the uranium production industry. It is likely that all present producers, irrespective of their costs of production, will find markets; the only factor to alter this situation on the supply side would be the development of additional reserves in the world. Working on the lead time of 5-8 years to develop a mine from initial discovery, it is possible to see some of the present

TABLE 9
Principal Australian uranium deposits

Company	Commenced exploration	Date of discovery	Deposit and location	Initial reserves (tonnes U_3O_8)	Latest resource estimate (tonnes U_3O_8)	Production plans (U_3O_8 tonnes/year)
Noranda Australia Ltd.	1966	1970	Koongarra, N.T.		18-30,000 assured	2000
Pancontinental Mining Ltd.	1970	1971	Jabiluka, N.T.	3,500 (Jan. 1973)	207,400	3000 rising to 9000
Electrolytic Zinc Co. of A'sia Ltd./Peko Wallsend Ltd./A.A.E.C.	1967	1970	Ranger, N.T.	71,000 (Nov. 1970)	100,350	3000 rising to 6000
Queensland Mines Ltd.	1959	1970	Nabarlek, N.T.	8,000 (Aug. 1971)	9,100	1080
Mary Kathleen Uranium Ltd.		1954	Mary Kathleen, Qld.		6-7,000	423 (actual 1976 production)
Oilmin N.L./Western Uranium Ltd.	1967	1970	Beverley, S.A.	2,500	15,000	1360
Western Mining Corporation Ltd.	Late 60s	1972	Yeelirrie, W.A.	46,000 (Mar. 1973)	46,000	2500 approx.
Other					47,000	

TABLE 10

Comparison of estimates of U.S.A. uranium requirements and domestic production capability
('000 tonnes uranium)

	1980	1985	1990	2000
U.S. Dept. of Energy (Oct. 1977)				
Requirements—high	15	28	45	77
—low	12	21	31	52
Production—"could"	21	31	42	48
The Uranium Institute (Oct. 1977)				
Requirements	15	26	35	45
Production	17	22	19	
Australian Atomic Energy Commission (June 1977)				
Requirements	17	29	43	
Edison Electrical Institute (March 1977)				
Requirements	16	28	30	
Production	18	20		
OECD (December 1977)				
Production	23	36	47	

market opportunities being eroded, notably by an increased domestic production capability in consuming countries. Fundamentally, there is no threat of supply shortfalls in the world up to 1985. Thereafter, new deposits (such as Australia's) will need to be developed to meet world requirements.

U.S.A.

The U.S.A. is the largest user of nuclear power and stands out as being one of Australia's biggest potential customers. A comparison of U.S.A. uranium demand and domestic production is set out in Table 10.

President Carter announced last year a desire to defer advanced nuclear technologies which will mean the U.S.A. will need to use more light-water reactors to help meet its energy needs. If accepted by Congress, U.S.A. uranium requirements will be stepped up in the late 1980s when the additional reactors might start taking effect on the demand for uranium.

An embargo on the importation of foreign uranium into the U.S.A. has existed but it is gradually being relaxed and will be removed entirely by 1985. The Ranger Uranium Environmental Inquiry First Report (1976) noted that the Australian Atomic Energy Commission submission to the Ranger Inquiry estimated that the most that foreign producers could expect to sell in the U.S.A. in 1985 would be 5,000 tonnes of uranium. From 1985 the U.S.A. consumption could move ahead but the extent to which this increased demand would be matched by domestic production capability is in question. The U.S.A. National Academy of Sciences (1975) has asserted that major shortfalls will result in U.S.A. uranium production to 2000 and beyond and, more recently, Boyd (1977) also confirmed a future shortfall if present U.S.A. policies of pollution, safety, and land management continue.

Australia could expect to sell little uranium to the United States for use up to 1983 because of its current contracted procurement position. However, sales could be made of 1,000 tonnes/year for delivery in 1985, increasing to 5,000 tonnes/year in 1990, assuming U.S.A. production remains at projected 1985 levels and incremental increases in requirements are met from foreign sources.

It must be noted, however, that demand forecasts are being continually revised downwards, not only for U.S.A. potential but for the world generally, to take account of energy trends, particularly slippage in nuclear power programmes. This situation has tended to make demand forecasts outdated in a short time and it makes production planning all the more difficult.

Japan

Japan serves as another important market for Australia. Japan already has contracts with Electrolytic Zinc Company of Australasia Limited, Peko-Wallsend Ltd., and Queensland Mines Ltd. who have, to-date, had their supply commitments honoured from the A.A.E.C. stockpile. As with the U.S.A., the potential Japanese market for Australian uranium will not be realized until the late 1980s by which time, all Australia's known deposits could be working.

Japan has cut back its future forecast for nuclear growth due to slowing down in the growth rate of its GNP. However, 1990 demand for uranium could be double the 1985 estimate. There should be 30,000 MWe of installed nuclear capacity in 1985, doubling to 60,000 MWe in 1990 and doubling to perhaps 120,000 MWe by the year 2000. At this rate nuclear capacity would provide 33 per cent of electrical generating capacity by the year 2000.

Japan is a special case. It depends almost entirely on imported fuels with oil providing 70 per cent of its energy requirements. Japan needs watertight assurances on fuel supply while Australia, apart from commercial considerations, re-

TABLE 11

Western Europe nuclear generating capacity (GWe)

	1977	1980	1985	1990
German Federal Republic	6	14	25-30	50-55
France	5	16	30-35	55-60
United Kingdom	8	9	11	14-16
Others	13	23	44-54	79-91
Total	32	62	120	210

TABLE 12

Summary of possible Australian U_3O_8 sales ('000 tonnes/year)

	1985	1990	1995
U.S.A.	1	5	7
Japan	2·5	5	8
W. Europe	6	13	15
Other	—	2	2
Total	9·5	25	32

quires suitable safeguard assurances from every country buying Australian uranium. Australia should obtain a large share of the uranium sales to be made to Japan to satisfy its nuclear power growth. Sales to Japan could be further increased if Japan accedes to the Carter plan to defer the breeder reactor which Japan has been planning for use in the 1990s. From 1990 Australia could expect to sell 5,000 tonnes of uranium to Japan rising from 2,500 tonnes/year in 1985.

Western Europe

Prospects of selling Australian uranium in Western Europe are good. The E.E.C. countries, together with Spain, Sweden, and Switzerland have vigorous nuclear power programmes. Taking Western Europe as a whole, nuclear capacity will grow by 15 per cent/year from 35 GWe now to about 200 GWe by 1990, of which the E.E.C. could be 150 GWe by 1990.

Estimates by Messer (1977) confirming nuclear growth are shown in Table 11. In 1985, the uranium demand in the E.E.C. will be about 20,000 tonnes uranium rising to about 35,000 tonnes in 1990. Indications are that about half 1985 demand has been committed leaving approximately 10,000 tonnes yet to be contracted. Australia could probably expect to secure contracts for up to 5,000 tonnes of uranium from the E.E.C. in 1985, increasing to 10,000 tonnes in 1990. In addition, there would be contracts for 1,000 and 3,000 tonnes respectively from other countries in Western Europe.

Public opposition to nuclear energy in Europe has been very evident and the market estimates take account of that fact. However, Europe like the rest of the Western world, faces energy shortages from 1985 if the current reliance on fossil fuels for electrical generation continues. It is expected that current opposition will subside and nuclear energy will reach its full potential in the 1990s, there being a time lag in society's requirements and the matching technological response.

Summary

A summary of Australia's future possible sales of uranium is shown in Table 12.

The market will play a dominating role in determining the development of Australian deposits. Not all the deposits could be developed before 1985 based on potential sales prospects for uranium. Due to the lack of market opportunities, deposits should come into production sequentially, i.e. once output from the first project has been contracted then another project can commence and so on.

Over-production is to be avoided as it would only result in forcing prices down, the possible re-introduction of an import embargo in the U.S.A., and the closing of sub-economic mines. With a looming energy gap, these cyclical changes will badly affect both suppliers and users.

The uranium supply industry has been bedevilled by over- and under-demand situations throughout its history with increasing and decreasing prices as a consequence. It is in the interests of both sides in the uranium market—supplier and user—that supply and demand be in equilibrium, without wide fluctuations. Stockpiling of uranium in suppliers' hands, when demand is slack, and in the users' hands when supply is in question, will not serve the long-term interest of either side. Supply of electrical energy is a long-term business and the long-term interests of both supplier and user must be protected. The consequence of an over-supply situation would be disastrous for an infant uranium mining industry in Australia.

CONCLUSION

People's aspirations to improve their standards of living, combined with increasing mechanization and mobility, will sustain a continuing increase in energy consumption in the world. There is cause for concern in the widening energy gap in the future as we continue to draw on fossil fuels as the major source of energy. What is alarming is the high depletion rate of oil, which should be reserved for purposes of transport and feedstock to the petrochemical industry.

Other sources of energy will need to be developed but for the time being, nuclear power is the only proven technology capable of meeting the shortfall of supply. Accordingly, the cumulative requirement for uranium could approach 4 million tonnes between now and the year 2000. The world's low-cost reserves would presently only fulfil half this need.

Many countries are looking to Australia to supply uranium in the 1980s and it is reasonable to forecast, because of the supply-demand position in the short-term, that Australia's entry to the market can only be moderate. Australia can anticipate a share only of the uncommitted market in the 1980s but after that the market will build up so that full Australian capacity could be sold from 1990 onwards. Selling for long-term delivery contracts to secure Australia's market share should commence now.

The economic benefits to Australia from the uranium industry would be significant as has been shown by W. D. Scott & Co. (1976). Uranium export earnings would exceed those from sugar or beef and almost equal those from wheat or wool. The ultimate benefits to Australia are not only in terms of the balance of payments. but also in employment opportunities and the development of the Northern Territory.

Up to 14.000 new jobs could be created from the industry with employment in construction, operations, and allied industries. The regional economic impact from uranium mining would be reflected in reduced income disparities, compared with other states, from the expansion of local industrial growth. It is quite likely that the economic benefits from uranium will assist in the development of the Northern Territory towards eventual statehood.

Energy resources are vital to the world. In the future it is likely that there could be very few countries as net energy exporters. Australia, with its uranium, could be one. At the same time, there will still be many countries depending on imported fuels. Australia has an obligation to the world to assure a long term supply of uranium and the Australian Government has already announced its intention of following such a policy.

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GEORGE A. MACKAY

Managing Director
Electrolytic Zinc Company of Australasia Limited
390 Lonsdale Street, Melbourne, Victoria, Australia

George A. Mackay was born in South Africa and arrived in Australia in 1961. Mr. Mackay is now an Australian citizen. In 1949 he graduated from the University of Witwatersrand, Johannesburg, with a degree in mining engineering and he then worked predominantly in the Orange Free State gold mines.

Since arriving in Australia Mr. Mackay has been Senior Mining Engineer and Underground Manager with The Zinc Corporation Ltd at Broken Hill, Underground Manager for The Zinc Corporation Ltd./New Broken Hill Consolidated Ltd. mines, and Manager at Mt. Tom Price operations of Hamersley Iron Pty. Ltd. in Western Australia.

In September, 1969 Mr. Mackay joined the Electrolytic Zinc Company of Australasia Ltd. (EZ) as General Manager, Mining Division. In 1973 he was appointed Managing Director of the company. He is a Director of a number of EZ companies and subsidiaries and of the Australian Mines and Metals Association.

He is a Councillor of the Australian Mineral Industries Research Association Ltd. and Australian Mining Industry Council. In February, 1974 Mr. Mackay was appointed Chairman of the Australian Uranium Producers' Forum and relinquished this post early in 1978.