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ASSESSMENT

FOSSIL FUELS AND THE GREENHOUSE EFFECT

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OFFICE OF NATIONAL ASSESSMENTS
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25 November 1981

Prime Minister

FOSSIL FUELS AND THE GREENHOUSE EFFECT

The attached assessment, which has been endorsed by the Economic Assessments Board, examines the implications of the increasing accumulation of carbon dioxide in the atmosphere as a result of the burning of fossil fuels, with special reference to Australia as a producer and exporter of coal.

The following is a summary of the assessment and includes its key judgements.

- Carbon dioxide emitted by fossil fuels enters the atmosphere, currently at the rate of around 18 billion tonnes per annum. Scientists now agree that if such emission continues it will some time in the next century lead to a discernible 'greenhouse effect' whereby the earth's atmosphere becomes measurably warmer with related climatic changes.

- A doubling of atmospheric carbon dioxide, which on present indications could occur around the middle of the next century, would require major economic and social adjustments, but would result in both benefits and disadvantages that would be unequally distributed. Some regions would make gains, such as from improved rainfall and agricultural prospects, whilst others would lose.

- A quadrupling of carbon dioxide, which scientists believe could occur by the end of the next century, would have widespread disadvantages resulting from massive changes such as a melting of the West Antarctic ice sheet.

- The rate of economic growth and of improvements in energy efficiency will affect the speed at which the problem develops.

. Results from detailed research of the problem will not be available until the end of this decade. Until then governments will not have available to them sufficient data on which to develop firm policy initiatives. This may not prevent mounting concern at the problem, which could force governments to address some of the issues involved before adequate data is available and before there is a need for action. By the end of this century, and in the absence of cost-effective technology to reduce the carbon dioxide problem, such concern could culminate in pressure for action to restrict fossil fuel usage.

. Any action to control atmospheric carbon dioxide would be directed at fuels with the highest emissions relative to useful energy, such as oil shale and coal. Such action would enhance the value of fuels such as oil and natural gas.

. The pro-nuclear lobby can be expected to emphasize the adverse nature of rising carbon dioxide levels in the atmosphere. Scientific data that confirm the problem would enhance the prospects of nuclear power, which could have a greatly expanded role next century if safety and safeguards problems are satisfactorily resolved.

. There are potentially adverse implications from these developments (if realised) for the security of Australia's export markets for coal beyond the end of the century.

M. J. Cook

(M.J. Cook)
Director-General

FOSSIL FUELS AND THE GREENHOUSE EFFECT

A. ORIGIN OF THE PROBLEM

The "greenhouse effect" occurs when the atmosphere, because of the release of carbon dioxide from the combustion of fossil fuels, ceases to be transparent to heat thrown back from the earth's surface, but instead absorbs some of it. The atmosphere thereupon warms up, and this in turn increases atmospheric water vapour, which amplifies the effect. Scientists generally agree that, if the present rate of build-up of carbon dioxide in the atmosphere continues for several decades, the result will be a warmer earth with a climate different from today's. The way this prospect can influence Australian fossil fuel exports is the subject of this assessment.

There is another reason for our looking at this matter. It is that the carbon dioxide problem is likely sooner or later to arouse public concerns and so engage the attention of governments. Already the "greenhouse effect" has been raised by Chancellor Schmidt with other western leaders, is of concern to environmentalists, and is used by the pro-nuclear lobby to support its case. Public attention to the problem is likely to increase as scientific research results are published and are sensationalised by the press and others.

B. BACKGROUND

Numerous substances that could alter our climate or environment are being added to the atmosphere by man. The list includes, besides carbon dioxide, various chemicals that are not considered in this assessment, such as sulphur dioxide, nitrogen oxides, and the fluorocarbons. Atmospheric carbon dioxide, which is uniformly distributed over the globe, has increased by an estimated 23% since the beginning of the industrial era, and the trend continues (Figure 1). Already some reports have sought to link small temperature rises and a reduction in the area of Antarctic ice shelves to this increase, but another ten to 20 years will pass before there is a clearly detectable

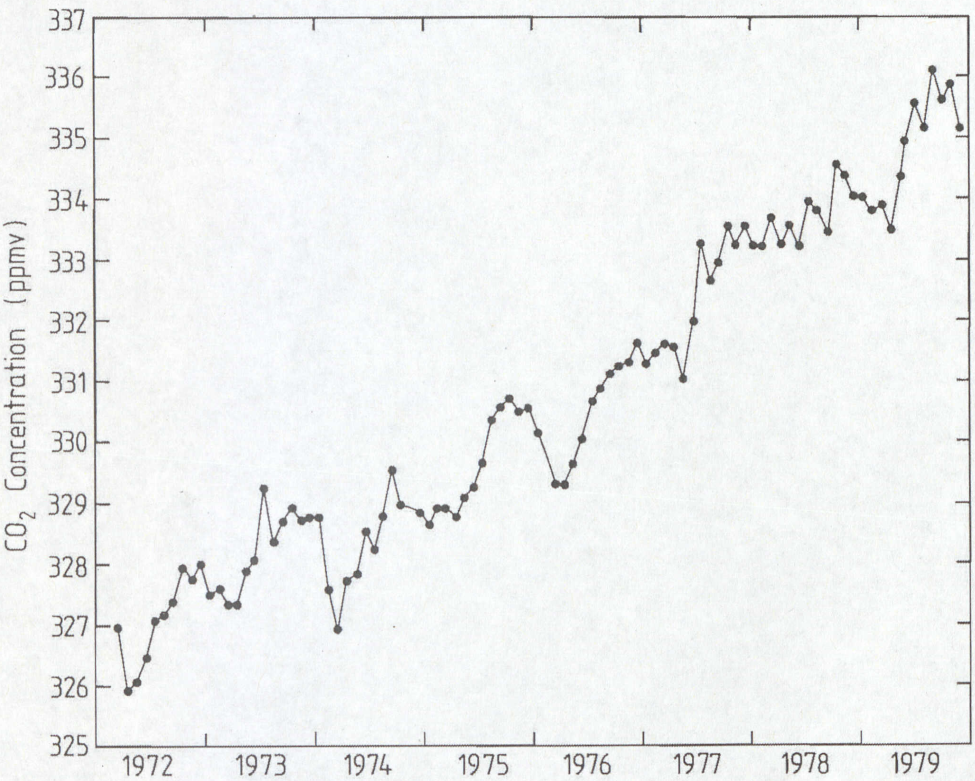

Figure 1

The carbon dioxide content of the atmosphere has been rising steadily since the beginning of the industrial age. This is confirmed by observations made in recent years at several remote locations around the world. Those shown in this figure were obtained in the atmosphere over Australia by CSIRO scientists. The main fluctuations are due to seasonal variations in biological activity and the movement of carbon dioxide from the northern hemisphere.

change in the earth's climate. So far, concern about the greenhouse effect is based solely on scientists' predictions, but since those predictions influence public opinion and consequently government policies the trend of scientific opinion is crucial. Already, long before any physical problems emerge, the publication of preliminary research results is causing speculation that could influence public opinion in as yet undetermined ways. The discussion is clouded by the attention of environmentalists, and by the partisans of nuclear power, who have their various reasons for discouraging the use of fossil fuels.

The carbon dioxide issue has attracted interest world-wide, from a variety of research groups in different disciplines. The relevance of their work has been emphasised by reports from such bodies as the US Council on Environmental Quality. In Australia, where dry conditions and location in the Southern Hemisphere mean that the carbon dioxide problem has specific consequences, the CSIRO, the universities and other research groups are investigating aspects of the problem. More exhaustive programs have been organised by the US Department of Energy (DOE), and by the International Institute for Applied Systems Analysis, which is based in Austria. The DOE intends to issue assessments in 1984 and 1989, which will represent "an international consensus of the perceived costs and benefits of the carbon dioxide problem, and the confidence that can be placed in those estimates". Until then, regional climatic changes cannot be predicted with precision, but there is a convergence of opinion among scientists working on the problem. Their statements abound with phrases like "basic agreement", "60% sure", or "80% sure". They feel that about ten years' large-scale, multi-disciplinary research is needed to clarify the issue. In some areas, such as studies of the possible economic and social consequences of predicted climate changes, work has hardly begun. This does not mean that the outline of results that follows is unreliable, but it does mean that a lot more research needs to be done. It expresses a consensus of scientists mature in the related disciplines, and final results are not expected to be grossly different from present estimates.

C. FUTURE CARBON DIOXIDE LEVELS

Straightforward compound growth rates of 4% and 2% per annum in the use of fossil fuels can be expected to cause a doubling of the pre-industrial level of atmospheric carbon dioxide by the years 2025 and 2050 respectively. Actual growth rates for the period 1940 to 1973 were 4%, and for 1973 to 1979 were about 2.5%. Estimates of total energy (predominately fossil fuels) growth rates for OECD countries for 1985 to 1990 run from 1.7% to 2.8% per annum, at economic growth rates of between 2.7% to 3.2%. Table 1 shows the carbon dioxide levels predicted by a more long-term model that recognises fossil fuels as constituting a finite resource, which fits actual data up to 1977, and which assumes future use of fossil fuels will be restricted only by cost and availability.

Together these models forecast a doubling of carbon dioxide levels by around the middle of the next century, which, for reasons explained below, may be judged bearable, and a quadrupling by around the end of that century, which would be unacceptable. However, growth rates lower than those assumed would retard the onset of the problem, while higher growth rates would accelerate it. If an international agreement were to be proposed on an upper limit for atmospheric carbon dioxide then that limit would probably be round about a doubling and certainly well short of a quadrupling.

D. QUADRUPLED CARBON DIOXIDE LEVELS

The most disturbing feature of Table 1 is the prediction of a quadrupling of carbon dioxide levels, and a global average temperature increase of $4^{o}-6^{o}C$, by 2100 AD. Given that the temperature difference between the ice ages and intermediate periods was a mere $5^{o}C$, this prediction suggests massive and unacceptable changes, including the probability of rising sea levels.

Speculation that in a century the main Antarctic and Greenland ice caps would completely melt, and thereby cause a 60m rise in sea levels, can be dismissed as fanciful. However, the West Antarctic ice sheet, which is

Table 1

Global average temperature is expected to rise with carbon dioxide levels. This table shows the predictions of a model that assumes future use of fossil fuels will be restricted only by cost and availability.

Date (AD)	pre-industrial era	1900	1958	1980	2035	2100
Origin of data	estimated	estimated	measured	measured	predicted	predicted
CO_2 levels in parts per million (ppmv)	275	290	315	338	600	1200
Approximate increase in CO_2 levels over pre-industrial level	-	-	15%	23%	2-fold	4-fold
Global average temperature increase in degrees Celsius ^{o}C	0	not measurable	not measurable	not measurable	$2^{o}-3^{o}$	$4^{o}-6^{o}$

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grounded below sea level, is a different matter: a global average temperature increase of 5°C would probably cause it to disintegrate, and raise sea levels by about 6m. Not enough is known yet to predict how quickly this might occur, but it is feared that once the process begins it could be irreversible. A rise of 6m would flood many of the major cities of the world, as well as the delta regions of rivers such as the Ganges and Mekong, which support large populations.

To avoid such changes, atmospheric carbon dioxide levels would need to be stabilized well short of a four-fold increase. That would take time. Thus even though the consequences of the greenhouse effect are long-term, pressure for action could occur sooner.

E. DOUBLED CARBON DIOXIDE LEVELS

The general scientific opinion is that, unless there are major changes in consumption patterns of fossil fuels, the level of atmospheric carbon dioxide will reach twice the pre-industrial level some time around the middle of the next century. Most of present work on the greenhouse effect revolves around the consequences of this doubling.

(i) General Effects

Scientists working on the carbon cycle are now fairly sure the increases in atmospheric carbon dioxide do in fact come from combustion of fossil fuels, and not from the destruction of forests. About half of the extra atmospheric carbon dioxide dissolves in the oceans; the rest remains in the atmosphere, accumulates there over the years, and causes the increases that have been measured. Numerous computer models, both simple and complex, converge in forecasting a global average increase in temperature of 2°-3°C for a doubling of carbon dioxide. This warming will not be uniform, but range from a rise of about 1°C at the equator to about 8°C at the poles. Such a reduction of the temperature difference between the poles and the equator would decrease the strength of global winds and shift existing climatic patterns as shown in Figure 2. It is emphasised that this diagram reflects predictions that will change as models improve and more information becomes available about periods in the earth's history when temperatures were higher than today. Existing models predict that the dry bands at present between 20° and 40° latitude will move towards the poles, and precipitation will increase over the polar regions and in low latitudes, where monsoon rains will increase. Changes of 50 to 100% in precipitation can be expected in some areas, while tropical cyclones could extend to somewhat higher latitudes. Some authorities believe that sea-level changes could occur, but a more definite answer must await a better understanding of the stability of the West Antarctic ice sheet.

In considering these predictions, it is a natural mistake to concentrate exclusively on precipitation, which is only part of the story. Research so far suggests that the effect of enhanced carbon dioxide levels on plants is either to encourage their growth or make them more efficient in their use of water. Together, the result could be that in some regions more carbon dioxide would compensate for less rain and that worldwide biomass will increase. This positive aspect can be over-emphasised, particularly because it is one part of the overall carbon dioxide problem that is amenable to investigation by controlled experiments. In contrast, there could be a reduction in the intensity of the global circulation of the ocean, which would decrease the supply of nutrients in waters on the continental margins; that would result in reduced fish catches, although there could be some compensating increase at warmer high latitudes

(ii) <u>Possible Regional Effects</u>

The more marked effects of a doubling of carbon dioxide are predicted at temperate latitudes, particularly in the USA. For example, northern wheat-growing belts could be pushed north. Since there are less suitable soils to the north, Canada's gain would not equal the USA's loss. The USSR and Canada would gain agricultural land, thanks to retreat of the permafrost, and both would probably enjoy freer navigation in their northern waters after

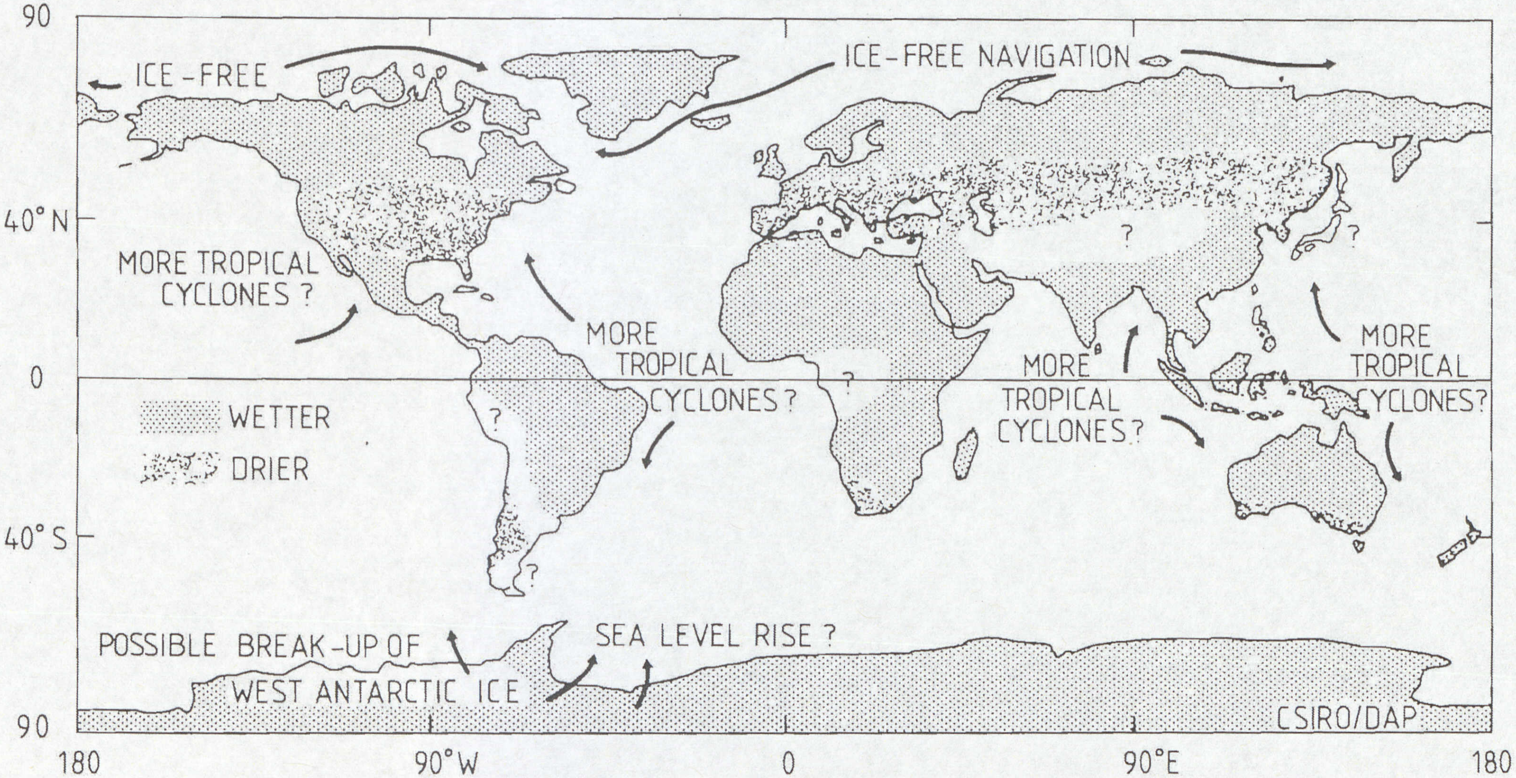

Figure 2

This map, which was prepared by CSIRO scientists, shows present best estimates of the probable climatic consequences of a doubling of atmospheric carbon dioxide. Regional details are uncertain, but the overall pattern suggests the sort of changes indicated.

a partial melting of the Arctic ice pack. However, the present Russian wheatbelt and parts of Europe could become drier. Through the rest of the world, average rainfall for each country would probably remain about the same, or increase, although there could be quite marked local and seasonal variations. Advanced countries with a good scientific, technical and administrative infrastructure, and with funds available for investment, might be able to cope with the expensive changes, which would be spread over a number of decades. Those changes include shifts in energy strategies, crop patterns, water usage and food distribution. Developing countries would have more difficulty. Low-lying delta areas would be particularly vulnerable to a rise in the sea level.

Australia would probably get increased summer rainfall north of the Victorian Alps, but would be somewhat drier to the south, particularly in Tasmania. Wheat production under our dry conditions should benefit considerably from enhanced carbon dioxide levels, and a substantial increase in yields is possible.

F. PUBLIC AND GOVERNMENT RESPONSE

As can be seen, present scientific opinion is that a doubling of carbon dioxide would mean costs at least partly balanced by an unequal distribution of benefits, but a quadrupling of carbon dioxide levels would have costs far outweighing benefits.

To make decisions in this field, national governments will need to know the detailed effect on their countries, the general impact on the world, the time-lag left to make decisions, and the long-term energy options available for each country. Such information will not be available until towards the end of this decade, when the research programs mentioned above are completed.

Meanwhile, many countries and business corporations are intent on expanding the use of coal as a fuel, apparently without full knowledge of the carbon dioxide problem. This is particularly true in developing countries. So far there is no anti-fossil fuel lobby comparable to the anti-nuclear groups, although some environmental groups are beginning to express concern. Perhaps because the problem is merely the gradual increase of a non-poisonous substance which has always been present, public alarm will only be generated by manifest change, or a threat of it, such as a rise in the sea level. Nevertheless, increasing awareness of the problem could begin to generate an opposition to fossil fuels, encouraged by pro-nuclear lobbies and environmental groups, in this decade.

Given a rational response, and depending on the research results that will become available through this decade, the long-term dangers of a quadrupling of carbon dioxide, if clearly demonstrated and publicised, would probably induce international pressures to limit the use of fossil fuels or control the venting of carbon dioxide into the atmosphere by the turn of the century. There will be ample scope for disagreement about what maximum carbon dioxide levels to fix, because each country will react to the locally unique costs and benefits of the proposed limit.

For example, the USA at present intends to expand production, consumption and trade in coal, but since it would suffer seriously even from a doubling of carbon dioxide it could well end up taking the lead in canvassing a low limit. Hoping to enhance the value of their product, oil-producing countries might follow, as would countries that rely heavily on fishing, such as Iceland. Ample coal reserves and the possibility of ice-free northern ports might induce the USSR to opt for a high limit, especially if that would harm the USA. Canada and Australia would also probably benefit from a high limit, as might China, which has both large coal reserves and a staple, rice, that would benefit from higher carbon dioxide levels. Third World countries, which could point to their relatively low per capita energy usage and their need to diversify away from oil, might press ahead with unrestricted coal use, or seek compensation from the developed world for not doing so. The attitudes of Japan and the EEC, which at present take roughly 70% and 15% respectively of Australia's coal exports, cannot yet be foreseen. Finally, countries vulnerable to a rise in sea levels might opt for a very low limit. These are, of course, all conjectures but they serve to illustrate the scope and complexity of the problem, and the importance of the research that is now under way.

G. POSSIBLE CHANGES IN ENERGY STRATEGIES

Man produces about 18 billion tonnes of carbon dioxide each year, about half of which is absorbed in the oceans. Since the chemistry of carbon dioxide is well known, the likelihood of a scientific breakthrough that will remove the problem is very small. Rather it will probably be a matter of developing major engineering projects to reduce emissions and making them economically viable, coupled with a move away from fossil fuels to other energy sources - although some of these are not without their own environmental and economic problems.

General opinion is that at present nuclear power is the only large-scale alternative to fossil fuels. Although many scientists feel optimistic about solving the associated problem of disposal of high-level radioactive wastes, because of this difficulty it has attracted an emotional and not very well-informed opposition. As the carbon dioxide problem becomes better known, an interesting contrast between public reaction to the two problems may develop. Perhaps because the nuclear threat is a personal one from small quantities of highly toxic substances, it may always arouse more fear than the more general, pervasive and long-term dangers of ever-increasing atmospheric carbon dioxide. Nevertheless, the next century could see nuclear power vastly expanded while fossil fuels would be used in such a way as to restrict emissions of carbon dioxide.

Natural gas and oil derivatives deliver more usable energy relative to carbon dioxide than other fossil fuels. That is why the greenhouse effect could enhance their value. Present shale oil, coal gasification and coal liquefaction processes generally cause more carbon dioxide than if the fuel were burnt directly, but methods might be found in future to use nuclear power to synthesise portable liquid fuels which give lower emissions. It might be possible for raw coal to be burned in central locations, such as power stations built close to the sea, where carbon dioxide can be chemically stripped from emissions and dissolved at depth in the oceans. Wood might be used for home heating and cooking; it is a renewable energy source which can cycle rather than increase atmospheric carbon dioxide because trees absorb carbon dioxide. The greenhouse effect will provide additional incentives to economize energy and to develop alternative energy sources, such as solar, biomass, hydro-power, wind, geothermal and other renewable energy sources. By the end of this century alternative energy sources other than hydropower might correspond to only 3% of current consumption, but they are probably destined to much greater growth thereafter. Other possibilities, such as nuclear fusion, are still at the basic research stage.

Implementing these energy strategies would be expensive and their effectiveness in terms of carbon dioxide emissions cannot be quantified. Policies aimed at restricting carbon dioxide emissions would have their biggest impact on fossil fuels that deliver relatively less usable energy per unit of carbon dioxide emitted, i.e., oil shale and coal liquefaction, followed by coal.

Fossil fuel consumption after an agreement to limit the level of carbon dioxide in the atmosphere cannot be predicted, but, because carbon dioxide from fossil fuels accumulates, the annual consumption of fossil fuels leading to emissions must not simply peak but thereafter decline. Without any form of emission control, some preliminary work indicates that if carbon dioxide levels are to be limited to a doubling and use of fossil fuels peak at about 2040, then the peak would be about 170% of today's level and annual fossil fuel growth rates would need to continuously decline from an initial growth rate of about 1.3% in 1980 to 1% in the year 2000, and to zero in 2040. Thereafter fossil fuel use would need to decline and approach a limiting value of about 90% of today's level. These growth rate figures are less than the unrestricted growth rate figures discussed in Section C.

H. IMPLICATIONS FOR AUSTRALIA

The development of Australian fossil fuels will almost certainly not be affected by restrictions on their use during this decade, while the problem is still being researched. At the end of the decade, as public knowledge increases, as detailed and authoritative research assessments appear, and as climatic changes perhaps become measurable, pressure to restrict carbon dioxide emissions might begin, with an urgency determined by the research results. If that pressure were in time to result in government actions to limit the burning of fossil fuels, the value of oil and natural gas reserves and of uranium would be enhanced at the expense of oil shale and coal. There could in those circumstances be adverse consequences for Australia's coal output and exports (and beneficial consequences for Australia's production and export of uranium).

In global terms, Australia's role in the fossil fuel market is modest. The estimated coal requirements of the OECD in 1985 are 1200 to 1500 million tonnes, while Australian exports of black coal in that year are expected to be 80 to 90 million tonnes. Australia could well find its export market particularly vulnerable to international policies aimed at limiting the use of coal.