Fossil Fuel Consumption and the Environment

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CONTENTS

FIGURES

TABLES

Foreword

In March 1989 the Institute was invited by the InterAction Council to write a position paper for a high-level expert group considering "Ecology and Energy Options". Our brief was to assess current and likely future levels of energy consumption, and the mix of fuels, and to comment on the ecological impact of such consumption. The paper did not address in any depth two important issues on which papers were presented by other delegates, namely the potential role for nuclear power, and for renewable energies. Nor did it attempt to discuss in detail the fascinating and vital subject of depletion of biomass fuel resources. This would require a lengthy paper in its own right.

The InterAction Council consists of a group of some thirty former heads of government, from East and West, from developed and developing nations, who meet together annually to discuss important policy issues. At each session the Council adopts a brief final statement, setting out specific practical proposals. Council members then communicate these proposals directly to government leaders, heads of international organizations and other influential individuals throughout the world. Before each session the Council convenes an expert group to discuss the relevant area. It was to this expert group that the attached paper was submitted. This meeting was held in Montreal on 29-30 April 1989. The discussions at the meeting were extremely interesting and wide-ranging. The general tenor of the debate did not differ greatly from the approach taken in our paper. The full Council meeting on the subject was due to be held at the end of May 1989.

1. INTRODUCTION

Energy consumption is intimately bound up with the natural environment. As "green" issues come to the forefront of political debate energy consumption patterns should also come under close scrutiny. This paper describes the major links between commercial energy consumption and the environment, focussing especially on fossil fuels. It then looks at what would be the impact of the growth in world energy demand that is forecast by most "energy experts". The environmental consequences of such growth would in fact be catastrophic, with far-reaching economic consequences. The paper therefore considers ways in which these effects may be avoided. Fuel substitution can offer a partial solution, but it is argued that the easiest, the most effective, and the cheapest solution is energy conservation.

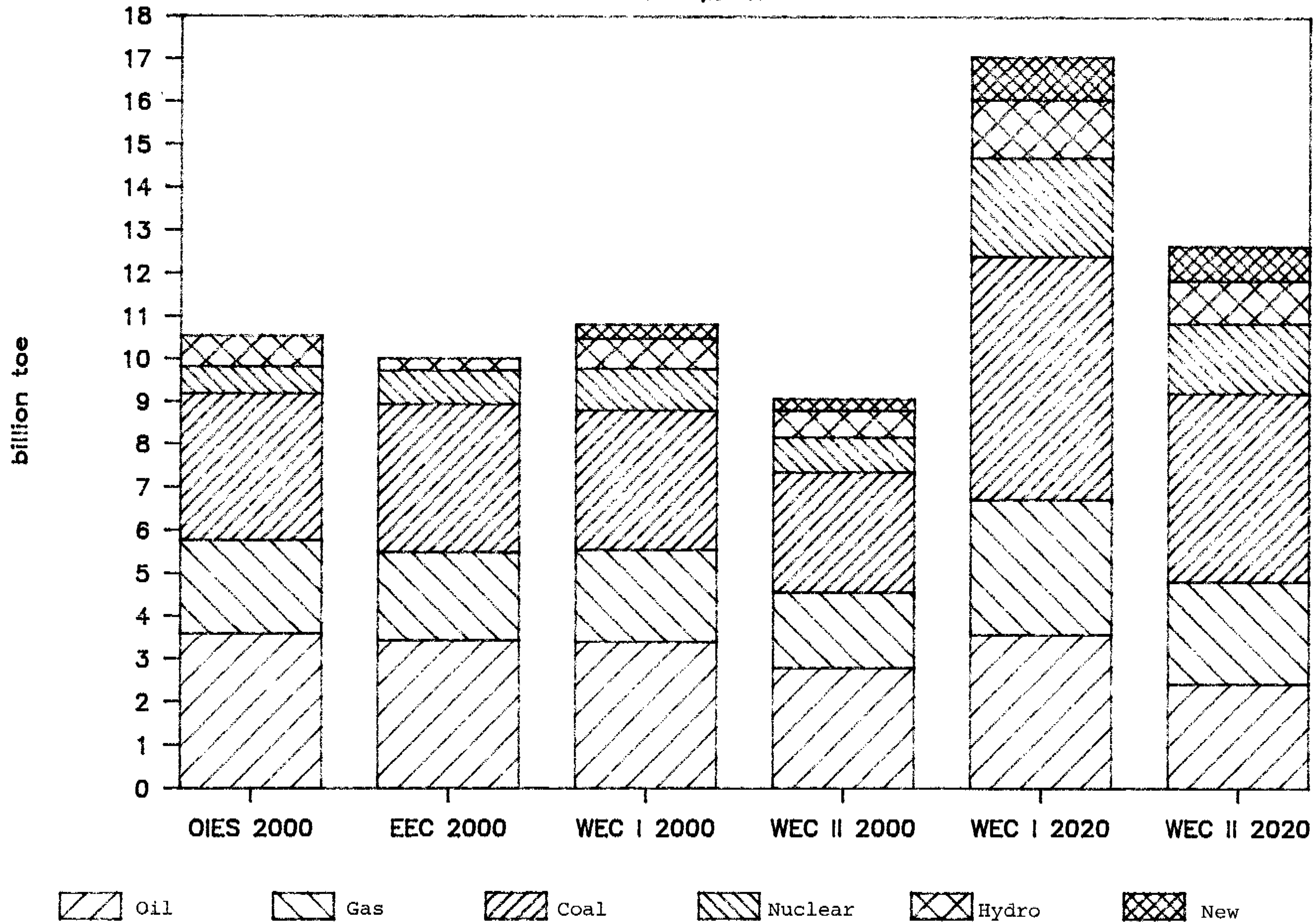
We start by looking briefly at the environmental problems associated with the use of various energy sources. The major cause for concern is the greenhouse effect, in which CO2 emissions from the burning of fossil fuels play a leading role. Meanwhile, SO2 and NOx, also emitted by fossil fuel burning, contribute to acid rain and to air pollution. However, nuclear power is associated with health risks to nuclear industry workers and to the populations surrounding power stations, as well as with the long-lasting problem of waste disposal and the hazard of disastrous accidents. Hydropower can cause enormous disruption to the natural environment and is by no means an altogether benign form of energy. The burning of traditional biomass fuels - wood, crop residues and dung - are major contributors along with coal and oil to air pollution, especially in Third World cities.

To add to all these direct effects of energy use there are numerous indirect effects, ranging from the desertification of land cleared of trees, through to the potential problems of quarrying large amounts of limestone from National Parks such as the Peak District in the UK and the subsequent disposal of vast amounts of gypsum produced from flue desulphurization in coal-fired power stations.

In order to put these various problems in perspective the paper next presents a picture of worldwide consumption of commercial energy in 1987 and projects a likely pattern of energy use in 2000. This scenario for the year 2000 has been drawn up at the OIES, on the basis of very recent figures quoted by several different oil companies and a 1987 US Department of Energy forecast for the "Free World", as well as forecasts for the whole world prepared by the EEC Commission and the World Energy Conference (WEC) in 1983. Figure 1 compares our scenario with those made by WEC and the EEC in 1983: it will be seen that our total for primary commercial energy consumption is on the high side compared with these two sources. This is largely due to the intervening collapse in oil prices, which has led most observers to revise upwards their forecasts for the year 2000. This scenario for 2000 is conventional, in the sense that it incorporates only minor changes to energy consumption habits in

Fig.1 ESTIMATES of ENERGY CONSUMPTION

2000,2020



natural gas and less coal for instance). In the absence of very rapid and dramatic political initiatives it seems unlikely (although not impossible) that these higher forecasts will prove very wide of the mark.

Beyond the year 2000 there is much more room for debate. Not least, public perceptions of environmental damage may have reached the point that, despite lack of leadership from those in power, policy initiatives are introduced to encourage increased energy conservation and more environmentally benign forms of energy, and these may begin to have an important effect. We have not therefore attempted to draw up new forecasts for energy use into the next century. Rather, we present two scenarios for 2020 prepared by the WEC, both of which predict continued growth in energy consumption, but at a relatively high or low rate.

This paper will argue that if either of these two scenarios proves accurate then the world will suffer from very serious environmental problems. A concerted effort to conserve energy could however considerably reduce the total energy consumed; and a massive promotion of new energy sources could capture a sizeable segment of the market for renewable energy. Neither of these is likely to occur however without a great effort being put into overcoming the inertia of established behaviour. We argue that such an effort is not only desirable but essential.

Finally therefore we look at the scope for using less energy, and at the costs involved in such a strategy, as well as at the means by which conservation can be encouraged/enforced in a world which has grown used to profligate and ever-increasing energy consumption, and where energy is still a relatively cheap commodity. In this context we consider a scenario described by Goldemberg and colleagues, which demonstrates the rather low levels of energy use that could prevail in 2020 if all the currently available and economic conservation measures were employed, without sacrificing projected economic growth. In conclusion we suggest a number of policy goals that need to be adopted by governments if the worst effects of energy consumption are to be avoided.

2. ENVIRONMENTAL IMPACTS OF FOSSIL FUEL CONSUMPTION

Three of the major environmental problems caused by commercial energy use are the result of burning fossil fuels: namely, air pollution, acid rain, and the greenhouse effect, in increasing order of seriousness. For each of these problems coal is the worst offender and natural gas the least noxious fuel.

(a) Air pollution

Air pollution is caused by emissions of toxic gases such as SO2, NOx and carbon monoxide together with fly ash and suspended particles. It can pose a serious threat to health, and cause a high incidence of respiratory problems. In principle these problems are soluble through the enforcement of clean air regulations. There is however a cost associated with such measures and a programme of cleaning up the air requires concerted action by governments if it is to succeed.

Both Japan and North America have made great strides in this direction. For example SO2 emissions in eastern Canada were reduced by 45 per cent between 1970 and 1985, and the eastern United States achieved a smaller 20 per cent reduction over the same period. But it is thought that these gains have now reached their limit, and it is predicted that SO2 emissions will once again increase from 24.1 million tons in 1980 to 26.8 million tones in 2000 unless further restrictions are imposed. (Harrington) NOx emissions meanwhile have not shown any decrease, and are set to increase further over coming decades.

Europe has lagged behind in clean air standards, but has belatedly brought in targets for reducing SO_2 emissions and the introduction of catalytic converters for cars.

Meanwhile cities in the Third World often sit under a pall of smog that far exceeds the worst cases of the 1950s in western industrialised countries. Sao Paulo, Rio de Janeiro, Buenos Aires, Lagos, New Delhi, Bangkok, Seoul and Mexico City are some of the worst cases. (WCED, p.18)

The simplest and cheapest way of alleviating localized air pollution is to build high chimney stacks, so that some of the fumes are transported elsewhere. The pollutants do not simply vanish in the sky however, and this practice in North America and Europe has merely led to the more intractable problem of acid rain.

(b) Acid Rain

By the 1970s Sweden was already reporting that a number of lakes had become so acidified that they had ceased to support any living organisms. "Dead" lakes are now to be found throughout Europe and the north east corner of North America, and there is little doubt that acid rain is the cause of this phenomenon. Meanwhile some 22 per cent of the total forest area of Europe (excluding the USSR) was reported as damaged in 1986, an area of 30.7 million hectares. Similar problems are reported from other areas of the world. (Brown and Flavin, p.13-14)

While these effects are difficult to assess in economic terms, it should be remembered that other growing things, including food crops, are inevitably affected as well. Japanese laboratory studies indicate that air pollution and acid rain can reduce some wheat and rice crop production by up to 30 per cent. (WCED, p.181) Furthermore it should be remembered that forest destruction by acid rain at the rates quoted above, adds significantly to the purposeful deforestation which continues in many parts of the world. The ability of forests to absorb CO_2, and hence defer the greenhouse effect, is thus reduced by pollution from those same fuels that emit the CO_2.

A major problem with acid rain is that its effects are diffuse and often found in a different country to its source. This makes it extraordinarily difficult to apply the principle of the polluter pays, and has already led to some acrimony between governments: for example between the Canadian and US governments and between the Scandinavian and UK governments. The costs of such damage are very considerable however. Corrosion damage alone in the seventeen eastern US states has been estimated at $7 billion a year. (WCED, p.181)

Technologies do exist to remove SO_2 and NO_x from smokestacks, but they can increase the cost of a new power plant by 20 per cent and add 20-25 per cent to electricity generating costs. (IEA, 1987a, p.8) Retrofitting old plants is even more expensive. Coal and high sulphur fuel oil are the worst offenders in producing acid rain, and considerable research is underway to develop "clean coal". Possible solutions include cleaning the coal before combustion, as well as actually burning it more cleanly, through the use of techniques such as fluidised bed combustion.

The high cost of "clean coal" is a very important dimension however. As discussed in the next section, in 1987 34 per cent of all coal consumption was in China and other developing countries, all of which suffer from severe capital constraints. The share of coal in the energy mix of these countries is forecast to increase, along with the total amount of energy consumed by them. China alone is likely to become the world's largest source of SO2 and carbon emissions by the year 2000. As yet very few measures have been taken in China to alleviate the effects of pollution from coal burning and localized effects are already apparent. For example a formerly forested section of Sichuan province has lost 90 per cent of its pines due to air pollution. (Brown and Flavin, p.15)

Coal is not the only culprit in air pollution and acid rain of course. In particular, vehicle exhausts are already a major contributor to pollution, and the number of vehicles worldwide is forecast to reach over 500 million by 2000 compared to just 250 million in 1975. (Goldemberg, p.62) Three-way catalytic converters can reduce emissions of some pollutants, but unfortunately they increase the quantity of fuel consumed and hence the amount of carbon dioxide released into the atmosphere. The only effective solution is to limit the number of vehicles, through promoting efficient public transport, and to enforce the use of more fuel-efficient vehicles. Prototype passenger cars such as the Toyota AVX already exist that can achieve 98 mpg, compared to the world average of 24 mpg and the US average of 19 mpg. (ibid, p.8)

(c) **The Greenhouse Effect**

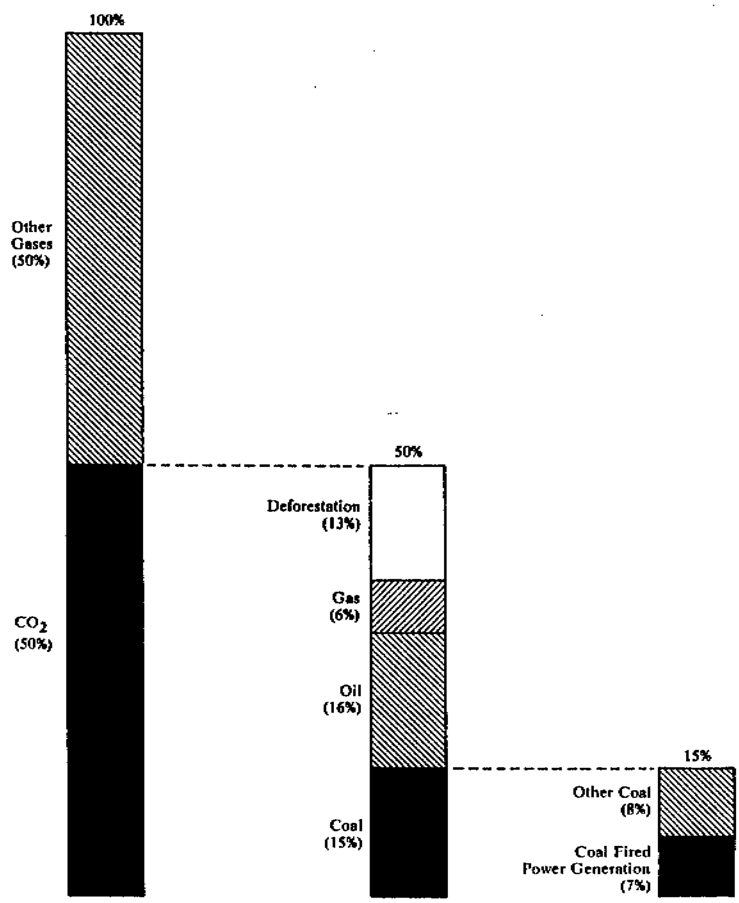
The third major environmental problem caused by fossil fuels is global warming, or the "greenhouse effect". The increasing concentration of carbon dioxide, methane, chlorofluorocarbons (CFCs), nitrous oxide and ozone in the atmosphere is acting to trap heat radiated from the earth's surface, and is raising the surface temperature of the earth.

Carbon dioxide constitutes about 50 per cent of the greenhouse gases, and most of the CO2 is released by fossil fuel combustion. Figure 2 shows British Coal estimates of the contribution of different fuels towards total CO2 emissions in 1984. Other contributors to the greenhouse effect are also the product of energy consumption however: leakages from natural gas wells and pipelines release significant amounts of methane, NOx is produced from fossil fuel combustion, and ozone results from the combination of fossil fuel pollutants and biomass-burning. Incomplete combustion produces carbon monoxide and a range of hydrocarbon gases including methane. Photochemical oxidation of the hydrocarbons leads to the formation of more CO2, CO, peroxides aldehydes and ketones. (Berreen, p.8)

The level of CO2 in the atmosphere has already increased from about 280 ppm in the second half of the 19th century to 315 ppm in 1958 and over 345 ppm in the late 1980s. If present trends in energy consumption continue, as suggested by the World Energy Conference and other forecasts discussed in the next section, then the concentration of CO2 alone would double by 2065, to 600 ppm.

Figure 2

Estimated Contribution to the Greenhouse Effect 1984



Source: British Coal Memorandum to the UK House of Commons Select Committee on Energy, HMSO, February 1989

The "natural sinks" for CO_2, forests and the ocean, simply cannot handle this level of excess CO_2. The world's forest cover is currently being massively reduced, with an area about the size of Wales destroyed each month, and damage to other forests amounting to about 80 per cent as much again. (Berreen, p.12) The oceans absorb CO_2, but at a very slow rate. Conversion of about 80 per cent of dissolved CO_2 to carbonate and its removal from the fast track of the carbon cycle is dependent on the slow mixing of the ocean surface with the deep water where the acids associated with dissolved CO_2 can be neutralised. It seems probable that the other 20 per cent of dissolved CO_2 is converted by phytoplankton at a relatively faster turnover. The precise rates of conversion are still uncertain, but overall, about 36 per cent of the excess CO_2 released into the atmosphere is absorbed by the ocean. A further 4 per cent is converted back into biomass and 60 per cent remains in the atmosphere. (Berreen, p.9) Warming of the sea surface as a result of the greenhouse effect is expected to be about 10-12 degrees C in the near-polar regions and this in itself will reduce the physico-chemical uptake of CO_2 by the oceans. (UK, p.84)

The simultaneous increase in other greenhouse gases means that the effective doubling date for carbon dioxide will be about 2030. The current scientific consensus is that this will bring about an average increase of global temperature of 3 degrees C (plus or minus 1.5 degrees). (By comparison, average temperatures during the last Ice Age were about 4 degrees colder than today.)

There is a time lag of about ten years between the increase in CO2 and a measureable effect on the climate, due to the relatively slow rate at which oceans heat up. Thus, the atmosphere is already committed to a warming of 0.7-2 degrees centigrade due to the emission of greenhouse gases up to the early 1980s. (Delhi, p.5) This is an important dimension of the problem, because it means that preventative action needs to be taken at least a decade before the negative effects of inaction are felt.

The practical implications of such a global warming are the subject of much scientific debate. But given its unprecedented nature and the complexity of the interactions between different factors, it is agreed that no certain predictions can be made. Nevertheless it is likely that many areas of low-lying land will be flooded, due to thermal expansion of water in the oceans and the melting of ice caps and glaciers adding to water volume. Widespread climatic disturbance is also expected. The average 3 degree rise in temperature by 2030 is likely to consist of a rise of only about 1 degree at the equator and up to 7 or 8 degrees at the poles.

The increased temperature differential between the regions of the world is likely to cause significant alterations to wind and ocean current patterns, to levels and frequency of precipitation, and to the incidence of storms. It is likely that more of the world will experience desert climates, including areas that are currently very heavily populated. Of course some countries might benefit from improved growing conditions, but it is very difficult to predict which ones these might be. It is not necessarily true that all climates will even get warmer; a shifting of the Gulf Stream may for instance make the climate of the UK more like the colder and wetter climate of Iceland today (ACE).

Some commentators are relatively optimistic about human ability to adapt to such changed conditions (Schelling); but it is undeniable that the world economy would be severely disrupted, and many millions of individuals would be adversely affected. The cost of adaptation is almost incalculable: it has been estimated that adjustments to existing irrigation systems alone might require some $200 billion (Brown and Flavin, p.17). The cost of additional flood protection just for East Anglia in the UK has been estimated as #5-6 billion. (ACE) Massive sea defence measures would be required by countries such as Bangladesh and Egypt, and it is hard to see where such capital sums could be found.

Two major conferences on global warming were held in 1988, in June in Toronto and in November in Hamburg. The conclusions of both meetings were that it was essential for CO2 emissions to be reduced, with more than a 50 per cent reduction being needed to stabilize the climate. The Toronto conference called for a 20 per cent cut from 1988 levels by 2005 as an initial goal for industrialised countries. Hamburg called for 30 per cent reductions by the major CO2 producing nations by 2000.

Table 1 shows which countries were the major contributors in 1985 to future global warming through CO2 emissions. It can be seen that, not surpisingly, these were mostly the industrialised countries of the world. Hence the emphasis given to action by these countries at both the 1988 conferences. It is also of course these countries that can more easily afford to invest in new technologies.

Table 1: Carbon Emissions from Fossil Fuel Use in Selected Countries. 1985.

Country	Carbon Emissions (million tons)	Carbon per Capita (tons)
USA	1,186	5.0
USSR	958	3.5
China	508	0.5
Japan	244	2.0
West Germany	181	3.0
UK	148	2.6
Poland	120	3.2
France	107	1.9
Italy	101	1.8
East Germany	89	5.2

Source: Brown and Flavin, p.16

It should be remembered however that, unlike SO2 and NOx, there is no known method of eliminating CO2 emissions when fossil fuels are burned. It is not simply a matter of investing in new pollution-control equipment. What the scientific community is calling for is either a massive change in energy sources, or a large reduction in energy consumption.

Before considering these options in detail however, the next section will describe current energy consumption patterns, and the expected direction of future energy developments. This will demonstrate the magnitude of the task, if the new targets for CO2 reduction are to be achieved. It will also show that in future the problem will by no means be restricted to the industrialised countries. Current expectations are that developing countries will be major contributors to the greenhouse effect by early in the next century, unless great care is taken in planning their energy development to prevent this eventuality. As argued in our final section such a strategy, based on new technologies and highly energy-efficient equipment, is in any case in the interest of the countries, since it entails a lower total capital investment than would the standard high energy-using development path.

3. CURRENT AND FUTURE PATTERNS OF ENERGY CONSUMPTION

In this section we describe the current energy mix in the various regions of the world, and discuss various projections of how consumption patterns may change over the next half century. All forecasts and scenarios are of course liable to be proven wrong. Indeed, their very publication may point to such dire effects that the world becomes determined not to allow them to come true. (We hope that the environmental implications of the scenarios presented here will have just such an effect.) But in the absence of any such new movements energy consumption is widely expected to grow along the lines presented in this paper.

Table A1 (in the Appendix) presents in detail, by region and by fuel, the current pattern of commercial energy consumption in the world, along with OIES projections for the year 2000. Table 2 then translates these figures into average annual growth rates.

It can be seen that gross commercial energy consumption over the last twenty years has grown at an average annual rate of 2.85 per cent, from a total of 4580 mtoe in 1968 to 7811 mtoe in 1987 - equivalent to a 70 per cent overall increase.

The rate of growth from 1987 to 2000 is expected to be slightly lower, at 2.3 per cent per annum, to give a total consumption figure of 10,545 mtoe in 2000. This would represent more than a doubling of primary energy consumed by the world, in just 32 years.

As the tables show, historical growth rates have varied significantly between different groups of countries, and have also varied for each of the fuels.

Table 2: Average Annual Growth Rates in Primary Energy Consumption. %

	1968-74	1974-84	1984-87	1987-2000
OECD	3.57	0.47	1.40	1.40
CPEs	6.62	3.22	3.59	2.89
LDCs	6.52	5.73	4.23	3.74
World	4.47	1.97	2.59	2.34

Source: All figures up to 1987 are taken from BP, and for 2000 are OIES estimates, unless otherwise stated.

If similar differential growth rates are projected forwards for another thirty years the shares of each fuel in the overall energy mix will be quite different to the current picture, and the relative consumption of the various world regions will also have changed markedly. In order to set the overall picture however the total consumption figures for the world as it is now will first be analysed. We will then discuss the role of the various fuels and the patterns for each fuel within each world region. Projections of energy demand in 2000 and 2020 can then be discussed within this context.

(a) Energy Consumption to 1987

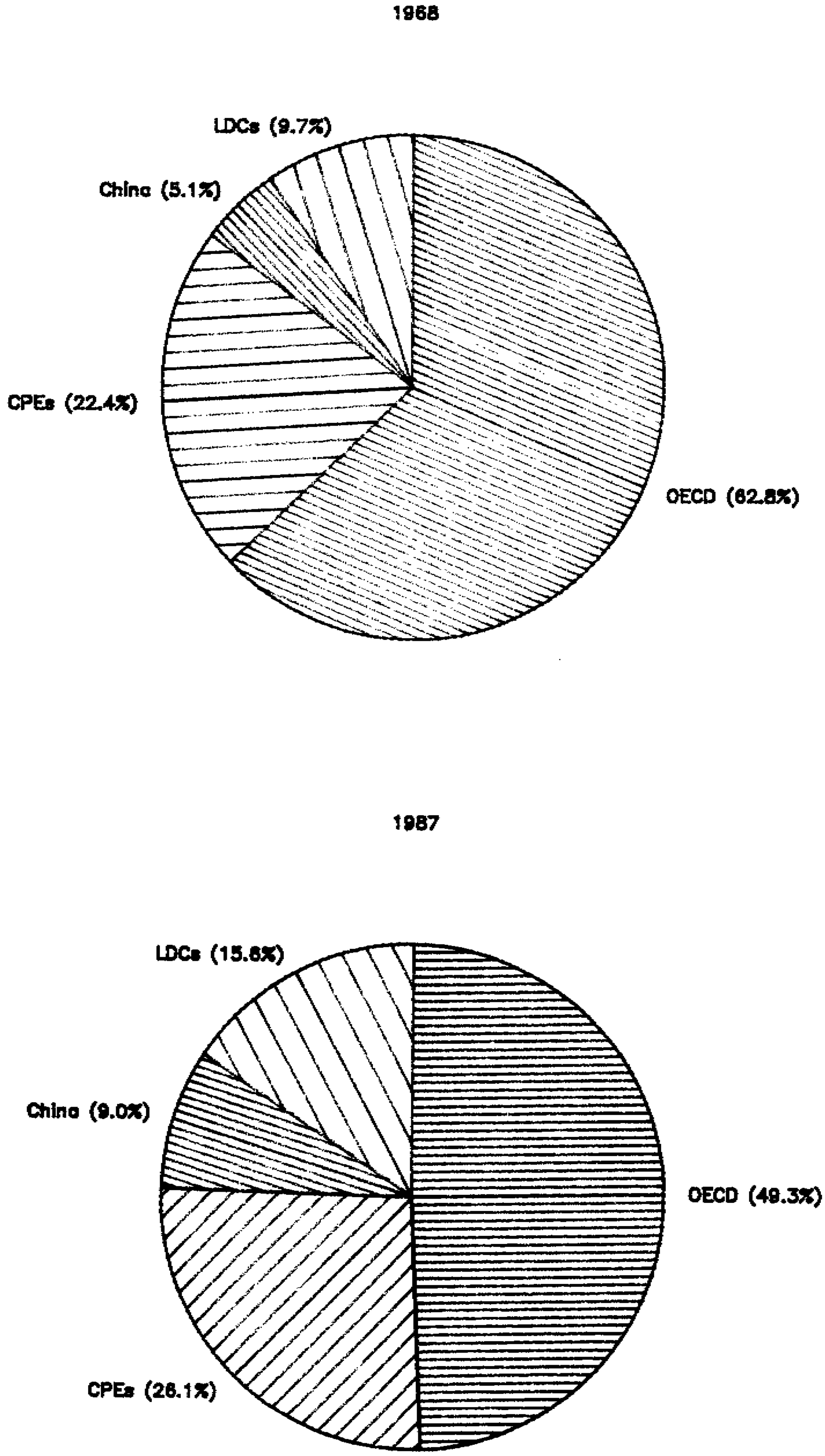
As stated above, the overall growth in world energy consumption has averaged 2.85 per cent per annum since 1968. This average conceals an important pattern however, of much faster growth prior to 1974 (4.47), followed by a period of relatively slow growth (1.97), but which has once again speeded up since 1984 (2.59). Both the OECD and CPE countries have followed this pattern. The Third World has meanwhile shown a gradual but steady decline in growth; but nevertheless its growth rates are a great deal higher than in the industrialised world.

The consequence of these varied growth rates has been a marked shift in the regional distribution of energy consumption, as shown in Figure 3. The share of the OECD fell from 63 per cent in 1968 to 49 per cent in 1987, while that of the developing countries had risen to 15.6 per cent of world energy consumption in 1987, (24.6 per cent if China is included), an enormous increase from the 9.7 per cent (14.8 per cent with China) consumed by those same countries in 1968.

Looking in detail at each of the different fuels expands further on this picture. One of the most noteworthy features is that consumption of oil has fallen over the last ten years, in both absolute and relative terms. 1979 represented the year of highest world oil consumption, at 3124.5 million toe. After that year consumption fell steadily to just 2816.1 mtoe in 1985; since then it has once again risen slightly, to reach 2940.7 mtoe in 1987, but this is still below the 1979 figure. From 1968 to 1977 the share of oil in total energy consumption increased from 42 to 46 per cent; but since then it has fallen to just 37.6 per cent.

The actual decrease in oil consumption occurred in OECD countries, where there was negative annual growth of 1.45 per cent in the years 1974-84; but the previously high rates of growth in other parts of the world were also greatly reduced in that period, as shown in Table A3. In oil importing developing countries growth in oil consumption fell from an average of 9.5

Fig.3 CONSUMPTION BY REGION



per cent per annum in the years 1970-73 to just 0.5 per cent in 1982-85, and for oil exporting developing countries from 8.2 per cent to 3.4 per cent for the same periods. (OIES)

With the fall in oil prices since 1984 consumption has picked up, with the OECD once again showing a positive growth rate of nearly 1 per cent per annum. The beneficial impact of lower oil prices on the economies of the developing countries is graphically illustrated in Table A4, which shows the proportion of export earnings that developing countries needed to spend on energy imports in 1983 and in 1986 - while the figures are still extremely high for many countries lower oil prices have certainly afforded considerable relief.

As a result of these differential growth rates the distribution of oil consumption through the world has dramatically changed over the last twenty years, as shown in Table 3.

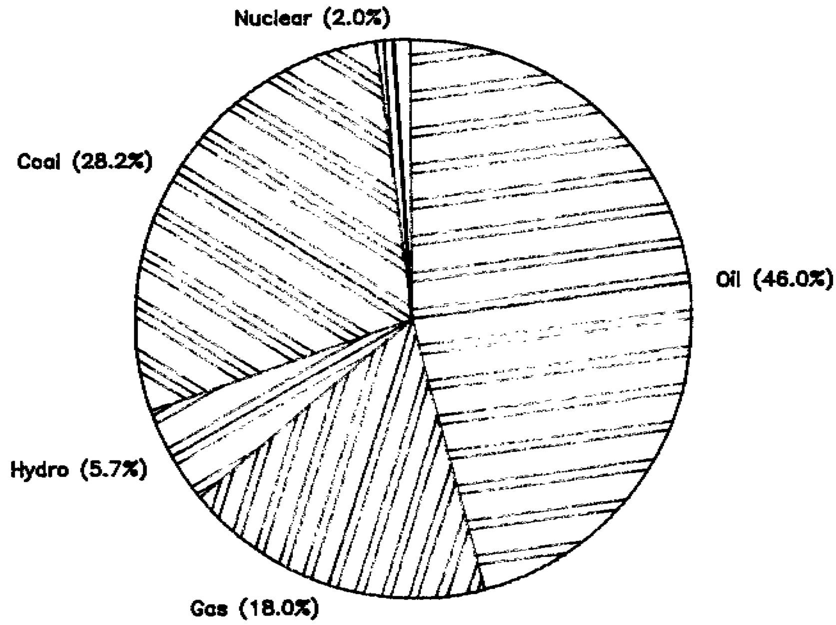
Table 3: Distribution of Oil Consumption by Region. %.

	1968	1974	1984	1987	2000
OECD	71.1	66.9	57.0	56.4	52.5
CPEs	15.6	18.9	23.1	23.1	22.9
LDCs	13.3	14.1	19.9	20.5	24.6
World	100.0	100.0	100.0	100.0	100.0

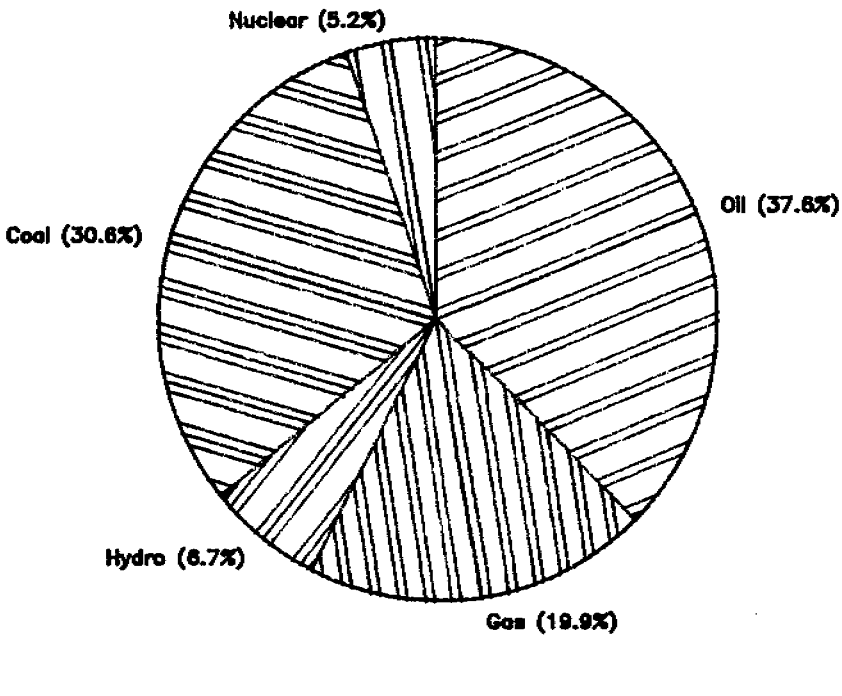
The absolute decrease in oil consumption over the last decade of course implies that other fuels have increased their shares, as shown in Figure 4. Indeed all the other fuels have increased in both absolute and relative terms, with each fuel

Fig.4 CONSUMPTION BY FUEL

1977



1987

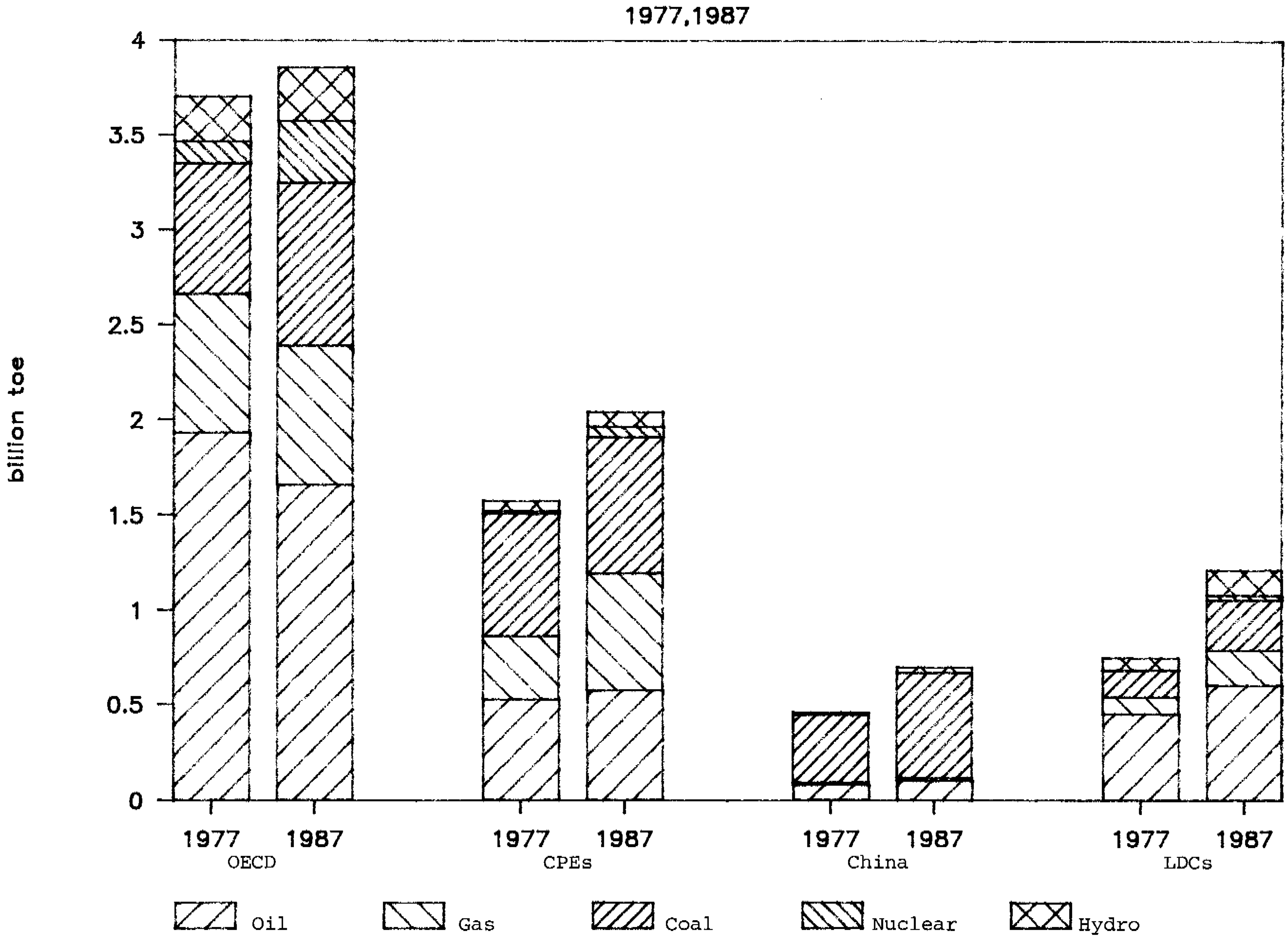


showing steady growth on a worldwide basis. As Table A5 shows, the average annual percentage growth rates were: 2.91 for natural gas, 2.69 for coal, 3.46 for hydro, and 11.84 for nuclear. The higher rates for hydro and nuclear reflect their rather low base levels in 1977; it is also noteworthy that both fuels showed reduced growth rates in very recent years, from 1984-87, whereas both natural gas and coal were showing increasing rates of growth over that period, with coal showing especially strong growth (3.10 per cent a year) considering its large base.

Figure 5 shows the relative growth in consumption between the different regions of the world, and also the shares of each fuel within the regions. The OECD has seen oil consumption fall from 1929 mtoe in 1977 to 1658 mtoe in 1987. This translates into a 9 per cent fall in the share of oil in the energy mix of the OECD, from 52 per cent of energy consumption in 1977 to 43 per cent in 1987. All the other fuels have increased their shares, with coal and nuclear taking the major part of the increment. Nuclear has consistently grown at more than 10 per cent per annum, albeit slackening slightly since 1984, and now accounts for 8.45 per cent of energy consumed in the OECD countries, compared to just 3.17 per cent ten years ago. Interestingly, most of the change in the energy mix had already occurred by 1984, although the same trend has continued since that year. (see Table A6)

The Centrally Planned Economies (Table A7) have also seen a decrease in the share of oil in the energy mix, from nearly 30 per cent in 1977 to just under 25 per cent in 1987, although unlike the OECD there was an increase in absolute terms. Unlike

Fig.5 PRIMARY ENERGY CONSUMPTION



the OECD there was also a reduction in the share of coal from the very high base of 49 per cent to 46 per cent. These lost shares were largely taken by natural gas, which increased from 17 to 23 per cent of the total over the ten years. There was also a very large increase in nuclear generation over the decade, from 13.6 mtoe to 53.9 mtoe, although this still represents a much smaller total than that obtaining for nuclear power in OECD countries (404.1 mtoe).

It is important to distinguish between rather different trends in the various CPE countries however. In particular Table A8 shows that coal grew to take a larger share in China, compared to its reduction in CPEs as a whole (an average annual growth rate of 4.56 per cent, as opposed to 2.4 per cent for CPEs as a whole); and natural gas reduced its share in China compared to a very large gain in the CPEs as a whole.

The Third World once again shows a much smaller share for oil in 1987 compared to 1977 (Table A9). Half of the share lost by oil has gone to natural gas, for which consumption in South East Asia has shown especially rapid growth, by an average of 13.5 per cent over the decade 1977-87 (compared to 7.8 per cent for the Third World as a whole).

When considering energy consumption in the Third World it is important to remember that non-commercial sources make a large contribution, and are of course also the cause of severe environmental degradation. Unfortunately statistics are extremely difficult to compile for this sector, since by definition such fuels are either not traded, or are only informally traded. However the World Energy Conference provided some estimates of both current and projected consumption of non-commercial fuels (see Table A10). In 1978 it was estimated that the developing countries accounted for 84 per cent of world consumption of such fuels, and that at 735 mtoe non-commercial fuels amounted to 10.78 per cent of total world primary energy consumption - a significant quantity! The WEC forecasts for 2000 predict that between 8 and 10 per cent of world consumption will still be provided by non-commercial fuels.

(b) 2000

Forecasting energy consumption is always a hazardous occupation, as mentioned earlier. Forecasts produced as recently as 1983 already seem to be understated, due to the 1986 collapse in oil prices, and subsequent surge in consumption. We have therefore produced a scenario for the year 2000 based on major studies published over the past few years, but modified in the light of recent events. The OIES figures represent what we consider to be reasonable modifications to these forecasts and scenarios in the light of the oil price collapse of 1986, increased public concern over nuclear power post-Chernobyl, and similar events. For the purposes of our argument in this paper it is the general direction of change, rather than precise predictions, that matter.

In broad terms we expect the major trends of the last decade to continue, at least until 2000. This is reflected in the pattern of growth rates shown in Table 4. Our projection is conventional and somewhat pessimistic in ecological terms, in the sense that it incorporates only rather minor changes to energy consumption habits in response to environmental problems. Already public opinion is leading politicians towards different attitudes (the referenda against nuclear power in a number of countries being the prime example), but dramatic changes will require considerably greater pressure to be exerted, especially if the effects are to be felt by the year 2000.

Table 4: OIES Estimates of Growth in Energy Consumption to 2000. % growth per annum.

	Coal	Oil	Gas	Nuclear	Hydro	Total
OECD	2.0	1.0	1.1	2.8	1.0	1.4
CPEs	3.0	1.5	3.5	6.1	4.0	2.8
LDCs	4.0	3.0	5.0	6.1	4.0	3.7
World	2.8	1.6	2.6	3.5	2.5	2.3

Low fuel prices mean that OECD growth in energy consumption is unlikely to fall back to the 1974-84 level, but the total share of OECD will nevertheless continue to decline, to just 44 per cent by the year 2000. The developing countries will be constrained by debt problems and lack of capital, but will still see a continued increase on their relatively low base level of energy consumption per capita. Continuing low oil prices until the mid 1990s will be especially important in contributing to this trend as discussed below. The centrally planned economies will more or less maintain their current overall growth rates in energy consumption.

By 2000 we project that oil will hold just 34 per cent of total world energy consumption, but this represents a rather higher growth rate than was expected prior to the 1986 collapse in oil prices. (For example WEC predicted a 30-31 per cent share for oil by the end of the century.) Consumption of oil immediately increased in all areas of the world, and the current glut is unlikely to be superseded by a supply crisis before the end of the century, with the result that high growth is likely to continue. Several oil companies are now predicting that oil will constitute 40 per cent or more of the total energy mix in 2000.

Continued fast growth in Third World oil consumption will however cause a further shift in world distribution of oil consumption. The OECD share will have fallen to 52.5 per cent by 2000, with the Centrally Planned Economies consuming nearly 23 per cent, and developing countries as much as 24.6 per cent. The slightly decreased share for the CPEs reflects a rather slow growth rate in both the USSR and China, both of which will try to maintain their oil exports in order to earn foreign exchange, using a relatively larger share of their gas and coal respectively in place of oil.

Both gas and coal are likely to continue to grow at fast rates, but competition from cheap oil and increased environmental worries about coal use will somewhat slacken its rate of increase. This is especially reflected in the growth rates for the OECD, where we have kept coal growth at 2 per cent a year (compared to 2.2 per cent over the decade 1977-87), whereas gas consumption is predicted to grow at 1.1 per cent compared to 0.05 per cent over the earlier decade. Gas consumption is also forecast to grow rather fast in the USSR and also in the Third World, reflecting the size of reserves and their rather low base figures respectively.

It is important to note that coal consumption is still predicted to grow at 3 per cent per annum in CPEs and 4 per cent per annum in developing countries. In absolute terms this would mean the world consuming 86 per cent more coal in 2000 than it did in 1977, with 67 per cent of total coal consumption in 2000 taking place in Third World and communist countries. For example China has the world's largest reserves of anthracite and bituminous coal, at 156,400 million tonnes, and plans to double its coal consumption by the year 2000. (World Bank, 1985) The quantity of coal consumed has clear environmental implications, and its geographical distribution may cause problems in the sense that most "clean" coal technologies require considerably more capital investment than traditional uses.

The rate of growth for nuclear power meanwhile is enormously reduced, reflecting the dearth of newly commissioned nuclear power stations. A combination of very high capital costs, consumer fears over nuclear safety, and the low prices of competing fuels, makes more rapid growth extremely unlikely - a significant change since the energy consumption forecasts made in 1983. A growth rate of 6 per cent is still shown for developing countries, reflecting the very small number of existing nuclear power stations; a similar 6 per cent growth rate for CPEs is considerably lower than earlier forecasts would have suggested, and reflects recent decommissioning of a number of plants in Lithuania and the effect of Chernobyl on future plans. The potential role for nuclear power in alleviating the problems of pollution caused by fossil fuels is discussed later, but whatever the outcome of this debate it is unlikely that a major impact will be felt before 2000, given the long lead time required to bring a nuclear station onstream.

The growth in hydro power is also expected to decline from the 3.5 per cent of the previous decade, as environmental protests begin to affect the over-ambitious plans of organizations such as the World Bank.

(c) 2020

Looking into the next century, the high and low scenarios forecast by the World Energy Conference are displayed in Table All and Figure 1. It should be remembered that these in turn are projected from figures for 2000 which already look on the low side, given the collapse in oil prices and actual energy consumption figures for 1987.

It is therefore perhaps realistic to look at the high scenario as the "base case" prediction in the absence of any major policy changes. The two cases would give a total primary energy consumption of either 12674 or 17067 mtoe in 2020, representing a trebling or even quadrupling (in the high case) from the 4580 mtoe consumed just fifty years earlier in 1968. Figures 6 and 7 represent the relative shares of each world region and of each fuel under the high scenario for 2020. Comparing these diagrams with those in Figures 3 and 4, it can be seen that the developing countries will have taken a further 8 per cent of the much larger total world energy consumption, at the expense of the OECD region, and the share of oil will have

Fig.6 CONSUMPTION BY REGION

WEC, 2020

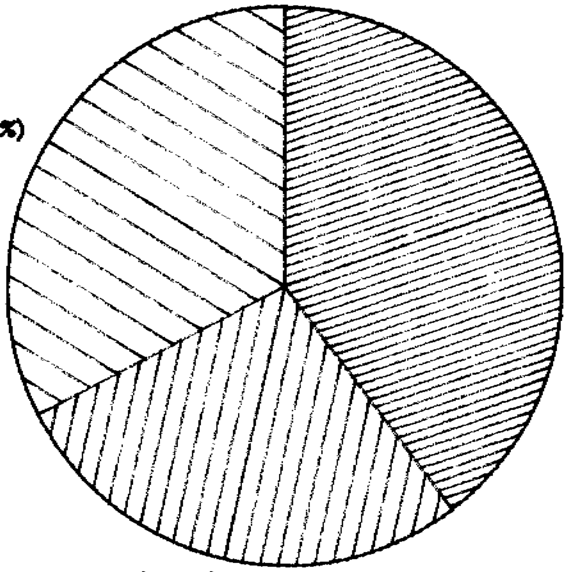
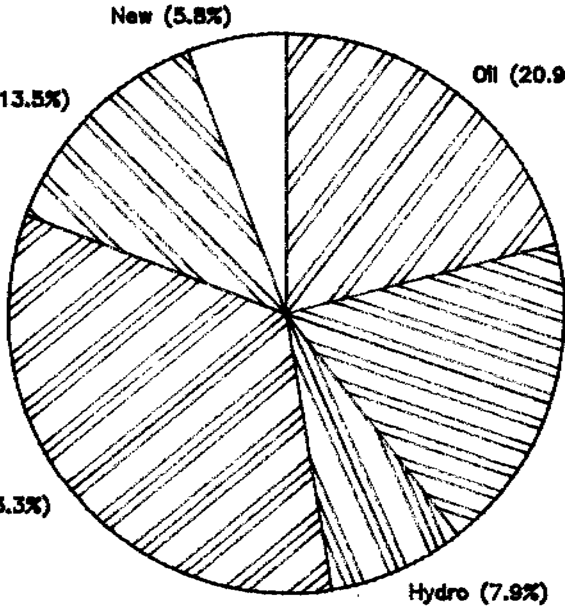


Fig.7 CONSUMPTION BY FUEL

WEC, 2020



fallen dramatically from 37.6 per cent of the total in 1987, to just 20.9 per cent in 2020.

When considering the environmental effects of the energy mix, the absolute figures are even more important than the relative shares however. It is especially noteworthy that the amount of coal consumed would be double the figure for 1987, although oil consumption is forecast as lower than the 1987 figure. The quantities of fossil fuel consumption in the early 1980s were already creating an unacceptable increase in CO2 levels in the atmosphere. Should the world continue to move in the direction suggested by the WEC scenario it is probable that major ecological catastrophe would be well underway by the year 2020. In fact the amount of economic dislocation caused by climatic change and rising sea levels would probably in itself prevent the realisation of either of the WEC scenarios for 2020.

Faced with this prospect, what can be done?

4. FUEL SUBSTITUTION

(a) Natural Gas

There is a clear hierarchy amongst fossil fuels in the environmental destruction they wreak. This is particularly true of CO_2 emissions, as shown in Table 5. The ratio of CO_2 emitted per unit of energy is approximately 10:8:6 for coal, oil and gas respectively.

Table 5: Carbon Release in the Production and Combustion of Fuels.

Fuel	Carbon, g/MJ
Shale oil mining	27.9
Coal	23.8
Oil	19.2
Gas	13.7
Solar	0.0
Hydro	0.0
Nuclear	0.0

Source: Edmonds and Reilly, p.76

Natural gas is also much preferable to coal or oil in terms of SO_2 and particulate matter. There is therefore some interest in substituting natural gas for coal in power generation, especially as an increasing share of future energy demand will be for electricity.

The American Gas Association has produced a comparison of emissions from coal-fired power stations and 100 new 240,000 kw gas-fired combined cycle power plants, reproduced in Table 6. This table demonstrates clear advantages in shifting away from coal burning and towards natural gas. "NSPS" coal plant refers to the US Environmental Protection Agency's new source performance standards. (Ironically, it has been suggested that because NSPS standards substantially increase the cost of new plant the economically useful life of existing more polluting equipment may be prolonged.) (Harrington)

Table 6: Emissions by Power Plants. Tons/year.

	Gas combined cycle*	NSPS coal	Uncontrolled coal
Sulphur dioxide	0.3	410	3,900
Particulate matter	0.9	21	1,700
Nitrogen oxides	135	240	680
Carbon dioxide	51,000	143,000	143,000

* Gas input 1.08 quadrillion BTU/year

Source: Oil and Gas Journal, 29 August 1988, p.14

Gas has thus acquired the image of a "clean fuel", and pressure is mounting in the European Community to revoke the directive limiting its burning in power stations. The efficiency of combined cycle plants, and their relatively low capital cost, also makes them very suitable for use in developing countries - many of which have substantial gas reserves. (Davison, Hurst and Mabro)

However it should be noted that natural gas still produces significant quantities of the greenhouse gases, NOx and CO2; the leaks of methane during gas production, transportation and burning also pose a considerable threat to the environment. It is thought that straight methane is an even more potent ingredient in the greenhouse cocktail than carbon dioxide, since it is thirty times as effective at absorbing infra-red radiation. (UK, p.4)

Moreover even though our energy scenario for 2000 includes a phenomenal 40 per cent increase in worldwide gas consumption there will still be 3407 mtoe of coal consumed in that year. It is not credible that natural gas could take a much larger share of the energy mix by that time, especially in view of the long lead time (8-10 years) needed to develop gas infrastructure to bring the fuel to market. British Coal has calculated that a 90 per cent increase in gas usage would be required worldwide to produce a 10 per cent reduction in CO_2 emissions, even at present levels of energy demand. (UK, p.17)

A postponement of the greenhouse effect is worthwhile however, if only because it will provide a "breathing space" during which better solutions may be found. Nevertheless attention should not be directed only at coal. It should be remembered that oil is also a major contributor to CO_2 emissions. This poses special problems since widespread substitution of fuels in the fast-growing transport sector is very unlikely in the short-term. Moreover, whereas there is already government involvement in power sector planning in many countries, enabling policy changes to be implemented fairly rapidly, the market for oil products, and especially transport fuels is more fragmented and market-led. New strategies are therefore more difficult to introduce.

What is the potential for replacement of fossil fuels by those that do not emit any CO_2 at all?

(b) Renewable Energy

"New" sources of energy such as solar and wind power carry considerable promise. But under current pricing regimes, which carry implicit subsidies for fossil fuels, renewable energy sources tend not to be economic for large-scale applications. Some areas such as photovoltaics also require more research before they can be commercialised.

Furthermore, while there may be considerable scope for the introduction of large-scale renewable energy sources, the current political climate is not over encouraging. Few, if any, governments are committed to their widespread use; while research and development programmes in general have tended to decline in the past few years, the percentage of research funds devoted to renewable energy has declined disproportionately.

Table 7: Expenditure on R d & d in IEA countries. 1987 US $ (millions)

	Total R d & d	Renewables	Renewables as % of total
1977	8321.1	572.6	6.8
1979	10542.8	1236.4	11.7
1980	11299.7	1443.6	12.8
1981	10751.3	1427.5	13.3
1982	9750.6	965.5	9.9
1983	9201.4	823.6	8.9
1984	8863.7	780.4	8.8
1985	8698.1	634.6	7.3
1986	7878.2	493.1	6.2
1987	6922.7	461.1	6.7

Source: IEA, 1987b

Under the heading of "renewable energy" it is worth remembering that the burning of fuelwood makes no net addition of CO_2 to the atmosphere if a corresponding number of new trees are planted. There are promising possibilities of efficient power generation using gasified biomass to fuel gas turbines, based on aircraft engines. Such solutions hold much promise for poor and remote areas of the Third World, but again there is a lack of research.

(c) Hydro Power

Hydro power is set to double from 1987 levels by 2020 in the WEC forecasts. While it used to be seen as a clean, renewable energy source with enormous potential, it has now become clear that hydroelectricity brings its own problems. In theory there remains enormous unused capacity, with the largest opportunities lying in China (378,532 MW), Brazil (213,140 MW), Zaire (120,000 MW) and India (100,000 MW). (World Bank, 1983) However the ecological damage associated with large hydro schemes has already made them extremely unpopular in Scandinavian countries. In tropical climates the creation of large lakes is associated with increases in water-borne diseases such as bilharzia.

The flooding of large areas of land inevitably means the destruction of agricultural land and/or tropical rainforest in most places, and often the displacement of very large populations. For example the Narmada dams project in India, involving up to 3,200 dams, would displace over 1 million people (who would not be compensated), flood 350,000 hectares of forest and 200,000 hectares of farming land. (New Internationalist, March 1988) The Xingu River Basin project in Brazil has recently hit the headlines, with well-organized opposition from local tribes gaining them support from the Pope and the UK government amongst unlikely sources. This project would create the world's largest artificial lake at Babaquara; the Babaquara and Kararo dams would flood an estimated 7200 square miles of rainforest, including the lands of 70,000 people. (FOE)

Increasing political pressure from environmentally concerned groups on funding organizations such as the commercial banks and World Bank makes it unlikely that large hydro schemes will continue to receive the unquestioning support of the past. There does however remain considerable scope throughout the world for very small hydro plants.

(d) Nuclear Power

In some quarters it is being argued forcefully that the greenhouse effect of burning fossil fuels, together with acid rain and air pollution, provide a new opportunity for nuclear power. Even some environmentalists have begun to view nuclear power in a more favourable light. It is argued that even a modest expansion in the nuclear programme would effectively buy time; it would forestall the worst greenhouse effects by some years, during which time adaptation could occur and other solutions be found.

The political acceptability of such a solution is highly doubtful however. While those in the industry are convinced that nuclear power is safe, the general public remains far from convinced. The fire at Sellafield in 1957, and the Three Mile

Island and Chernobyl accidents have all proved the nuclear advocates wrong; and the long-term effects of these accidents are still being felt. As well as the risks associated with plants while they are operating and their regular discharges of low-level waste, the long-term problem of waste disposal remains unsolved. Once again, scientists claim that disposal is safe; but the only communities willing to have waste dumps in their midst are those that are economically dependent on the nuclear industry. Even those communities are beginning to see lawsuits brought by citizens against their employers for cancers allegedly caused from nuclear contamination. In short, the political chances of a major expansion in nuclear power are extremely small. It is most unlikely that voters will be persuaded that in order to forestall the risk of one ecological disaster they should instead court the danger of several others. This is especially true given that a differnt alternative exists, which is both safer and cheaper than nuclear power, namely increasing energy efficiency.

Leaving to one side the question of nuclear pollution, and the problem of nuclear weapons proliferation, it is still highly doubtful how great a contribution nuclear power could make to delaying global warming. A recent study by Keepin and Kats (1989) has shown that even if a large nuclear plant of 1000 MW was built every three days from now until 2025 global CO2 emissions would still continue to grow, in the absence of other measures.

Keepin's model includes the complete displacement of coal by nuclear energy within forty years, based on a "typical middle-of-the-road" energy scenario that predicts total energy consumption of 21.3 TW by the year 2025 (WEC's figures for 2020 in its high and low scenarios are 24.6 and 19.1 TW respectively). In order to achieve this goal by 2025 the global installed capacity of nuclear power would need to reach 5200 GW, an 18-fold increase over today's capacity. CO2 emissions would still increase from today's value of about 5.2 Gt/year to 6.48 Gt/year at the turn of the century, and then decline to 5.27 Gt/year by 2025. Thus, although the acceleration is somewhat slowed, global warming continues to grow, thanks to oil and gas consumption.

Such an enormous number of nuclear plants would of course increase both the probability and the number of nuclear accidents. This would have a devastating effect on the environment, and would also be likely to cause severe political disruptions. Moreover such a programme would involve quite prohibitive capital costs, put conservatively at $5.3 trillion (1987 $), or an average of $144 billion annually, of which the Third World would be responsible for $64 billion a year. In addition total electricity generation costs would average $525 billion a year, of which LDCs would have to pay $170 billion annually. Given this scale of required capital, the authors justifiably say that "large-scale nuclear investment by developing countries can perhaps be more accurately viewed as an alternative to - rather than as a prerequisite for - economic development." (Keepin and Kats, p.546)

They proceed to show that such investments would not only be difficult but misguided, both for developing and industrialised countries. A much better use of funds would be to implement a wide-ranging energy conservation programme, which would simultaneously alleviate the feared environmental disaster and prolong the lifetime of known reserves of fossil fuels.

Most importantly of all, a strategy that delays the effect of global warming also allows time in which possible solutions can be arrived at. The figure quoted earlier of a doubling of CO_2 levels by 2075 assumes a 1-percent annual energy efficiency improvement. A 2 per cent annual improvement in energy efficiency would keep carbon dioxide concentrations to 463 parts per million in 2075, rather than 600 ppm. (Flavin, p.25)

5. CONSERVATION

Conservation has been called "the fifth fuel". The advantage of conservation is that it not only postpones shortages of fossil fuels and reduces environmental damage, it can also save considerable amounts of money, even when energy costs are low. This message however is only slowly reaching a wide audience. The efficient use of energy is also of paramount importance to developing countries, as it can forestall the need for very large capital investments in additional and unnecessary energy infrastructure.

There is undoubtedly enormous potential for energy conservation, which could considerably decrease total world energy consumption, and thereby the effects of such consumption on the environment. Already between 1973 and 1985 energy intensity in OECD countries fell by as much as 20 per cent - partly reflecting a structural change towards low energy-using service industries, and partly in response to high oil prices. In that period energy demand rose by just 5 per cent in the OECD, whilst GDP increased by 20 per cent.

High energy prices had been responsible for prompting consumers to switch to less intensive energy use. But the IEA estimated in 1987 that, even at the relatively low prices then prevailing, conservation measures economically viable at that time could provide as much as a further 30 per cent increase in energy efficiency. They found scope for improvement in energy use in buildings, transport, industry and power generation. (IEA, 1987c) The 1986 oil price collapse had not substantially affected the scope for conservation measures since the high rate of return on energy efficiency investments meant that they were still cost effective.

In practice, however, low fuel prices meant that consumers no longer perceived energy efficiency as an urgent need, and consequently the momentum towards conservation was lost.

One of the problems in implementing a programme to encourage energy conservation and efficient energy use is that it requires a myriad of small changes in consumption patterns. Unlike a fuel substitution programme it is somewhat open-ended, and may even seem intangible. But the cumulative effect of apparently small measures can bring remarkable fuel savings.

For example the increase in average fuel efficiency of US cars between 1973 and 1985, from 13.1 to 17.9 mpg, cut US gasoline consumption by 20 billion gallons a year, lowering oil imports by 1.3 mbd. (Goldemberg, p.57) Electric lighting currently accounts for 20 per cent of US electricity consumption. (ibid, p.48) New compact fluorescent light bulbs use 18 Watts of power compared to 75 Watts for traditional incandescent bulbs and last ten times as long; over their useful life each bulb saves 180 kg of coal and keeps 130 kg of carbon out of the atmosphere. The widespread introduction of such bulbs could make a significant difference to total energy consumption.

An important point is that many of these simple efficiency measures could be implemented in a relatively short time, since there is a rapid stock turnover for lightbulbs, cars and fridges - unlike power stations.

A number of analysts have all reached the important conclusion that despite the high capital costs of some efficiency measures they can result in considerable net savings of cash as well as energy. This is true for individual consumers, and is even more true for economies as a whole, where one can for example count into the equation the savings on power stations that no longer need to be built, or on energy distribution infrastructure that is not required.

It is worth remembering that as much energy leaks through American windows every year as flows through the Alaskan pipeline. (Flavin and Durning, p.47) In the USA several utility companies have begun to pursue a path of "least-cost planning". Rather than simply costing one type of power station against another, they also calculate whether it might be cheaper to invest in energy efficiency measures on behalf of their customers in order to avoid the need for new plant. In many cases this does indeed prove worthwhile. Six of the largest utilities have offset the need for 7,240 MW of generating capacity, by investing in energy efficiency measures in the homes and businesses of their customers, at less than a fifth of the price of new plant construction (Flavin, p.34). Others are beginning to buy "saved energy" from consumers, offering a fixed return on every kilowatt-hour saved.

Keepin estimated that in the USA each dollar invested in energy efficiency can displace nearly seven times more carbon than a dollar invested in nuclear power. (Keepin, p.552) The European Commission has argued that even a 10 per cent improvement in efficiency of electricity use up to the year 2000 would mean reduction in EEC primary energy requirements of 45 mtoe, avoided investment in over 40,000 MW of new capacity, and avoided atmospheric emissions of 125,000 tons a year of SO2, 200,000 tons a year of NOx and 160 million tons of CO2 (if just half of the new plants were burning coal). (UK, p.7)

Such savings are of worth to any economy, but may be particularly attractive to developing countries that suffer from acute shortage of capital. The growth in energy demand in developing countries that is projected in the scenarios described earlier will require enormous amounts of foreign exchange, both to invest in power stations and infrastructure and to buy imported fuels. This in itself will have an environmental impact, since one way of earning foreign exchange is for increasing shares of good agricultural land to be turned over to cash export crops. This in turn leads to cultivation of increasingly marginal land in order to grow staple food supplies, and to progressive erosion of soils and eventual desertification.

It is clearly in the interest of developing country goverments, as for all others, to ensure that investments reap full value for money. Although more energy-efficient devices tend to be more costly than conventional units, the extra investment is typically much less than would be required for an equivalent amount of energy supply expansion.

Moreover developing countries have the opportunity to "leap frog". They have an advantage over the industrialised countries, in that investment in new efficient technology is typically much cheaper than retrofitting old plant. It is therefore important that the expansion of developing country economies, especially the introduction of new industries, is based on the latest technology available - bypassing the inefficient and wasteful technologies that have been used in the industrialised countries.

Lower electricity and energy demand growth will mean reduced borrowing, less environmental degradation, and more resources to invest in other infrastructure, education, agriculture, and so on. Few aid institutions put any emphasis on promoting energy efficiency however, and there is also a tendency for equipment that is no longer in demand in the industrialised countries to be offloaded in the Third World. This is not only damaging to the economies of the Third World countries, since such equipment requires greater expenditure on imported fuels and on energy infrastructure. It also threatens the wellbeing of the industrialised countries, through the contribution of unnecessarily high energy consumption to global warming.

What is the extent of possible energy conservation? This is of course a difficult question to answer precisely. But the following figures give an idea of the scope available. Current energy consumption amounts to approximately 10 kW per capita in the USA, 8 kW in the USSR and 6 kW in Europe. A reduction to 3 kW per capita in all three regions would be quite possible, at roughly the same cost as the investment that would otherwise be required for additional energy production. A reduction to 1 kW per capita would require rather more investment, and probably some change in lifestyles. It might be judged wise to make such additional investment, in order to forestall the costs of global warming. Again, it is likely that lifestyles may be forcibly altered, in a negative and uncontrolled way, if preventative measures are not taken. A voluntary change to an arguably healthier and pleasanter lifestyle might seem preferable to many people.

Goldemberg et al (1987) developed a hypothetical scenario in which all economic conservation measures are implemented worldwide. By 2020 total world energy consumption could amount to only 11.2 TW, compared to 19.1 or 24.6 TW under the two WEC scenarios. (1980 consumption was already as much as 10.3 TW.) Per capita energy use would have fallen from 6.3 kW to just 3.2 kW in industrialised countries (compared to levels of 8.1 or 9.7 in the WEC forecasts), and would have risen from 1.0 to 1.3 kW in developing countries (1.1 or 1.6 kW in WEC).

"Any living standard up to that of Western Europe in the mid-1970s could be obtained with about the same per capita energy use as that prevailing today in developing countries. This result is achieved by shifting from traditional, inefficiently used non-commercial (biomass) fuels...to modern energy forms...and by emphasizing efficiency improvements in energy-using equipment as economic development proceeds." (p.31) For example, to provide efficient cooking stoves to all 400 million rural households of developing countries would call for an annual investment of about $1 billion, and would save enough fuelwood to produce electricity in biomass-fired power plants equal to the output of about eighty large nuclear power plants costing $160 billion. (p.44)

Goldemberg envisages a development path for the Third World which concentrates on satisfying the basic human needs of the majority of the populations (clean water, food, education and health) as opposed to production for export markets with the forlorn hope of trickledown of wealth. Similarly, energy-intensive low-labour industrial processes would be eschewed in favour of more appropriate labour-intensive low-energy processes: he cites the success of the charcoal-fired steel industry in Brazil as an example. (p.70) A study in Brazil by H.S. Geller has also shown that a total investment of less than $10 billion between 1985 and 2000 in more efficient electricity use could eliminate the need to construct 22 GW(e) of electricity capacity costing some $44 billion. (p.58)

Altogether in Goldemberg's scenario fossil fuel use would not increase by the year 2020, and coal use would be reduced by about 20 per cent. CO_2 in the atmosphere would rise to 1.3 times the pre-industrial level. (p.32)

6. CONCLUSION

As the Brundtland Commission concluded in 1987, "Choices must be made, but in the certain knowledge that choosing an energy strategy inevitably means choosing an environmental strategy." (WCED, p.168)

More or less expensive equipment can minimize the environmental effects of pollutants such as SO_2; but combustion of all fossil fuels produces carbon dioxide, and no means exist to prevent this. A massive reafforestation programme is called for, but this alone will not be able to absorb the projected increase in CO_2. Consequently any increase in world consumption of fossil fuels will add to the already measured climatic effects of greenhouse warming of the earth's atmosphere.

In the absence of a concerted campaign to restrict energy demand it is very likely that worldwide energy demand will in fact lead to rapid global warming within the next three decades. A certain amount of fuel substitution will help, but can at best postpone events by a few decades. On the other hand a universal drive towards better fuel efficiency already makes economic sense, and in tandem with a substitution programme can forestall the worst effects of global warming by an appreciable period.

During this time a determined research effort should be able to commercialize renewable energy sources to the point where they can take over a very large part of world energy consumption. Research on traditional fuels may in the meantime produce new ways of using fossil fuels without producing such intractable pollution problems.

The encouraging feature of conservation is that it makes sense for each consumer and for each government, and does not require international conferences and agreements before it can start.

Observers such as Schelling are pessimistic about slowing global warming, because the action of any individual government would have only a minor impact: he argues that if the USA unilaterally were to phase out fossil fuels this would only gain five years on the doubling of atmospheric CO_2 levels. Consequently he argues that there is no point in any individual government taking action without there being an enforceable international agreement on CO_2 reductions, and this is a somewhat unlikely outcome in the near future. If, however, the US economy could be shown to benefit substantially from an increased energy efficiency programme, as many analysts suggest, then this in itself can become a motivator. For example it has been suggested that the USA is at a $200 billion disadvantage to Japan as a result of a poorer energy efficiency performance, and the UK suffers in a similar way in comparison with West Germany, Sweden or Japan.

Far from investments in energy efficiency putting countries at a competitive disadvantage they would improve economic performance. The environment will benefit from a strategy adopted for purely economic reasons.

There is however a problem in translating the arguments of overall economic efficiency into clear cash benefits to those making investments. Consumers typically require much shorter payback periods for their investments than do planners of power stations. Similarly, fuel prices do not reflect the external social costs associated with their use; nor do they account for the welfare of future generations. Meanwhile there are signs that, far from encouraging conservation programmes some governments are losing interest in energy efficiency. For example the UK government has recently halved its allocation to the Energy Efficiency Office (5th Fuel). The argument has even been used that if energy conservation is economic in any case, then there is no need for the government to take action.

The problem is urgent however. As mentioned earlier we are already committed to an appreciable increase in temperature, with unpredictable effects on the climate; and meanwhile energy consumption is still increasing. Energy conservation can offer the potential for very rapid improvements in the level of pollution and of CO_2 emissions. But the signs are that this will not occur without a concerted campaign.

Admittedly most of the actual measures need to be carried out by consumers rather than by governments, and there is also a useful role for other bodies in educating consumers about the need for conservation and the benefits it will bring. But there remains an important role that can most effectively, if not only, be played by government. The areas for government action fall under three main headings.

1. A number of measures can be implemented immediately to foster energy efficiency and conservation, without unduly interfering with market mechanisms. Some are extremely simple and cheap, and

others require more wholesale re-ordering of energy markets. But the net effect on energy consumption could be dramatic. Some of these include:

- an information campaign, to raise awareness of the problems caused by profligate energy use and the economic benefits of conservation
- the labelling of consumer goods, vehicles and houses, to enable consumers to make an informed choice
- the setting of stringent efficiency standards for manufacturers
- providing facilities for energy audits to both private and commercial consumers, together with grants and fiscal incentives to encourage the take-up of efficiency measures
- setting energy prices at their true market value. This requires the removal of overt subsidies in many developing and centrally planned economies, and the indirect subsidies found in so-called market economies in the form of depletion allowances, tax breaks, and support to nuclear programmes
- requiring power authorities to apply rigorously the principles of least-cost planning, whereby the cost of any new supply investment is compared to the cost of an electricity conservation programme
- strict application of energy efficiency standards to government-owned buildings and vehicles (a large share of the total in many countries)
- the imposition of a carbon/climate protection tax on all fuels
- a new emphasis on energy efficiency in aid programmes for developing countries.

2. There remains scope for a great deal more research into methods of energy conservation.

3. A considerable increase is required in research and development expenditure for renewable energy sources.

The major problem lies in overcoming the inertia of old habits. The attitudes of those with political power need to change; so do those of leaders within the energy industries - at present various energy utilities still advertise in an attempt to encourage greater consumption; and finally consumers will need to think anew. The signs in most European countries are that consumers are well ahead of their "leaders", but are hampered by lack of information and thoughtless planning by governments and utilities.

The task is not impossible, but will require a great deal of political will and determination. Already politicians are finding it necessary to present a "green" image. What is needed is statements such as the following by President George Bush to be translated into action: "Those who think we're powerless to do anything about the 'greenhouse effect' are forgetting the "White House effect'. As President, I intend to do something about it." (UK, p.55) The world cannot afford a ten-year timelag before the effect is felt.

APPENDIX

Table A1: Primary Commercial Energy Consumption, 1977, 1987, 2000 mtoe

	Oil	Gas	Coal	Nuclear	Hydro	TOTAL
1977						
OECD	1929.3	730.4	689.1	117.3	238.7	3704.8
CPEs	525.9	337.2	644.8	13.6	54.6	1576.1
China	82.0	10.9	354.4	-	12.3	459.6
LDCs	448.5	89.2	141.6	1.2	67.7	748.3
World	2985.8	1167.7	1829.9	132.1	373.3	6488.8
1987						
OECD	1658.9	734.3	855.6	326.0	280.5	3855.3
CPEs	575.1	619.3	713.2	53.9	78.8	2040.3
China	103.9	12.8	553.4	-	30.0	700.1
LDCs	602.8	189.4	264.3	24.2	134.6	1215.3
World	2940.7	1555.8	2386.5	404.1	523.9	7811.0
2000						
OECD	1888	836	1107	467	319	4617
CPEs	824	989	1860	116	181	3970
LDCs	885	357	440	52	224	1958
World	3597	2182	3407	635	724	10545

"CPEs" includes China for 2000

Source: All figures up to 1987 are taken from BP, and for 2000 are OIES estimates, unless otherwise stated.

Table A2: Shares of Total Primary Commercial Energy Consumption, %.

	1968	1974	1984	1987	2000
OECD	62.7	59.5	51.1	49.3	44.0
CPEs	22.4	23.1	26.0	26.1	38.0
China	5.1	6.5	8.1	9.0	
LDCs	9.7	10.9	14.8	15.6	19.0
World	100.0	100.0	100.0	100.0	100.0

Table A3: Average Annual Growth in Oil Consumption, %.

	1968-87	1968-74	1974-84	1984-87	1987-2000
OECD	1.02	5.11	-1.45	0.84	1.00
CPEs	4.39	9.71	2.53	1.21	1.50
LDCs	4.61	7.31	4.15	2.25	3.00
World	2.26	6.18	0.31	1.22	1.56

Note: World annual growth rate for 1958-68 was 7.5 per cent.

Table A4: Energy Imports as a Percentage of Merchandise Exports.

	1983	1986
Latin America		
Argentina	9	3
Brazil	56	19
Chile	24	7
Colombia	21	4
Costa Rica	22	8
Dominican Rep	71	28
Guatemala	68	10
Nicaragua	46	20
Uruguay	28	13
Africa		
Burkina Faso	50	7
Egypt	12	8
Ivory Coast	16	5
Madagascar	32	12
Morocco	57	22
Senegal	58	25
Asia		
Bangladesh	20	17
Indonesia	20	14
Korea, Rep of	28	14
Malaysia	16	4
Pakistan	49	23
Philippines	44	17
Singapore	40	22
Thailand	39	13

Source: World Bank, World Development Report 1985 and 1988.

Table A5: Annual Average Percentage Growth Rates Worldwide.

	1977-87	1977-84	1984-87	1987-2000
Natural Gas	2.91	2.88	2.97	2.64
Coal	2.69	2.52	3.10	2.78
Nuclear	11.84	12.28	10.80	3.54
Hydro	3.46	4.25	1.64	2.52

Table A6: Energy Mix in the OECD, % shares for each fuel.

	1977	1984	1987	2000
Oil	52.07	43.74	43.03	40.89
Gas	19.71	20.22	19.04	18.11
Coal	18.60	21.78	22.19	23.97
Nuclear	3.17	7.71	8.45	10.11
Hydro	6.44	7.70	7.27	6.90

Table A7: Energy Mix in CPE countries including China, %.

	1977	1984	1987	2000
Oil	29.86	26.56	24.78	20.76
Gas	17.10	21.31	23.06	24.91
Coal	49.08	46.58	46.22	46.85
Nuclear	0.67	1.68	1.97	2.92
Hydro	3.29	3.86	3.97	4.56

Table A8: Energy Mix in China, %.

	1977	1984	1987
Oil	17.84	14.87	14.84
Gas	2.37	1.84	1.83
Coal	77.11	79.27	79.05
Nuclear	-	-	-
Hydro	2.68	4.03	4.29

Table A9: Energy Mix in LDCs, %.

	1977	1984	1987	2000
Oil	59.95	52.57	49.60	45.20
Gas	11.92	14.18	15.58	18.23
Coal	18.92	20.94	21.75	22.47
Nuclear	0.16	1.23	1.99	2.66
Hydro	9.05	11.10	11.08	11.44

Table A10: World Noncommercial Energy Consumption, mtoe.

	1978	2000-I	2000-II
Fuel wood	486	608	711
Vegetable and Animal Wastes	249	316	340
Total	735	924	1,051

Source: World Energy Conference, 1983

Table A11: WEC Forecasts for 2000 and 2020, mtoe.

	Oil	Gas	Coal	Nuclear	Hydro	New	TOTAL
2000-I							
OECD	1406	903	1575	640	348	181	5053
CPEs	794	847	1225	247	120	31	3264
LDCs	1203	405	441	90	240	124	2503
World	3403	2155	3241	977	708	336	10820
2020-I							
OECD	865	928	2794	1299	410	469	6765
CPEs	820	1260	1630	630	280	110	4730
LDCs	1891	969	1255	369	669	419	5572
World	3576	3157	5679	2298	1359	998	17067
2000-II							
OECD	1310	807	1421	566	334	148	4586
CPEs	673	698	1010	183	94	23	2681
LDCs	805	276	357	55	194	99	1786
World	2788	1781	2788	804	622	270	9053
2020-II							
OECD	787	776	2341	1033	389	415	5741
CPEs	616	1030	1260	460	160	60	3586
LDCs	1025	595	788	160	454	325	3347
World	2428	2401	4389	1653	1003	800	12674

Source: World Energy Conference, 1983

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