Our Common Future, Chapter 7: Energy: Choices for Environment and Development

1. Energy is necessary for daily survival. Future development crucially depends on its long-term availability in increasing quantities from sources that are dependable, safe, and environmentally sound. At present, no single source or mix of sources is at hand to meet this future need.

2. Concern about a dependable future for energy is only natural since energy provides 'essential services' for human life - heat for warmth, cooking, and manufacturing, or power for transport and mechanical work. At present, the energy to provide these services comes from fuels - oil, gas, coal, nuclear, wood, and other primary sources (solar, wind, or water power) - that are all useless until they are converted into the energy services needed, by machines or other kinds of end-use equipment, such as stoves, turbines, or motors. In many countries worldwide, a lot of primary energy is wasted because of the inefficient design or running of the equipment used to convert it into the services required; though

there is an encouraging growth in awareness of energy conservation and efficiency.

3. Today's primary sources of energy are mainly non-renewable: natural gas, oil, coal, peat, and conventional nuclear power. There are also renewable sources, including wood, plants, dung, falling water, geothermal sources, solar, tidal, wind, and wave energy, as well as human and animal muscle-power. Nuclear reactors that produce their own fuel ('breeders') and eventually fusion reactors are also in this category. In theory, all the various energy sources can contribute to the future energy mix worldwide. But each has its own economic, health, and environmental costs, benefits, and risks - factors that interact strongly with other governmental and global priorities. Choices must be made, but in the certain knowledge that choosing an energy strategy inevitably means choosing an environmental strategy.

4. Patterns and changes of energy use today are already dictating patterns well into the next century. We approach this question from the standpoint of sustainability. The key elements of sustainability that have to be reconciled are:

- sufficient growth of energy supplies to meet human needs (which means accommodating a minimum of 3 per cent per capita income growth in developing countries);
- energy efficiency and conservation measures, such that waste of primary resources is minimized;
- public health, recognizing the problems of risks to safety inherent in energy sources; and
- protection of the biosphere and prevention of more localized forms of pollution.

5. The period ahead must be regarded as transitional from an era in which energy has been used in an unsustainable manner. A generally acceptable pathway to a safe and sustainable energy future has not yet been found. We do not believe that these dilemmas have yet been addressed by the international community with a sufficient sense of urgency and in a global perspective.

I. Energy, Economy, and Environment

6. The growth or energy demand in response to industrialization, urbanization, and societal affluence has led to an extremely uneven global distribution of primary energy consumption./*1* The consumption of energy per person in industrial market economies, for example, is more than 80 times greater than in sub-Saharan Africa. (See Table 7-1.) And about a quarter of the world's population consumes three-quarters of the world's primary energy.

Table 7-1

Global Primary Energy Consumption Per Capita, 1984

	GNP Per Capita	Energy Consumption	Mid-1984 Population	Total Consumption

	(1984 dollars)	(kW per capita*)	(million)	(TW)
World Bank GNP Economy Category				
Low Income	260	0.41	2,390	0.99
Sub-Saharan Africa	210	0.08	258	0.02
Lower-middle	740	0.57	691	0.39
Upper-middle	1,950	1.76	497	0.87
Sub-Saharan Africa	660	0.25	148	0.04
High-Income Oil Exporters	11,250	5.17	19	0.10
Industrial Market Economies	11,430	7.01	733	5.14
East European Non-Market Economies		6.27	389	2.44
World		2.11**	4.718	9.94

*kW per capita is kW years/year per capita.

** Population-weighted average energy consumption (kW/capita) for first three main categories is 0.654 and for industrial market and East European categories is 6.76.

Source: Based on World Bank, World Development Report 1985 (New York: Oxford University Press, 1986).

7. In 1980, global energy consumption stood at around 10TW./2 (See Box 7-1.) if per capita use remained at the same levels as today, by 2025 a global population of 6.2 billion/3 would need about 14TW (over 4TW in developing and over 9TW in industrial countries) - an increase of 40 per cent over 1980. But if energy consumption per head became uniform worldwide at current industrial country levels, by 2025 that same global population would require about 55TW.

Box 7-1 Energy Units

A variety of units are used to measure energy production and use in physical terms. This chapter user; the kilowatt (kW); the Gigawatt (GW), which is equal to 1 million kW; and the Terawatt (TW), which is equal to 1 billion kilowatts. One kilowatt - a thousand watts of energy - if emitted continuously for a year is lkW year. Consuming 1 kW year/year is equivalent to the energy liberated by burning 1,050 kilogrammes - approximately 1 ton - of coal annually. Thus a TW year is equal to approximately 1 billion tons of coal. Throughout the chapter, TW years/year is written as TW.

8. Neither the 'low' nor the 'high' figure is likely to prove realistic, but they give a rough idea of the range within which energy futures could move, at least hypothetically. Many other scenarios can be generated in-between, some of which assume an improved energy base for the developing world. For instance, if the average energy consumption in the low- and middle-income economies trebled and doubled, respectively, and if consumption in the high-income oil-exporting and industrial market and non-market countries remained the same as today, then the two groups would be consuming about the same amounts of energy. The low- and middle-income categories would need 10.5TW and the three 'high' categories would use 9.3TW - totalling 20TW globally, assuming that primary energy is used at the same levels of efficiency as today.

9. How practical are any of these scenarios? Energy analysts have conducted many studies of global energy futures to the years 2020-2030.*/4* Such studies do not provide forecasts of future energy needs, but they explore how various technical, economic, and environmental factors may interact with supply and demand. Two of these are reviewed in Box 7-2, though a much wider range of scenarios - from 5TW up to 63TW - are available. In general, the lower scenarios (14.4TW by 2030,*/5* 11.2TW by 2020.*/6* and 5.2 by 2030*/7*) require an energy efficiency revolution. The higher scenarios (18.8TW by 2025.*/8* 24.7TW by 2020,*/9* and 35.2 by 2030*/10*) aggravate the environmental pollution problems that we have experienced since the Second World War.

Box 7-2 Two Indicative Energy Scenarios

Case A: High Scenario

By the year 2030, a 35TW future would involve producing 1.6 tines as much oil, 3.4 times as much natural gas, and nearly 5 times as much coal as in 1960. This increase in fossil fuel use implies bringing the equivalent of a new Alaska pipeline into production every one to two years. Nuclear capacity would have to be increased 30 times over 1960 levels - equivalent to installing a new nuclear power station generating 1-gigawatt of electricity every two to four days. This 35TW scenario is still well below the 55TW future that assumes today's levels of energy consumption per capita in industrial countries are achieved in all countries.

Case B: Low Scenario

Taking the 11.2TW scenario as a highly optimistic example of a strong conservation strategy. 2020 energy demand in developing and industrial countries is quoted as 7.3TW and 3.9TW respectively, as compared with 3.3TW and 7.0TW in 1980. This would mean a saving of 3.1TW in industrial countries by 2020 and an additional requirement of 4.0TW in developing countries. Even if developing countries were able to acquire the liberated primary resource, they would still be left with a shortfall of 0.9TW in primary supply. Such a deficit is likely to be much greater (possibly two to three times), given the extreme level of efficiency required for this scenario, which is unlikely to be realized by most governments. In 1980, the following breakdown of primary supply was quoted: oil, 4.2TW; coal, 2.4; gas, 1.7; renewables, 1.7; and nuclear, 0.2. The question is - where will the shortfall in primary energy supply come from? This rough calculation serves to illustrate that the postulated average growth of around 30 per cent per capita in primary consumption in developing countries will still require considerable amounts of primary supply even under extremely efficient energy usage regimes.

Sources: The 35TW scenario was originated in Energy Systems Group of the International Institute for Applied Systems Analysis, **Energy in a Finite World - A Global Systems Analysis**, (Cambridge, Mass.: Ballinger, 1981); all other calculations are from J. Goldemberg et al., 'An End-Use Oriented Global Energy Strategy', **Annual Review of Energy, Vol. 10**, 1985.

10. The economic implications of a high energy future are disturbing. A recent World Bank Study indicates that for the period 1960-95, a 4.1 per cent annual growth in energy consumption, approximately comparable to Case A in Box 7-2, would require an average annual investment of some $130 billion (in 1982 dollars) in developing countries alone. This would involve doubling the share of energy investment in terms of aggregate gross domestic product.*/11* About half of this would have to come from foreign exchange and the rest from internal spending on energy in developing countries.

11. The environmental risks and uncertainties of a high energy future are also disturbing and give rise to several reservations. Four stand out:

- the serious probability of climate change generated by the 'greenhouse effect' of gases emitted to the atmosphere, the most important of which is carbon dioxide (CO2) produced from the combustion of fossil fuels*/12*;
- urban-industrial air pollution caused by atmospheric pollutants from the combustion of fossil fuels*/13*;
- acidification of the environment from the same causes*/14*; and
- the risks of nuclear reactor accidents, the problems of waste disposal and dismantling of reactors after their service life is over, and the dangers of proliferation associated with the use of nuclear energy.

Along with these, a major problem arises from the growing scarcity of fuelwood in developing countries. If trends continue, by the year 2000 around 2.4 billion people may be living in areas where wood is extremely scarce.*/15*

12. These reservations apply at even lower levels of energy use. A study that proposed energy consumption at only half the levels of Case A (Box 7-2) drew special attention to the risks of global warning from CO2.*/16* The study indicated that a realistic fuel mix - a virtual

quadrupling of coal and a doubling of gas use, along with 1.4 times as much oil - could cause significant global warming by the 2020s. No technology currently exists to remove CO_2 emissions from fossil fuel combustion. The high coal use would also increase emissions of oxides of sulphur and nitrogen, much of which turns to acids in the atmosphere. Technologies to remove these latter emissions are now required in some countries in all new and even some old facilities, but they can increase investment costs by 15-25 per cent./*17* If countries are not prepared to incur these expenses, this path becomes even more infeasible, a limitation that applies much more to the higher energy futures that rely to a greater extent on fossil fuels. A near doubling of global primary energy consumption will be difficult without encountering severe economic, social, and environmental constraints.

> Energy is, put most simply, the fundamental unit of the physical world. As such, we cannot conceive of development without changes in the extent or the nature of energy flows. And because it is so fundamental, every one of those changes of flows has environmental implications. The implications of this are profound. It means that there is no such thing as a simple energy choice. They are all complex. And they all involve trade-offs. However, some of the choices and some of the trade-offs appear to be unequivocally better than others, in the sense that they offer more development and less environmental damage.
>
> David Brooks
> Friends of the Earth
> WCED Public Hearings
> Ottawa, 26-27 May 1986

13. This raises the desirability of a lower energy future, where GDP growth is not constrained but where investment effort is switched away from building more primary supply sources and put into the development and supply of highly efficient fuel-saving end-use equipment. In this way, the energy services needed by society could be supplied at much reduced levels of primary energy production. Case B in Box 7-2 allows for a 50 per cent fall in per capita primary energy consumption in industrial countries and a 30 per cent increase in developing countries./*18* By using the most energy-efficient technologies and processes now available in all sectors of the economy, annual global per capita GDP growth rates of around 3 per cent can be achieved. This growth is at least as great as that regarded in this report as a minimum for reasonable development. But this path would require huge structural changes to allow market penetration of efficient technologies, and it seems unlikely to be fully realizable by most governments during the next 40 years.

14. The crucial point about these lower, energy-efficient futures is not whether they are perfectly realisable in their proposed time frames. Fundamental political and institutional shifts are required to restructure investment potential in order to move along these lower, more energy-efficient paths.

15. The Commission believes that there is no other realistic option open to the world for the 21st century. The ideas behind these lower scenarios are not fanciful. Energy efficiency has already shown cost-effective results. In many industrial countries, the primary energy required to produce a unit of GDP has fallen by as much as a quarter or even a third over the last 13 years, much of it from implementing energy efficiency measures./*19* Properly managed, efficiency measures could allow industrial nations to stabilize their primary energy consumption by the turn of the century. They would also enable developing countries to achieve higher levels of growth with much reduced levels of investment, foreign debt, and environmental damage. But by the early decades of the 21st century they

will not alleviate the ultimate need for substantial new energy supplies globally.

II. Fossil Fuels: The Continuing Dilemma

16. Many forecasts of recoverable oil reserves and resources suggest that oil production will level off by the early decades of the next century and then gradually fall during a period of reduced supplies and higher prices. Gas supplies should last over 200 years and coal about 3.000 years at present rates of use. These estimates persuade many analysts that the world should immediately embark on a vigorous oil conservation policy.

17. In terms of pollution risks, gas is by far the cleanest fuel, with oil next and coal a poor third. But they all pose three interrelated atmospheric pollution problems: global warming,*/20* urban industrial air pollution,*/21* and acidification of the environment.*/22* Some of the wealthier industrial countries may possess the economic capacity to cope with such threats. Most developing countries do not.

18. These problems are becoming more widespread particularly in tropical and subtropical regions, but their economic, social, and political repercussions are as yet not fully appreciated by society. With the exception of CO_2, air pollutants can be removed from fossil fuel combustion processes at costs usually below the costs of damage caused by pollution.*/23* However, the risks of global warming make heavy future reliance upon fossil fuels problematic.

1. Managing Climatic change

19. The burning of fossil fuels and, to a lesser extent, the loss of vegetative cover, particularly forests, through urban-industrial growth increase the accumulation of CO_2 in the atmosphere. The pre-industrial concentration was about 280 parts of carbon dioxide per million parts of air by volume. This concentration reached 340 in 1980 and is expected to double to 560 between the middle and the end of the next century.*/24* Other gases also play an important role in this 'greenhouse effect', whereby solar radiation is trapped near the ground, warming the globe and changing the climate.

20. After reviewing the latest evidence on the greenhouse effect in October 1985 at a meeting in Villach, Austria, organized by the WMO, UNEP, and ICSU, scientists from 29 industrialized and developing countries concluded that climate change must be considered a 'plausible and serious probability. They further concluded that: 'Many important economic and social decisions are being made today on ... major water resource management activities such as irrigation and hydropower; drought relief; agricultural land use; structural designs and coastal engineering projects; and energy planning - all based on the assumption that past climatic data, without modification, are a reliable guide to the future. This is no longer a good assumption'.*/25*

21. They estimated that if present trends continue, the combined concentration of CO_2 and other greenhouse gases in the atmosphere would be equivalent to a doubling of CO_2 from pre-industrial levels, possibly as early as the 2030s, and could lead to a rise in global mean temperatures 'greater than any in man's history'.*/26* Current modelling studies and 'experiments' show a rise in globally averaged surface temperatures, for an effective CO_2 doubling, of somewhere between 1.5°C and 4.5°C, With the warming becoming more pronounced at higher latitudes during winter than at the equator.

22. An important concern is that a global temperature rise of 1.5-4.5°C, with perhaps a two to three times greater warming at the poles, would lead to a sea level rise of 25-140

centimetres./27 A rise in the upper part of this range would inundate low-lying coastal cities and agricultural areas, and many countries could expect their economic, social, and political structures to be severely disrupted. It would also alow the 'atmospheric heat-engine', which is driven by the differences between equatorial and polar temperatures, thus influencing rainfall regimes./28 Experts believe that crop and forest boundaries will move to higher latitudes; the effects of warmer oceans on marine ecosystems or fisheries and food chains are also virtually unknown.

23. There is no way to prove that any of this will happen until it actually occurs. The key question is: How much certainty should governments require before agreeing to take action? If they wait until significant climate change is demonstrated, it may be too late for any countermeasures to be effective against the inertia by then stored in this massive global system. The very long time lags involved in negotiating international agreement on complex issues involving all nations have led some experts to conclude that it is already late./29 Given the complexities and uncertainties surrounding the issue, it is urgent that the process start now. A four track strategy is needed, combining:

- improved monitoring and assessment of the evolving phenomena;
- increased research to improve knowledge about the origins, mechanisms, and effects of the phenomena;
- the development of internationally agreed policies for the reduction of the causative gases; and
- adoption of strategies needed to minimize damage and cope with the climate changes, and rising sea level.

24. No nation has either the political mandate or the economic power to combat climatic change alone. However, the Villach statement recommended such a four track strategy for climate change, to be promoted by governments and the scientific community through WMO, UNEP, and ICSU - backed by a global convention if necessary./30

> It is difficult to imagine an issue with more global impacts on human societies and the natural environment than the greenhouse effect. The signal is unclear but we may already be witnessing examples, if not actual greenhouse effects, in Africa.
>
> The ultimate potential impacts of a greenhouse warming could be catastrophic. It is our considered judgement that it is already very late to start the process of policy consideration. The process of heightening public awareness, of building support for national policies, and finally for developing multilateral efforts to slow the rate of emissions growth will take time to implement.
>
> The greenhouse issue is an opportunity as well as a challenge; not surprisingly, it provides another important reason to implement sustainable development strategies.
>
> Irving Mintzer
> World Resources Institute
> WCED Public Hearing
> Oslo, 24-25 June 1985

25. While these strategies are being developed, more immediate policy measures can and should be adopted. The most urgent are those required to increase and extend the recent steady gains in energy efficiency and to shift the energy mix more towards renewables. Carbon dioxide output globally could be significantly reduced by energy efficiency measures without any reduction of the tempo of GDP growth./*31* These measures would also serve to abate other emissions and thus reduce acidification and urban-industrial air pollution. Gaseous fuels produce less carbon dioxide per unit of energy output than oil or coal and should be promoted, especially for cooking and other domestic uses.

26. Gases other than carbon dioxide are thought to be responsible for about one-third of present global warming, and it is estimated that they will cause about half the problem around 2030./*32* some of these, notably chlorofluorocarbons used as aerosols, refrigeration chemicals, and in the manufacture of plastics, may be more easily controlled than CO2. These, although not strictly energy-related, will have a decisive influence on policies for managing carbon dioxide emissions.

27. Apart from their climatic effect, chlorofluorocarbons are responsible to a large extent for damage to the earth's stratospheric ozone./*33* The chemical industry should make every effort to find replacements, and governments should require the use of such replacements when found (as some nations have outlawed the use of these chemicals as aerosols). Governments should ratify the existing ozone convention and develop protocols for the limitation of chlorofluorocarbon emissions, and systematically monitor and report implementation.

28. A lot of policy development work is needed. This should proceed hand in hand with accelerated research to reduce remaining scientific uncertainties. Nations urgently need to formulate and agree upon management policies for all environmentally reactive chemicals released into the atmosphere by human activities, particularly those that can influence the radiation balance on earth. Governments should initiate discussions leading to a convention on this matter.

29. If a convention on chemical containment policies cannot be implemented rapidly, governments should develop contingency strategies and plans for adaptation to climatic change. In either case, WMO, UNEP, WHO, ICSU, and other relevant international and national bodies should be encouraged to coordinate and accelerate their programmes to develop a carefully integrated strategy of research, monitoring, and assessment of the likely impacts on climate, health, and environment of all environmentally reactive chemicals released into the atmosphere in significant quantities.

2. Reducing Urban-Industrial Air Pollution

30. The past three decades of generally rapid growth worldwide have seen dramatic increases in fuel consumption for heating and cooling, automobile transport, industrial activities, and electricity generation. Concern over the effects of increasing air pollution in the late 1960s resulted in the development of curative measures, including air-quality criteria, standards, and add-on control technologies that can remove pollutants cost-effectively. All these greatly reduced emissions of some of the principal pollutants and cleaned air over many cities. Despite this, air pollution has today reached serious levels in the cities of several industrial and newly industrialized countries as well as in those of most developing countries, which in some cases are by now the world's most polluted urban areas.

31. The fossil fuel emissions of principal concern in terms of urban pollution, whether from stationary or mobile sources, include sulphur dioxide, nitrogen oxides, carbon monoxide, various volatile organic compounds, fly ash, and other suspended particles. They can injure human health and the environment, bringing increased respiratory complaints, some potentially fatal. But these pollutants can be contained so as to protect human health and the environment and all governments should take steps to achieve acceptable levels of air quality.

32. Governments can establish and monitor air quality goals and objectives, allowable atmospheric loadings, and related emission criteria or standards, as some successfully do already. Regional organizations can support this effort. Multilateral and bilateral development assistance agencies and development banks should encourage governments to require that the most energy-efficient technology be used when industries and energy utilities plan to build new or extend existing facilities.

3. Damage from the Long-Range Transport of Air Pollution

33. Measures taken by many industrialized countries in the 1970s to control urban and industrial air pollution (high chimney stacks, for example) greatly improved the quality of the air in the cities concerned. However, it quite unintentionally sent increasing amounts of pollution across national boundaries in Europe and North America, contributing to the acidification of distant environments and creating new pollution problems. This was manifest in growing damage to lakes, soils, and communities of plants and animals.*/34* Failure to control automobile pollution in some regions has seriously contributed to the problem.

34. Thus atmospheric pollution, once perceived only as a local urban-industrial problem involving people's health, is now also seen as a much more complex issue encompassing buildings, ecosystems, and maybe even public health over vast regions. During transport in the atmosphere, emissions of sulphur and nitrogen oxides and volatile hydrocarbons are transformed into sulphuric and nitric acids, ammonium salts, and ozone. They fall to the ground, sometimes many hundreds or thousands of kilometres from their origins, as dry particles or in rain, snow, frost, fog, and dew. Few studied of their socio-economic costs are available, but these demonstrate that they are quite large and suggest that they are growing rapidly.*/35* They damage vegetation, contribute to land and water pollution, and corrode buildings, metallic structures and vehicles, causing billions of dollars in damage annually.

35. Damage first became evident in Scandinavia in the 1960s. Several thousand lakes in Europe, particularly in southern Scandinavia*/36*, and several hundreds in North America*/37* have registered a steady increase in acidity levels to the point where their natural fish populations have declined or died out. The same acids enter the soil and groundwater, increasing corrosion of drinking water piping in Scandinavia.*/38*

36. The circumstantial evidence indicating the need for action on the sources of acid precipitation is mounting with a speed that gives scientists and governments little time to assess it scientifically. Some of the greatest observed damage has been reported in Central Europe, which is currently receiving more than one gramme of sulphur on every square metre of ground each year, at least five times greater than natural background.*/39* There was little evidence of tree damage in Europe in 1970. In 1962, the Federal Republic of Germany reported visible leaf damage in its forest plot samples nationwide, amounting in 1983 to 34 per cent, and rising in 1985 to BO per cent.*/40* Sweden reported light to moderate damage in 30 per cent of its forests, and various reports from other countries in Eastern

and Western Europe are extremely disquieting. So far an estimated 14 per cent of all European forestland is affected./41

37. The evidence is not all in, but many reports show soils in parts of Europe becoming acid throughout the tree rooting layers,/42 particularly nutrient-poor soils such as those of Southern Sweden/43 The precise damage mechanisms are not known, but all theories include an air pollution component. Root damage/44 and leaf damage appear to interact - affecting the ability of the trees both to take up water from the soil and to retain it in the foliage, so that they become particularly vulnerable to dry spells and other stresses. Europe may be experiencing an immense change to irreversible acidification, the remedial costs of which could be beyond economic reach./45 (See Box 7-3.) Although there are many options for reducing sulphur, nitrogen, and hydrocarbon emissions, no single pollutant control strategy is likely to be effective in dealing with forest decline. It will require a total integrated mix of strategies and technologies to improve air quality, tailored for each region.

> A forest in an ecosystem that exists under certain environmental conditions, and if you change the conditions, the system is going to change. It is a very difficult task for ecologists to foresee what changes are going to be because the systems are so enormously complex.
>
> The direct causes behind an individual tree dying can be far removed from the primary pressure that brought the whole system into equilibrium. One time it might be ozone, another time it may be SO_2, a third time it may be aluminium poisoning.
>
> I can express myself by an analogy: If there is famine, there are relatively few people who die directly from starvation: they die from dysentery or various infectious diseases. And in such a situation, it is not of very much help to send medicine instead of food. That means that in this situation, it is necessary to address the primary pressures against the ecosystem.
>
> Alf Johnels
> Swedish Museum of Natural History
> WCED Public Hearing
> Oslo, 24-25 June 1985

38. Evidence of local air pollution and acidification in Japan and also in the newly industrialized countries of Asia, Africa, and Latin America is beginning to emerge. China and the Republic of Korea seem particularly vulnerable, as do Brazil, Colombia, Ecuador, and Venezuela. So little is known about the likely environmental loading of sulphur and nitrogen in these region and about the acid-neutralizing capacity of tropical lakes and forest soils that a comprehensive programme of investigation should be formulated without delay./46

39. Where actual or potential threats from acidification exist, governments should map sensitive areas, assess forest damage annually and soil impoverishment every five years according to regionally agreed protocols, and publish the findings. They should support transboundary monitoring of pollution being carried out by agencies in their region and, where there is no such agency, create one or give the job to any suitable regional body. Governments in many regions could gain significantly from early agreement to prevent transboundary air pollution and the enormous damage to their economic base now being

experienced in Europe and North America. Even though the exact causes of the damage are hard to prove, reduction strategies are certainly within reach and economic. They could be viewed as a cheap insurance policy compared with the vast amount of potential damage these strategies avoid.

Box 7-3 The Damage and Control Costs of Air Pollution

It is very difficult to quantify damage control costs, not least because cost figures are highly dependent on the control strategy assumed. However, in the eastern United States, it has been estimated that halving the remaining sulphur dioxide emissions from existing sources would cost $5 billion a year, increasing present electricity rates by 2-3 per cent. If nitrogen oxides are figured in, the additional costs might be as high as $6 billion a year. Materials corrosion damage alone is estimated to cost $7 billion annually in 17 states in the eastern United states.

Estimates of the annual costs of securing a 55 to 65 per cent reduction in the remaining sulphur emissions in the countries of the European Economic Community between 1980 and 2000 range from $4.6 billion to $6.7 billion (1982 dollars) per year. Controls on stationary boilers to reduce nitrogen levels by only 10 per cent annually by the year 2000 range between $100,000 and $400,000 (1982 dollars). These figures translate into a one-time increase of about 6 per cent in the price of electrical power to the consumer. Studies place damage costs due to material and fish losses alone at $3 billion a year, while damage to crops, forests, and health are estimated to exceed $10 billion per year. Technologies for drastically reducing oxides of nitrogen and hydrocarbons from automobile exhaust gases are readily available and routinely used in North America and Japan, but not in Europe.

Japanese laboratory studies indicate that air pollution and acid rain can reduce some wheat and rice crop production, perhaps by as much as 30 per cent.

Sources: U.S. Congress, Office of Technology Assessment, **Acid Rain and Transported Air Pollutants: Implications for Public Policy** (Washington, DC: U.S. Government Printing Office, 1985); U.S. Environmental Protection Agency, **Acid Deposition Assessment** (Washington, DC: 1985); I.M. Torrens, 'Acid Rain and Air Pollution: A Problem of Industrialization', prepared for WCED, 1985; P. Mandelbaum, **Acid Rain - Economic Assessment** (New York: Plenum Press, 1985); M. Hashimoto, 'National Air quality Management Policy of Japan', prepared for WCED, 1985; OECD, **The State of the Environment** (Paris: 1985).

III. Nuclear Energy: Unsolved Problems

1. The Peaceful Atom

40. In the years following the Second World War, the nuclear knowledge that under military control had led to the production of atomic weapons was redeployed for peaceful 'energy' purposes by civilian technologists. Several benefits were obvious at the time.

41. It was also realized that no energy source would ever be risk-free. There was the danger of nuclear war, the spread of atomic weapons, and nuclear terrorism. But intensive international cooperation and a number of negotiated agreements suggested that these dangers could be avoided. For instance, the *Nonproliferation Treaty* (NPT), drafted in its final form in 1969, included a promise by signatory governments possessing nuclear weapons and expertise to pursue and undertake nuclear disarmament ad also to assist the non-nuclear signatories in developing nuclear power, but strictly for peaceful purposes only. Other problems, such as radiation risks, reactor safety, and nuclear waste disposal were all acknowledged as very important but, with the right amount of effort, containable.

42. And now, after almost four decades of immense technological effort to support nuclear development, nuclear energy has become widely used. Some 30 governments produce from nuclear generators a total of about 15 per cent of all the electricity used globally. Yet it has not met earlier expectations that it would be the key to ensuring an unlimited supply of low-cost energy. However, during this period of practical experience with building and running nuclear reactors, the nature of the costs, risks and benefits have become much more evident and as such, the subject of sharp controversy.

2. The Growing Understanding of Nuclear Issues

43. The potential for the spread of nuclear weapons is one of the most serious threats to world peace. It is in the interest of all nations to prevent proliferation of nuclear weapons. All nations therefore should contribute to the development of a viable non-proliferation regime. The nuclear weapon states must deliver on their promise to reduce the number and ultimately eliminate nuclear weapons in their arsenals and the role those weapons play in their strategies. And the non-nuclear-weapon states must cooperate in providing credible assurances that they are not moving towards a nuclear weapon capability.

> The health risks for the development of peaceful uses of nuclear technology, including nuclear electricity, are very small when compared with the benefits from the use of nuclear radiation for medical diagnosis treatment.
>
> The safe application of nuclear radiation technology promises many benefits in environmental clean-up and in increasing world food supplies by eliminating spoilage.
>
> With a recent and very notable exception, the international cooperation that has marked the development of nuclear power technology provides an excellent model by which to address common environmental and ethical problems posed by the development of other technologies.
>
> Ian Wilson
> Vice-President, Canadian Nuclear Association
> WCED Public Hearing
> Ottawa, 26-27 May 1986

44. Most schemes for non-proliferation mandate an institutional separation between military and civilian uses of nuclear energy. But for countries with full access to the complete nuclear fuel cycle, no technical separation really exists. Not all states operate the necessary clear-cut administrative separation of civilian and military access. Cooperation is needed also among suppliers and buyers of civilian nuclear facilities and materials and the

International Atomic Energy Agency, in order to provide credible safeguards against the diversion of civilian reactor programmes to military purposes, especially in countries that do not open all their nuclear programmes to IAEA inspection. Thus, there still remains a danger of the proliferation of nuclear weapons.

2.1 Costs

45. The costs of construction and the relative economics of electricity generating stations - whether powered by nuclear energy, coal, oil or gas - are conditioned by the following factors throughout the service life of a plant:

- the cost of borrowing money to finance plant construction,
- the impact of inflation;
- the duration of the period of planning, licensing, and construction;
- the cost of fuel and maintenance ;
- the costs of protective measures, to ensure safe operation; and
- waste disposal costs (land, air, and water pollution containment) and the costs of dismantling at the end of service life.

46. All these factors vary widely depending on differing institutional, legal, and financial arrangements in different countries. Cost generalizations and comparisons are therefore unhelpful or misleading. However, costs associated with several of these factors have increased more rapidly for nuclear stations during the last 5-10 years, so that the earlier clear cost advantage of nuclear over the service life of the plant has been reduced or lost altogether./*47* Nations should therefore look very closely at cost comparisons to obtain the best value when choosing an energy path.

2.2 Health and Environment Risks

47. Very strict codes of safety practice are implemented in nuclear plants so that under officially approved operating conditions, the danger from radiation to reactor personnel and especially to the general public is negligible. However, an accident occurring in a reactor may in certain very rare canes be serious enough to cause an external release of radioactive substances. Depending upon the level of exposure, people are under a certain level of risk of becoming ill from various forms of cancer or from alteration or genetic material, which may result in hereditary defects.

48. Since 1928, the International Commission on Radiological Protection (ICRP) has issued recommendations on radiation dosage levels above which exposure is unacceptable. These have been developed for occupationally exposed workers and for the general public. The 'Nuclear Safety Standards (NUSS) codes of IAEA were developed in 1975 to reduce safety differences among member states. Neither system is in any way binding on governments, if an accident occurs, individual governments have the responsibility of deciding at what level of radioactive contamination pasture land, drinking water, milk, meat, eggs, vegetables, and fish, are to be banned for consumption by livestock or humans.

49. Different countries - even different local government authorities within a country - have different criteria. Some have none at all, ICRP and NUSS notwithstanding. States with more

rigorous standards may destroy large amounts of food or may ban food imports from a neighbour states with more permissive criteria. This causes great hardship to farmers who may not receive any compensation for their losses. It may also cause trade problems and political tension between states. Both of these difficulties occurred following the Chernobyl disaster, when the need to develop at least regionally conformable contamination criteria and compensation arrangements was overwhelmingly demonstrated.

2.3 Nuclear Accidents Risks

50. Nuclear safety returned to the newspaper headlines following the Three Mile Island (Harrisburg, United States) and the Chernobyl (USSR) accidents. Probabilistic estimates of the risks of component failure, leading to a radioactive release in Western style light water reactors wore made in 1975 by the U.S. Nuclear Regulatory Commission.*/48* The most serious category of release through containment failure was placed at around 1 in 1,000,000 years of reactor operation. Post-accident analysis of both Harrisburg and Chernobyl - a completely different type of reactor - have shown that in both cases, human operator error was the main cause. They occurred after about 2,000 and 4,000 reactor-years respectively.*/49* The frequencies of such occurrences are well nigh impossible to estimate probabilistically. However, available analyses indicate that although the risk of a radioactive release accident is small, it is by no means negligible for reactor operations at the present time.

51. The regional health and environment effects of an accident are largely predictable from radioactive fall-out studies following early atomic weapons testing in the atmosphere and have been confirmed in practice following the Chernobyl accident. What could not be confidently predicted before Chernobyl were the local effects of such an accident. A much clearer picture is now emerging as a result of the experiences there when a reactor exploded, following a series of infringements of the official safety regulations, on 26 April 1986, causing the worst reactor accident ever experienced. As a result, the whole district had to be managed on something like a 'war footing' and efforts resembling a large military operation were needed to contain the damage.

2.4 Radioactive Waste Disposal

52. Civil nuclear energy programmes worldwide have already generated many thousands of tons of spent fuel and high-level waste. Many governments have embarked on large-scale programmes to develop ways of isolating these from the biosphere for the many hundreds of thousands of years that they will remain hazardously radioactive.

53. But the problem of nuclear waste disposal remains unsolved. Nuclear waste technology has reached an advanced level of sophistication.*/50* This technology has not however been fully tested or utilized and problems remain about disposal. There is particular concern about future recourse to ocean dumping and the disposal of contaminated waste in the territories of small or poor states that lack the capacity to impose strict safeguards. There should be a clear presumption that all countries that generate nuclear waste dispose of it within their own territories or under strictly monitored agreements between states.

3. The Current International Situation

54. During the last 25 years, a growing awareness of the difficulties outlined above has resulted in a wide range of reactions from technical experts, the public, and governments.

Many experts still feel that so much can be learned from the problems experienced up to now. They argue that if the public climate allows then to solve the nuclear waste disposal and decommissioning issues and the cost of borrowing money remains reasonably below its 1980-82 peak, in the absence of viable new supply alternatives there is no reason why nuclear energy should not emerge as a strong runner in the 1990s. At the other extreme, many experts take the view that there are so many unsolved problems and too many risks for society to continue with a nuclear future. Public reactions also vary. Some countries have exhibited little public reaction, in others there appears to be a high level of anxiety that expresses itself in anti-nuclear results in public opinion polls or large anti-nuclear campaigns.

> Today the assessment of practical consequences can be based on practical experience. The consequences of Chernobyl has made Soviet specialists once again pose a question: Is not the development of nuclear energy on an industrial scale premature? Will it not be fatal to our civilization, to the ecosystem of our planet? On our planet so rich in all sorts of energy sources, this question can be discussed quite calmly. We have a real choice in this, both on a state and a governmental level, and also on the level of individuals and professionals.
>
> We must put all our efforts to improve the technology itself, to develop and elaborate strict standards and norms of quality, of safety of a technology. We must work for the creation of anti-accident centres and centres devoting themselves to compensating for the losses to the environment. The upgrading of the industrial level of safety and the solution of the problem of the relations between man and machine would be a lot more natural thing to do than concentrating the efforts on only one element of the energy structure in the world. This would benefit the whole of humanity.
>
> V. A. Legasov
> Member, Academy of Sciences of the USSR
> WCED Public Hearing
> Moscow, 8 Dec 1986

55. And so, whilst some states still remain nuclear-free, today nuclear reactors supply about 15 per cent of all the electricity generated. Total electricity production worldwide is in turn equivalent to around 15 per cent of global primary energy supply. Roughly one-quarter of all countries worldwide have reactors. In 1986, there were 366 working and a further 140 planned,*/51* with 10 governments possessing about 90 per cent of all installed capacity (more than 5 GW (e)). Of these, there are 8 with a total capacity of more than 9 GW (e),*/52* which provided the following percentages of electric power in 1985: France, 65; Sweden, 42; Federal Republic of Germany, 31; Japan, 23; United Kingdom, 19; United States, 16; Canada, 13; and USSR, 10. According to IAEA, in 1985 there were 55 research reactors worldwide, 33 of them in developing countries.*/53*

56. Nevertheless, there is little doubt that the difficulties referred to above have in one way or another contributed to a scaling back of future nuclear plans - in some countries, to a de facto nuclear pause. In Western Europe and North America, which today have almost 75 per cent of current world capacity, nuclear provides about one-third of the energy that was forecast for it 10 years ago. Apart from France, Japan, the USSR, and several other East European countries that have decided to continue with their nuclear programmes, ordering, construction, and licensing prospects for new reactors in many other countries

look poor. In fact, between 1972 and 1986, earlier global projections of estimated capacity for the year 2000 have been revised downwards by a factor of nearly seven. Despite this, the growth of nuclear at around 15 per cent a year over the last 20 years is still impressive./*54*

57. Following Chernobyl, there were significant changes in the nuclear stance of certain governments. Several - notably China, the Federal Republic of Germany, France, Japan, Poland, United Kingdom, United States, and the USSR - have maintained or reaffirmed their pro-nuclear policy. Others with a 'no nuclear' or a 'phase-out' policy (Australia, Austria, Denmark, Luxembourg, New Zealand, Norway, Sweden - and Ireland with an unofficial anti-nuclear position) have been joined by Greece and the Philippines. Meanwhile, Finland, Italy, the Netherlands, Switzerland, and Yugoslavia are re-investigating nuclear safety and/or the anti-nuclear arguments, or have introduced legislation tying any further growth of nuclear energy and export/import of nuclear reactor technology to a satisfactory solution of the problem of disposal of radioactive wastes. Several countries have been concerned enough to conduct referenda to test public opinion regarding nuclear power.

4. Conclusions and Recommendations

58. These national reactions indicate that as they continue to review and update all the available evidence, governments tend to take up three possible positions:

- remain non-nuclear and develop other sources of energy:
- regard their present nuclear power capacity as necessary during a finite period of transition, to safer alternative energy sources; or
- adopt and develop nuclear energy with the conviction that the associated problems and risks can and must, be solved with a level of safety that is both nationally and internationally acceptable.

The discussion in the Commission also reflected these tendencies, views, and positions.

59. But whichever policy is adopted, it is important that the vigorous promotion of energy-efficient practices in all energy sectors and large-scale programmes of research, development, and demonstration for the safe and environmentally benign use of all promising energy sources, especially renewables, be given the highest, priority.

60. Because of potential transboundary effects, it is essential that governments cooperate to develop internationally agreed codes of practice covering technical, economic, social (including health and environment aspects), and political components of nuclear energy. In particular, international agreement must be reached on the following specific items:

- full governmental ratification of the conventions on 'Early Notification of a Nuclear Accident' (including the development of an appropriate surveillance and monitoring system) and on 'Assistance in the Case of a Nuclear Accident or Radiological Emergency' as recently developed by IAEA;
- emergency response training - for accident containment and for decontamination and long-term clean-up of affected sites, personnel, and ecosystems;
- the transboundary movement of all radioactive materials - including fuels, spent fuels, and other wastes by land, sea, or air;

- a code of practice on liability and compensation;
- standards for operator training and international licensing;
- codes of practice for reactor operation, including minimum safety standards;
- the reporting of routine and accidental discharges from nuclear installations;
- effective, internationally harmonized minimum radiological protection standards;
- agreed site selection criteria as well as consultation and notification prior to the siting of all major civil nuclear - related installations;
- standards for waste repositories;
- standards for the decontamination and dismantling of time-expired nuclear reactors; and
- problems posed by the development of nuclear powered shipping.

61. For many reasons, especially including the failure of the nuclear weapons states to agree on disarmament, the *Nonproliferation Treaty* has not proved to be a sufficient instrument to prevent the proliferation of nuclear weapons, which still remains a serious danger to world peace. We therefore recommend in the strongest terms the construction of an effective international regime covering all dimensions of the problem. Both nuclear weapons states and non nuclear weapons states, should undertake to accept safeguards in accordance with the statutes of IAEA.

62. Additionally, an international regulatory function is required, including inspection of reactors internationally. This should be quite separate from the role of IAEA in promoting nuclear energy.

63. The generation of nuclear power is only justifiable if there are solid solutions to the presently unsolved problems to which it gives rise. The highest priority must be accorded to research and development on environmentally sound and economically viable alternatives, as well as on means of increasing the safety of nuclear energy.

IV. Wood Fuels: The Vanishing Resource

64. Seventy per cent of the people in developing countries use wood and, depending on availability, burn anywhere between an absolute minimum of about 350 kilogrammes to 2,900 kilogrammes of dry wood annually, with the average being around 700 kilogrammes per person.*/55* Rural woodfuel supplies appear to be steadily collapsing in many developing countries, especially in Sub-Saharan Africa.*/56* At the same time, the rapid growth of agriculture, the pace of migration to cities, and the growing numbers of people entering the money economy are placing unprecedented pressures on the biomass base*/57* and increasing the demand for commercial fuels: from wood and charcoal to kerosene, liquid propane, gas, and electricity. To cope with this, many developing country governments have no option but to immediately organize their agriculture to produce large quantities of wood and other plant fuels.

65. Wood is being collected faster than it can regrow in many developing countries that still rely predominantly on biomass wood, charcoal, dung, and crop residues - for cooking, for heating their dwellings, and even for lighting. FAO estimates suggest that in 1900, around 1.3 billion people lived in wood-deficit areas.*/58* If this population-driven overharvesting

continues at present rates, by the year 2000 some 2.4 billion people may be living in areas where wood is 'acutely scarce or has to be obtained elsewhere'. These figures reveal great human hardship. Precise data on supplies are unavailable because much of the wood is not commercially traded but collected by the users, principally women and children, but there is no doubt that millions are hard put to find substitute fuels, and their numbers are growing.

66. The fuelwood crisis and deforestation - although related are not the same problems. Wood fuels destined for urban and industrial consumers do tend to come from forests. But only a small proportion of that used by the rural poor comes from forests. Even in these cases, villagers rarely chop down trees; most collect dead branches or cut them from trees.*/59*

67. When fuelwood is in short supply, people normally economize; when it is no longer available, rural people are forced to burn such fuels as cow dung, crop stems and husks, and weeds. Often this does no harm, since waste products such as cotton stalks are used. But the burning of dung and certain crop residues may in some cases rob the soil of needed nutrients. Eventually extreme fuel shortages can reduce the number of cooked meals and shorten the cooking time, which increases malnourishment.

68. Many urban people rely on wood, and most of this is purchased. Recently, as the price of wood fuels has been rising, poor families have been obliged to spend increasing proportions of their income on wood. In Addis Ababa and Maputo, families may spend a third to half of their incomes this way.*/60* Much work has been done over the past 10 years to develop fuel-efficient stoves, and some of these new models use 30-50 per cent less fuel. These, as well as aluminium cooking pots and pressure cookers that also use much less fuel, should be made more widely available in urban areas.

> Fuelwood and charcoal are, and will remain, the major sources of energy for the great majority of rural people in developing countries. The removal of trees in both semiarid and humid land in African countries is a result to a large extent of increasing

V. Renewable Energy: The Untapped Potential

73. Renewable energy sources could in theory provide 10-13TW annually - equal to current global energy consumption.*/63* Today they provide about 2TW annually, about 21 per cent of the energy consumed worldwide, of which 15 per cent is biomass and 6 per cent hydropower. However, most of the biomass is in the form of fuelwood and agricultural and animal wastes. As noted above, fuelwood can no longer be thought of as a 'renewable' resource in many areas, because consumption rater have overtaken sustainable yields.

74. Although worldwide reliance on all these sources has been growing by more than 10 per cent a year since the late 1970s, it will be some time before they make up a substantial portion of the world's energy budget. Renewable energy systems are still in a relatively primitive stage of development. But they offer the world potentially huge primary energy sources, sustainable in perpetuity and available in one form or another to every nation on Earth. But it, will require a substantial and sustained commitment to further research and development if their potential is to be realized.

75. Wood as a renewable energy source is usually thought of as naturally occurring trees and shrubs harvested for local domestic use. Wood, however, is becoming an important feedstock, specially grown for advanced energy conversion processes in developing as well

as industrial countries for the product ion of process heat, electricity, and potentially for other fuels, such as combustible gases and liquids.

76. Hydropower, second to wood among the renewables, has been expanding at nearly 4 per cent annually. Although hundreds of thousands of megawatts of hydropower have been harnessed throughout the world, the remaining potential is huge./*64* In neighbouring developing countries, interstate cooperation in hydropower development could revolutionize supply potential especially in Africa.

> In the choice of resources to be utilized we should not stare at renewable resources of energy blindly, we should not blow it out of proportion, we should not promote it for the sake of the environment per se. Instead we should develop and utilize all resources available, renewable sources of energy included, as a long-term endeavour requiring a continuous and sustained effort that will not be subject to short-term economic fluctuations, in order that we, in Indonesia, will achieve a successful and orderly transition to a more diversified and balanced structure of energy supply and environmentally sound energy supply system, which is the ultimate goal of our policy.
>
> Speaker from the floor
> WCED Public Hearings
> Jakarta, 26 March 1985

77. Solar energy use is small globally, but it is beginning to assume an important place in the energy consumption patterns of some countries. Solar water and household heating is widespread in many parts of Australia, Greece, and the Middle East. A number of East European and developing countries have active solar energy programmes, and the United States and Japan support solar sales of several hundred million dollars a year. With constantly improving solar thermal and solar electric technologies, it is likely that their contribution will increase substantially. The cost of photovoltaic equipment has fallen from around $500-600 per peak watt to $5 and is approaching the $1-2 level where it can compete with conventional electricity production./*65* But even at $5 per peak watt, it still provides electricity to remote places more cheaply than building power lines.

78. Wind power has been used for centuries - mainly for pumping water. Recently its use has been growing rapidly in regions such as California and Scandinavia. In these cases the wind turbines are used to generate electricity for the local electricity grid. The costs of wind-generated electricity, which benefited initially from substantial tax incentives, have fallen dramatically in California in the last five years and may possibly be competitive with other power generated there within a decade./*66* Many countries have successful but small wind programmes, but the untapped potential is still high.

79. The fuel alcohol programme in Brazil produced about 10 billion litres of ethanol from sugar-cane in 1984 and replaced about 60 per cent of the gasoline that would have been required./*67* The cost has been estimated at $50-60 per barrel of gasoline replaced. When subsidies are removed, and a true exchange rate is used, this is competitive at 1981 oil prices. With present lower oil prices, the programme has become uneconomical. But it saves the nation hard currency, and it provides the additional benefits of rural development, employment generation, increased self-reliance, and reduced vulnerability to crises in the world oil markets.

80. The use of geothermal energy, from natural underground heat sources, has been

increasing at more than 15 per cent per year in both industrial and developing countries. The experience gained during the past decades could provide the basis for a major expansion of geothermal-capacity./*68* By contrast, technologies for low-grade heat via heat pumps or from solar ponds and ocean thermal gradients are promising but still mostly at the research and development stage.

81. These energy sources are not without their health and environment risks. Although they range from rather trivial to very serious problems, public reactions to them are not necessarily in proportion to the damage sustained. For instance, some of the commonest difficulties with solar energy are, somewhat surprisingly, the injuries from roof falls during solar thermal maintenance and the nuisance of sun-glare off their glass surfaces. Or a modern wind turbine can be a significant noise nuisance to people living nearby. Yet, these apparently small problems often arouse very strong public reactions.

82. But these are still minor issues compared with the ecosystem destruction at hydropower sites or the uprooting of homesteads in the areas to be flooded, as well as the health risks from toxic gases generated by rotting submerged vegetation and soils, or from waterborne diseases such as schistosomiasis (snail fever). Hydrodams also act as an important barrier to fish migration and frequently to the movement of land animals. Perhaps the worst problem they pose is the danger of catastrophic rupture of the dam-wall and the sweeping away or flooding of human settlements downstream - about once a year somewhere in the world. This risk is small but not insignificant.

83. One of the most widespread chronic problems is the eye and lung irritation caused by woodsmoke in developing countries. When agricultural wastes are burned, pesticide residues inhaled from the dusts or smoke of the crop material can be a health problem. Modern biofuel liquids have their own special hazards. Apart from competing with food crops for good agricultural land, their production generates large quantities of organic waste effluent, which if not used as a fertilizer can cause serious water pollution. Such fuels, particularly methanol, may produce irritant or toxic combustion products. All these and many other problems, both large and small, will increase as renewable energy systems are developed.

84. Most renewable energy systems operate best at small to medium scales, ideally suited for rural and suburban applications. They are also generally labour-intensive, which should be an added benefit where there if surplus labour. They are less susceptible than fossil fuels to wild price fluctuations and foreign exchange costs. Most countries have some renewable resources, and their use can help nations move towards self-reliance.

85. The need for a steady transition to a broader and more sustainable mix of energy sources is beginning to become accepted. Renewable energy sources could contribute substantially to this, particularly with new and improved technologies, but their development will depend in the short run on the reduction or removal of certain economic and institutional constraints to their use. These are formidable in many countries. The high level of hidden subsidies for conventional fuels built into the legislative and energy programmes of most countries distorts choices against renewables in research and development, depletion allowances, tax write-offs, and direct support of consumer prices. Countries should undertake a full examination of all subsidies and other forms of support to various sources of energy and remove those that are not clearly justified.

86. Although the situation is changing rapidly in some jurisdictions, electrical utilities in most have a supply monopoly on generation that allows them to arrange pricing policies that discriminate against other, usually small, suppliers./*69* In some countries a relaxation of this control, requiring utilities to accept power generated by industry, small systems, and

individuals, has created opportunities for the development of renewables. Beyond that, requiring utilities to adopt an end-use approach in planning, financing, developing, and marketing energy can open the door to a wide range of energy-saving measures as well as renewables.

87. Renewable energy sources require a much higher priority in national energy programmes. Research, development, and demonstration projects should command funding necessary to ensure their rapid development and demonstration. With a potential of 10TW or so, even if 3-4TW were realized, it would make a crucial difference to future primary supply, especially in developing countries, where the background conditions exist for the success of renewables. The technological challenges of renewables are minor compared with the challenge of creating the social and institutional frameworks that will ease these sources into energy supply systems.

88. The Commission believes that every effort should be made to develop the potential for renewable energy, which should form the foundation of the global energy structure during the 21st Century. A much more concerted effort must be mounted if this potential is to be realized. But a major programme of renewable energy development will involve large costs and high risks, particularly massive-scale solar and biomass industries. Developing countries lack the resources to finance all but a small fraction of this cost although they will be important users and possibly even exporters. Large-scale financial and technical assistance will therefore be required.

VI. Energy Efficiency: Maintaining the Momentum

89. Given the above analysis, the Commission believes that energy efficiency should be the cutting edge of national energy policies for sustainable development. Impressive gains in energy efficiency have been made since the first oil price shock in the 1970s. During the past 13 years, many industrial countries saw the energy content of growth fall significantly as a result of increases in energy efficiency averaging 1.7 per cent annually between 1973 and 1983.*/70* And this energy efficiency solution costs less, by savings made on the extra primary supplies required to run traditional equipment.

90. The cost-effectiveness of 'efficiency' as the most environmentally benign 'source' of energy is well established. The energy consumption per unit of output from the most efficient processes and technologies is one-third to less than one-half that of typically available equipment.*/71*

91. This is true of appliances for cooking, lighting and refrigeration, and space cooling and heating - needs that are growing rapidly in most countries and putting severe pressures on the available supply systems. It is also true of agricultural cultivation and irrigation systems, of the automobile, and of many industrial processes and equipment.

92. Given the large disproportion in per capita energy consumption between developed and developing countries in general, it is clear that the scope and need for energy saving is potentially much higher in industrial than in developing countries. Nonetheless, energy efficiency is important everywhere. The cement factory, automobile, or irrigation pump in a poor country is fundamentally no different from its equivalent in the rich world. In both, there is roughly the same scope for reducing the energy consumption or peak power demand of these devices without loss of output or welfare. But poor countries will gain much more from such reductions.

93. The woman who cooks in an earthen pot over an open fire uses perhaps eight times more energy than an affluent neighbour with a gas stove and aluminium pans. The poor

who light their homes with a wick dipped in a jar of kerosene get one-fiftieth of the illumination of a 100-watt electric bulb, but use just as much energy. These examples illustrate the tragic paradox of poverty. For the poor, the shortage of money is a greater limitation than the shortage of energy. They are forced to use 'free' fuels and inefficient equipment because they do not have the cash or savings to purchase energy-efficient fuels and end-use devices. Consequently, collectively they pay much more for a unit of delivered energy services.

94. In most cases, investments in improved end-use technologies save money over time through lowered energy-supply needs The costs of improving the end-use equipment is frequently much less than the cost of building more primary supply capacity. In Brazil, for example, it has been shown that for a discounted total investment of $4 billion in more efficient end-use technologies (such as more efficient refrigerators, street-lighting, or motors) it would be feasible to defer construction of 21 gigawatts of new electrical supply capacity, corresponding to a discounted capital savings for new supplies of $19 billion in the period 1986 to 2000./72

> We must change our attitude towards consumption goods in developed countries and we must create technological advances that will allow us to carry on economic development using less energy. We must ask ourselves can we solve the problems of underdevelopment without using or increasing the tremendous amount of energy used by these countries.
>
> The idea that developing countries use very little energy is an incorrect idea. We find that the poorest countries of all have a different problem; their problem is inefficient use of energy. Medium countries such as Brazil use more efficient and modern sources of fuel. The great hope for these countries is that the future will be built not based on technologies of the past, but using advanced technology. This will allow them to leap forward in relation to countries that are already developed.
>
> Jose Goldemberg
> President, Companhia Energetica de Sao Paulo
> WCED Public Hearing
> Brasilia, 30 Oct 1985

95. There are many examples of successful energy efficiency programmes in industrial countries. The many methods used successfully to increase awareness include information campaigns in the media, technical press, and schools; demonstrations of successful practices and technologies; free energy audits; energy 'labelling' of appliances; and training in energy-saving techniques. These should be quickly and widely extended. Industrialized countries account for such a large proportion of global energy consumption that even small gains in efficiency can have a substantial impact on conserving reserves and reducing the pollution load on the biosphere. It is particularly important that consumers, especially large commercial and industrial agencies, obtain professional audits of their energy use. This kind of energy 'book-keeping' will readily identify those places in their consumption patterns where significant savings can be made.

96. Energy pricing policies play a critical role in stimulating efficiency. At present, they sometimes include subsidies and seldom reflect the real costs of producing or importing the energy, particularly when exchange rates are undervalued. Very rarely do they reflect the external damage costs to health, property, and the environment. Countries should evaluate

all hidden and overt subsidies to see how far real energy costs can be passed on to the consumer. The true economic pricing of energy - with safeguards for the very poor - needs to be extended in all countries. Large numbers of countries both industrial and developing are already adopting such policies.

97. Developing countries face particular constraints in saving energy. Foreign exchange difficulties can make it hard to purchase efficient but costly energy conversion and end-use devices. Energy can often be saved cost-effectively by fine-tuning already functioning systems.*/73* But governments and aid agencies may find it less attractive to fund such measures than to invest in new large-scale energy supply hardware that is perceived as a more tangible symbol of progress.

98. The manufacture, import, or sale of equipment conforming to mandatory minimal energy consumption or efficiency standards is one of the most powerful and effective tools in promoting energy efficiency and producing predictable savings. International cooperation may be required when such equipment is traded from nation to nation. Countries and appropriate regional organizations should introduce and extend increasingly strict efficiency standards for equipment and mandatory labelling of appliances.

99. Many energy efficiency measures cost nothing to implement. But where investments are needed, they are frequently a barrier to poor households and small-scale consumers, even when pay-back times are short. In these latter cases, special small loan or hire-purchase arrangements are helpful. Where investment costs are not insurmountable, there are many possible mechanisms for reducing or spreading the initial investment, such as loans with favourable repayment periods and 'invisible' measures such as loans repaid by topping up the new, reduced energy bills to the pre-conservation levels.

100. Transport has a particularly important place in national energy and development planning. It is a major consumer of oil, accounting for 50-60 per cent of total petroleum use in most developing countries.*/74* It is often a major source of local air pollution and regional acidification of the environment in industrial and developing countries. Vehicle markets will grow much more rapidly in developing countries, adding greatly to urban air pollution, which in many cities already exceeds international norms. Unless strong action is taken, air pollution could become a major factor limiting industrial development in many Third World cities.

101. In the absence of higher fuel prices, mandatory standards providing for a steady increase in fuel economy may be necessary. Either way, the potential for substantial future gains in fuel economy is enormous. If momentum can be maintained, the current average fuel consumption of approximately 10 litres per 100 kilometres in the fleet of vehicles in use in industrial countries could be cut in half by the turn of the century.*/75*

102. A key issue is how developing countries can rapidly improve the fuel economy of their vehicles when these are, on average, used for twice as long those as in industrial countries, cutting rates of renewal and improvement in half. Licensing and import agreements should be reviewed to ensure access to the best available fuel efficient designs and production processes. Another important fuel-saving strategy especially in the growing cities of developing countries is the organizing of carefully planned public transport systems.

103. Industry accounts for 40 60 pet cent of all energy consumed in industrial countries and 10-40 per cent in developing countries. (See *Chapter 6*.) There has been significant improvement in the energy efficiency of production equipment, processes, and products. In developing countries, energy savings of as much as 20-30 per cent could be achieved by such skilful management of industrial development.

104. Agriculture worldwide is only a modest energy consumer, accounting for about 3.5 per cent of commercial energy use in the industrial countries and 4.5 per cent in developing countries as a whole./*76* A strategy to double food production in the Third World through increases in fertilizers, irrigation, and mechanization would add 140 million tons of oil equivalent to their agricultural energy use. This is only some 5 per cent of present world energy consumption and almost certainly a small part of the energy that could be saved in other sectors in the developing world through appropriate efficiency measures./*77*

105. Buildings offer enormous scope for energy savings, and perhaps the most widely understood ways of increasing energy efficiency are in the home and workplace. Buildings in the tropics are now commonly designed to avoid as much direct solar heating as possible by having very narrow east- and west-facing walls, but with long sides facing north and south and protected from the overhead sun by recessed windows or wide sills.

106. An important method of heating buildings is by hot water produced during electricity production and piped around whole districts, providing both heat and hot water. This extremely efficient use of fossil fuels demands a coordination of energy supply with local physical planning, which few countries are institutionally equipped to handle./*78* Where it has been successful, there has usually been local authority involvement in or control of regional energy-services boards, such as in Scandinavia and the USSR. Given the development of these or similar institutional arrangements, the cogeneration of heat and electricity could revolutionize the energy efficiency of buildings worldwide.

VII. Energy Conservation Measures

107. There is general agreement that the efficiency gains achieved by some industrialized countries over the past 13 years were driven largely by higher energy prices, triggered by higher oil prices. Prior to the recent fall in oil prices, energy efficiency was growing at a rate of 2.0 per cent annually in some countries, having increased gradually year by year./*79*

108. It is doubtful whether such steady improvements can be maintained and extended if energy prices are held below the level needed to encourage the design and adoption of more energy-efficient homes, industrial processes, and transportation vehicles. The level required will vary greatly within and between countries, depending on a wide range of factors. But whatever it is, it should be maintained. In volatile energy markets, the question is how.

109. Nations intervene in the 'market price' of energy in a variety of ways. Domestic taxes (or subsidies) on electrical power rates, oil, gas and other fuels are most common. They vary greatly between and even within countries where different states, provinces, and sometimes even municipalities have the right to add their own tax. Although taxes on energy have seldom been levied to encourage the design and adoption of efficiency measures, they can have that result if they cause energy prices to rise beyond a certain level - a level that varies greatly among jurisdictions.

110. Some nations also maintain higher than market prices on energy through duties on imported electricity, fuel, and fuel products. Others have negotiated bilateral pricing arrangements with oil and gas producers in which they stabilize prices for a period of time.

111. In most countries, the price of oil eventually determines the price of alternative fuels. Extreme fluctuations in oil prices, such as the world has experienced recently, endanger programmes to encourage conservation. Many positive energy developments worldwide that made sense with oil above $25 per barrel, are harder to justify at lower prices.

Investments in renewables, energy-efficient industrial processes, transport vehicles, and energy-services may be reduced. Most are needed to ease the transition to a safer and more sustainable energy future beyond this century. This goal requires a long, uninterrupted effort to succeed.

112. Given the importance of oil prices on international energy policy, the Commission recommends that new mechanisms for encouraging dialogue between consumers and producers be explored.

113. If the recent momentum behind annual gains in energy efficiency is to be maintained and extended, governments need to make it an explicit goal of their policies for energy pricing to consumers. Prices needed to encourage the adoption of energy-saving measures may be achieved by any of the above means or by other means. Although the Commission expresses no preference, conservation pricing requires that governments take a long-term view in weighing the costs and benefits of the various measures. They need to operate over extended periods, dampening wild fluctuations in the price of primary energy, which can impair progress towards energy conservation.

VIII. Conclusion

114. It is clear that a low energy path is the best way towards a sustainable future. But given efficient and productive uses of primary energy, this need not mean a shortage of essential energy services. Within the next 50 years, nations have the opportunity to produce the same levels of energy services with as little as half the primary supply currently consumed. This requires profound structural changes in socio-economic and institutional arrangements and is an important challenge to global society.

115. More importantly, it will buy the time needed to mount major programmes on sustainable forms of renewable energy, and so begin the transition to a safer, more sustainable energy era. The development of renewable sources will depend in part on a rational approach to energy pricing to secure a stable matrix for such progress. Both the routine practice of efficient energy use and the development of renewables will help take pressure off traditional fuels, which are most needed to enable developing countries to realize their growth potential worldwide.

116. Energy is not so much a single product as a mix of products and services, a mix upon which the welfare of individuals, the sustainable development of nations, and the life-supporting capabilities of the global ecosystem depend. In the past, this mix has been allowed to flow together haphazardly, the proportions dictated by short-term pressures on and short-term goals of governments, institutions, and companies. Energy is too important for its development to continue in such a random manner. A safe, environmentally sound, and economically viable energy pathway that will sustain human progress into the distant future is clearly imperative. It is also possible. But it will require new dimensions of political will and institutional cooperation to achieve it.

Footnotes

1/ World Bank, **World Development Report 1986** (New York: Oxford University Press, 1986).

2/ British Petroleum Company, **BP Statistical Review of World Energy** (London: 1986).

3/ Medium variant in Department of International Economic and Social Affairs, **World Population Prospects as Assessed in 1980**, Population Studies No. 78 (Annex), and Long **Range Population Projections of the World and Major Regions 2025-2150, Five Variants as Assessed in 1980** (New York: UN, 1981).

4/ For a useful comparison of various scenarios, see J. Goldemberg et al., 'An End-Use Oriented Global Energy strategy', **Annual Review of Energy**, Vol. 10, 1985; and W. Keepin et al., 'Emissions of CO2 into the Atmosphere', in B. Bolin et al. (eds.), **The Greenhouse Effect, Climate Change and Ecosystems** (Chichester, UK: John Wiley & Sons, 1986).

5/ U. Colombo and O. Bernadini, 'A Low Energy Growth Scenario and the Perspectives for Western Europe', Report for the **Commission of the European Communities Panel on Low Energy Growth**, 1979.

6/ Goldemberg et al., 'Global Energy Strategy', op. cit.

7/ A.B. Lovins et al., 'Energy Strategy for Low Climatic Risk', Report for the German Federal Environment Agency, 1981.

8/ J.A. Edmonds et al., 'An Analysis of Possible Future Atmospheric Retention of Fossil Fuel CO2', Report for U.S. Department of Energy, DOE/OR/21400 1, Washington, DC, 1984.

9/ J-R Frisch (ed.), **Energy 2000-2020: World Prospects and Regional Stresses**, World Energy Conference (London: Graham and Trotman, 1983).

10/ Energy Systems Group of the International Institute for Applied Systems Analysis, **Energy in a Finite World - A Global Systems Analysis** (Cambridge, Mass.: Ballinger, 1981).

11/ World Bank, **The Energy Transition in Developing Countries** (Washington, DC: 1983).

12/ World Meteorological Organization, **A Report of the International Conference on the Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts**, Villach, Austria, 9-15 October 1985, WMO No. 661 (Geneva: WMO/ICSU/UNEP, 1986).

13/ B.N. Lohani, 'Evaluation of Air Pollution control Programmes and Strategies in Seven Asian Capital Cities', prepared for WCED, 1986; H. Weidner, 'Air Pollution Control Strategies and Policies in the Federal Republic of Germany', prepared for WCED, 1986; M. Hashimoto, 'National Air quality Management Policy of Japan', prepared for WCED, 1985; CETESB, 'Air Pollution Control Programme and Strategies in Brazil - Sao Paulo and Cubatao Areas, 1985', prepared for WCED, 1985.

14/ National Research Council, **Acid Deposition: Long Term Trends** (Washington, DC: National Academy Press, 1985); L.P. Muniz and H. Leiverstad, 'Acidification Effects on Freshwater Fish', in D. Drablos and A. Tollan (eds.), **Ecological Impact of Acid Precipitation** (Oslo: SNSF, 1980); L. Hallbacken and C.O. Tamm, 'Changes in Soil Acidity from 1927/ to 1982- 4 in a Forest Area of South West Sweden', **Scandinavian Journal of Forest Research**, No. 1, pp. 219-32, 1986.

15/ FAO, **Fuelwood Supplies in the Developing Countries**, Forestry Paper No. 42 (Rome: 1983); Z. Mikdashi, 'Towards a New Petroleum Order', **Natural Resources Forum**, October 1986.

16/ Edmonds et al., op. cit.

17/ I.M. Torrens, 'Acid Rain and Air Pollution, A Problem of Industrialization', prepared for WCED, 1985.

18/ Goldemberg et al., 'Global Energy Strategy', op. cit.

19/ British Petroleum Company, op. cit.

20/ WMO, **Report of International Conference**, op. cit.; I. Mintzer, 'Societal Responses to Global Warming', submitted to WCED Public Hearings, Oslo, 1985; F.K. Hare, 'The Relevance of Climate', submitted to WCED Public Hearings, Ottawa, 1986.

21/ Lohani, op. cit.; Weidner, op. cit.; Hashimoto, op. cit.; CETESB, op. cit.

22/ Torrens, op. cit.; F. Lixun and D. Zhao, 'Acid Rain in China', prepared for WCED, 1985; H. Rodhe, 'Acidification in Tropical Countries', prepared for WCED, 1985; G.T. Goodman, 'Acidification of the Environment, A Policy Ideas Paper', prepared for WCED, 1986.

23/ Torrens, op. cit.

24/ Bolin et al., op. cit.

25/ WMO, **Report of International Conference**, op. cit.

26/ Ibid.

27/ Ibid.

28/ Goldemberg et al., 'Global Energy Strategy', op. cit.

29/ Mintzer, op. cit.

30/ WMO, **Report of International Conference**, op. cit.

31/ D.J. Rose et al., **Global Energy Futures and CO2 - Induced Climate Change**, MITEL Report 83-015 (Cambridge, Mass.: Massachusetts Institute of Technology, 1983); A.M. Perry et al., 'Energy Supply and Demand Implication of CO2', **Energy**, Vol. 7, pp. 991-1004, 1982.

32/ Bolin et al., op. cit.

33/ G. Brasseur, The Endangered Ozone Layer: New Theories on Ozone Depletion', **Environment**, Vol. 29, No. 1, 1987.

34/ National Research Council, op. cit.; Muniz and Leiverstad, op. cit.

35/ OECD, **The State of the Environment** (Paris: 1985).

36/ Muniz and Leiverstad, op. cit.

37/ National Research Council, op. cit.

38/ National Swedish Environmental Protection Board, **Air Pollution and Acidification** (Solna, Sweden, 1986).

39/ J. Lehmhaus et al., 'Calculated and Observed Data for 1980 Compared at EMEP

Measurement Stations', Norwegian Meteorological Institute, EMEP/MSO W Report 1 86, 1986; C.B. Epstein and M. Oppenheimer, 'Empirical Relation Between Sulphur Dioxide Emissions and Acid Deposition Derived from Monthly Data', **Nature**, No. 323, pp. 245-47, 1985.

40/ 'Neuartige Waldschaden in der Bundesrepublik Deutschland', Das Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, 1983; 'Waldschaden Sernebungen', Das Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, 1985; S. Nilsson, 'Activities of Teams of Specialists: Implications of Air Pollution Damage to Forests for Roundwood Supply and Forest Products Markets: Study on Extent of Damage', TIM/R 124 Add.1 (Restricted), 1986.

41/ S. Postel, 'Stabilizing Chemical Cycles' (after **Allgemeine Forst Zeitschrift**, Nos. 46 (1985) and 41 (1986)); in L.R. Brown et al., **State of the World 1987** (London: W.W. Norton, 1987).

42/ T. Paces, 'Weathering Rates of Eneiss and Depletion of Exchangeable Cations in Soils Under Environmental Acidification', **Journal Ecological Society**, No. 143, pp. 673-77, 1986; T. Paces, 'Sources of Acidification in Contra] Europe Estimated from Elemental Budgets in Small Basins', **Nature**, No. 315, pp. 31-36, 1985.

43/ Hallbacken and Tamm, op. cit.

44/ G. Tyler et al., 'Metaller i Skogsmark - Deposition och omsattning', SNV PM 1692, Solna, Sweden, 1983.

45/ 'Neuartige Waldschaden', 1983, op. cit; Paces, 'Weathering Rates', op. cit.

46/ Rodhe, op. cit,

47/ R. Eden et al., **Energy Economics** (New York: Cambridge University Press, 1981); Nuclear Energy Agency, **Projected Costs of Generating Electricity from Nuclear and Coal-Fired Power Stations for Commissioning in 1995** (Paris: OECD, 1986).

48/ Nuclear Regulatory Commission, **Physical Processes in Reactor Meltdown Accidents, Appendix VIII to Reactor Safety Study** (WASH-1400) (Washington, DC: U.S. Government Printing Office, 1975).

49/ S. Islam and K. Lindgren, 'How many reactor accidents will there be?', **Nature**, No. 122, pp. 691-92, 1986; A.W.K. Edwards, 'How many reactor accidents?' **Nature**, No. 324, pp 417-18, 1986.

50/ F.L. Parker et al., **The Disposal of High Level Radioactive Waste - 1984**, Vols. 1 & 2 (Stockholm: The Beijer Institute, 1984); F.L. Parker and R.E. Kasperson, **International Radwaste Policies** (Stockholm: The Beijer Institute, in press).

51/ International Atomic Energy Agency, **Nuclear Power: Status and Trends, 1986 Edition** (Vienna: 1986).

52/ 'World List of Nuclear Power Plants', **Nuclear News**, August 1986.

53/ **IAEA Bulletin**, Summer 1986.

54/ C, Flavin, 'Reassessing Nuclear Power', in Brown et al., op. cit.; British Petroleum Company, op. cit.

55/ G. Foley, 'Wood Fuel and Conventional Fuel Demands in the Developing World', **Ambio**, Vol. 14 No. 5, 1985.

56/ FAO, **Fuelwood Supplies**, op. cit.; FAO/UNEP, **Tropical Forest Resources**, Forestry Paper No. 30 (Rome: 1982).

57/ The Beijer Institute, **Energy, Environment and Development in Africa, Vols, 1-10** (Uppsala, Sweden: Scandinavian Institute of African Studies, 1984 87); 'Energy Needs in Developing Countries', **Ambio**, Vol. 14, 1985; E.N. Chidumayo, 'Fuelwood and Social Forestry', prepared for WCED, 1985; G.T. Goodman, 'Forest-Energy in Developing Countries: Problems and Challenges', International Union of Forest Research Organizations, **Proceedings**, Ljubljana, Yugoslavia, 1986.

58/ FAO, **Fuelwood Supplies**, op. cit.

59/ Beijer Institute, op. cit.; J. Bandyopadhyay, 'Rehabilitation of Upland Watersheds', prepared for WCED, 1986.

60/ Beijer Institute, op. cit.

61/ R. Overend, 'Bioenergy Conversion Process: A Brief State of the Art and Discussion of Environmental Implications', International Union of Forestry Research Organization, **Proceedings**, Ljubljana, Yugoslavia, 1986.

62/ W. Fernandes and S. Kulkarni (eds.), **Towards a New Forest Policy: People's Rights and Environmental Needs** (New Delhi, India: Indian Social Institute, 1983); P.N. Bradley et al., 'Development Research and Energy Planning in Kenya', **Ambio**, Vol. 14, No. 4; R. Hosier, 'Household Energy Consumption in Rural Kenya', **Ambio**, Vol 14, No. 4, 1985; 1985; R. Engelhard et al., 'The Paradox of Abundant On-Farm Woody Biomass, Yet Critical Fuelwood Shortage: A Case Study of Kakamega District (Kenya)', International Union of Forest Research Organization, **Proceedings**, Ljubljana, Yugoslavia, 1986.

63/ D. Deudney and C. Flavin, **Renewable Energy: The Power to Choose** (London: W.W. Norton, 1983).

64/ World Resources Institute/International Institute Environment and Development, **World Resources 1987** (New York, Basic Books, in press).

65/ Ibid.

66/ Ibid.

67/ Goldemberg et al., 'Global Energy Strategy', op. cit.; J. Goldemberg et al., 'Ethanol Fuel: A Use of Biomass Energy in Brazil', **Ambio**, Vol. 14, pp. 293-98, 1985; J. Goldemberg et al., 'Basic Needs and Much More, With One Kilowatt Per Capita', **Ambio**, Vol. 14, pp. 190-201, 1985.

68/ WRI/IIED, op. cit.

69/ N.J.D. Lucas, 'The Influence of Existing Institutions on the European Transition from Oil', **The European**, pp. 173-89, 1981.

70/ OECD, op. cit.

71/ E. Hirst et al., 'Recent Changes in U.S. Energy Consumption, What Happened and Why?' in D.J. Rose (ed.), **Learning About Energy** (New York: Plenum Press, 1986).

72/ H.S. Geller, 'The Potential for Electricity Conservation in Brazil', Companhia Energetica de Sao Paulo, Sao Paulo, Brazil, 1985.

73/ World Bank, **Energy Transition in Developing Countries**, op. cit.

74/ G. Leach et al., **Energy and Growth; A Comparison of Thirteen Industrialized and Developing Countries** (London: Butterworth, 1986).

75/ MIT International Automobile Program, **The Future of the Automobile** (London: George Allen & Unwin, 1984).

76/ FAO, **Agriculture; Towards 2000** (Rome: 1981).

77/ Ibid.

78/ Lucas, op. cit.

79/ OECD, op. cit.