WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT

SIXTH MEETING
Harare, Zimbabwe
September 15 - 20, 1986

WCED/86/17

MEMORANDUM

TO: All Members of the World Commission on Environment and Developmen

FROM: W. H. Lindner, Secretary

DATE: September 1, 1986

RE: Sixth Meeting of the Commission

Please find attached a draft of Chapter 6 - Energy and Sustainable Development which carries its proposed new title "Energy - The Power to Choose".

The point of departure for the formulation of this chapter was, of course, the Final Report of the Energy Advisory Panel; although various additional points have been incorporated to reflect the views of our Special Advisor on Energy and those of the Commissioners who commented on an earlier draft of this chapter.

A table of contents has been included to provide an overview of the chapter.

Action Required: Discussion and Decision

September 1, 1986

# C H A P T E R  VI

## ENERGY: THE POWER TO CHOOSE

3rd Draft - 28 August 1986

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## I. CHOOSING THE ENERGY FUTURE

1. The energy supply and consumption patterns of today are already influencing those which will prevail to the year 2000 and beyond. The same is true, of course, of patterns of population growth, industrialization, urbanization, agriculture and transport. They can all widen the opportunities for future economic and social development or they can constrain them, in some cases eliminating them altogether. They can provide the basis for a high and sustainable level of security and comfort; or they can destroy it, reinforcing insecurity, widespread poverty and human misery. At the limit, they can determine the capacity of this planet to sustain the life support systems on which all other development depends.

### A. UNSUSTAINABLE TRENDS

2. But there is no doubt that in an important sense, certain energy patterns today are overwhelmingly influential in that they can threaten the sustainable development of the countries and regions in which they are dominant. This is clearly true of the fuelwood crisis: according to an FAO study [1)], in 1980, 1,300 million people lived in wood deficit areas (defined as areas where people can still satisfy minimum needs, but only through unsustainable over-cutting), and over 110 million in acute scarcity areas (defined as areas where even through over-cutting people cannot satisfy minimum needs). The same study suggests that by the year 2000 about 3,000 million people will live in wood deficit and acute scarcity areas, leading to increasing deforestation, erosion, desertification and the diversion of plant and animal wastes from soil replenishment (See Table 1).

3. It is also true of acidification of the environment in Europe and North America. The silent accumulation of acid has led to the widespread sterilization of lakes and, more recently, of soils. The latter may be the principal cause of the accelerating death of Europe's forests, the front line in the resource security system of any community, nation and region.

4. Certain patterns of energy consumption could undermine sustainable development on a global basis. Climate change, largely accelerated by the "greenhouse" effect of carbon dioxide emissions from the combustion of fossil fuels, has now emerged as a "serious and probable"[2] threat to the economic and social development of nations. It could place intolerable burdens on worldwide political stability within the next 40 to 60 years.

5. Fortunately, however, there are choices open to most nations and to the international community that could reduce, if not prevent, the threats that certain types of energy patterns pose to sustainable development. Some of these choices hinge on policies to reduce the future demand for energy without reducing the potential for economic growth. Others hinge on policies to manage the burning of fossil and other fuels better, internalizing the enormous costs they now pass on to their own users and countries and on to other nations and regions. Still others hinge on policies to induce a steady shift in the energy mix from non-renewable to renewable sources of energy. But all of these policies require changes in existing policies and new and strengthened institutions to implement them at the national and international level.

## B. A HIGH OR LOW ENERGY FUTURE

6. The major strategic choice before governments and the world community is illustrated in Figure 1, which reflects some of the better known estimates of projections[3] of energy use through the middle of the next century. It will be seen that by the year 2000, global energy consumption could in theory vary by a factor of five between the lowest and the highest projections, and by the year 2020 the spread between the projections is too large to portray on this figure.

7. In examining Figure 1, it is vital to understand that energy use projections are not in any sense predictions of the future. They are logical projections of current states and trends, useful only to analyse what could happen under different, pre-set assumptions concerning the way energy could be used by societies globally. The differences in Figure 1, thus reflect not so much differences in methodology, as different assumptions which will influence the patterns of energy supply and demand.

8. Given the rich range of projections now available in various studies, the Commission has not felt it necessary to add yet another of its own. Nor would it have had the time to do so. Rather, for the sole purpose of illustrating the energy, economic and environmental implications of a high and a low energy future, two of these projections have been selected to represent respectively a credible "upper bound" and "lower bound".[4]

9. The purpose in selecting these projections, therefore, is not to evaluate and defend the absolute numbers they bound. Rather it is to show how two radically different energy futures are possible reflecting different policies and institutional arrangements. The projections also provide boundary limits within which to discuss the consequences of two broad directions for development and for sustaining the environmental bases of development.

10. The high scenario is indicative of the direction in which energy consumption and supply patterns are heading if existing policies and institutions remain essentially unchanged. It is a normative trend scenario. It is included in a carefully validated study published in 1981 by the International Institute for Applied Systems Analysis[5]. It projects a tripling of global energy consumption over 1980 levels by 2020. This would necessitate an enormous but apparently feasible increase in supply levels and consequently very severe environmental impacts, and most energy observers nowadays consider it an unlikely scenario. Nevertheless, the study is probably a good representation of a possible "upper bound" for how the energy future might unfold in the next forty years.

11. The most recent examination of the technical feasibility of reaching a low energy future is that contained in a 1985 study by an international group of energy analysts.[6] It is not strictly an energy projection, but rather a feasibility study, demonstrating what could be achieved if all future development incorporated the most energy-efficient technologies and processes now available and in use

in the housing, industry, transportation and other sectors. Assuming this were possible, the study projects a 50 per cent drop in per capita energy consumption in industrialized and only a 30 per cent increase in developing countries by the year 2020.

12. These and other assumptions produce a mere 10 per cent increase in global energy consumption by 2020, a striking figure recognizing that it is compatible with economic growth rates similar to those employed to project the high scenario.

13. Their assumptions imply that average annual gains in energy efficiency of 3.3 per cent and 2.7 per cent can be reached and sustained in industrialized and developing countries respectively. While this may be technically feasible, it presumes very high, and very unlikely rates of penetration of energy efficient technologies and processes, an assumption which is not reasonable based on past performance and well known economic, social and institutional constraints. Nevertheless, the study is probably a good representation of a technically, if not institutionally, feasible "lower bound" of how the energy future might unfold in the next forty years.

## C. ENERGY SUPPLY IMPLICATIONS

14. The energy supply implications of a high energy future are simply staggering. By the year 2020, oil and natural gas would have to be produced at almost twice the 1980 rate, while coal production would need to increase by a factor of 1.8. This increase in fossil fuel use implies a capacity equivalent to bringing a new Alaska Pipeline (2

million barrel of oil equivalent -mboe-day) into production every one to two months! (It should be noted that even the 1980 level of oil consumption carried through to 2020 would exhaust existing reserves, and would require the discovery of 20 per cent more proven reserves than existed in 1985.[7]) More than 6 Terawatts (TW -is a thousand million kilowatts) of nuclear capacity would also have to be installed by the year 2020, an increase of 3,000 per cent over 1983 levels!. That would require commissioning approximately 150 large, nuclear reactors per year, of 1GW (gigawatt - equivalent to million kilowatts) electrical capacity each.

15. Existing reserves would be able to cover the requirements for natural gas and coal, but it is questionable if the necessary infrastructure for mining, transporting and converting these fuels could be developed in this short period in all the countries concerned. In the case of coal, for example, about 90 per cent of all reserves are found in just three countries (USA, USSR and China), and these countries would have essentially to double their production. Furthermore, this coal would have to be transported to the other countries, requiring an enormous increase in rail, pipeline and terminal handling capacity.

16. In the case of a low energy future, the implications on energy supply are still considerable, but clearly much more manageable. Oil and coal would be used at rates approximately 20 per cent less than in 1980, and only nuclear, hydro and natural gas would increase above 1980 levels by factors of 2.4, 1.4 and 0.8

respectively. Since new additions to the supply of a particular energy source are proportionately much more expensive than existing sources, the potential gain by not having to open up new supplies could be very large indeed. The main implications of a low energy future, however, are on energy demand management, particularly by the deployment of end-use efficient hardware upon which immense pressure would be placed.

## D. ECONOMIC AND DEVELOPMENT IMPLICATIONS

17. The economic implications of a high energy future are also substantial. The investment requirements are so enormous that even the industrialized countries would find them difficult to support. In developing countries, the high level of investment required would siphon off capital required for other sectors, which would be starved. In fact, many now believe that these requirements would be a drag on development making it impossible to improve living standards in developing countries.

18. According to World Bank estimates, US$130 billion would have to be invested every year in energy projects in order to raise per capita levels of commercial energy consumption in developing countries from 0.54 to 0.78 KW between 1980-1995 (which is necessary to reach the high projection by 2020). Moreover, half of this, that is US$65 billion a year (compared to the US$3.5 billion a year currently being loaned in the energy sector) would be in foreign exchange, equivalent to about 4 per cent of aggregate GNP of these countries.[8] This level of investment, involving such a huge charge on foreign exchange earnings would push most energy importing developing countries further into the already serious debt crisis (See Table 2).

19. The economic implications of a low energy future, on the other hand, could be beneficial. While achieving more or less the same level of economic growth as the high scenario, it does so with a much lower level of energy consumption. Not only are investment requirements and corresponding debt burdens lower, but also a greater reliance on renewable forms of energy would have a much higher employment impact, especially in rural areas. Lower levels of conventional energy production would also reduce the required investment to prevent or control that damage. Greater reliance on renewables, if properly managed, could lead to significant opportunities for environmental regeneration, providing an economic base for reforestation, wasteland reclamation and other measures.

20. Although it is not possible to quote a figure for the overall investment requirements of a low energy future, it can be shown that under a wide range of circumstances, the extra capital requirements for improved end-use technologies will be more than offset by capital savings for lowered energy needs.[9] Although many of the pay-back times will be as long as 10-15 years, they will be worthwhile in the long run. In the case of Brazil, for example, it has been shown that for a discounted, total investment of $4 billion in more efficient end-use technologies (e.g., more efficient refrigerators, lighting, motors, etc.) 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.[10]

## E. ENVIRONMENTAL IMPLICATIONS

21. A high energy future with its heavy reliance on fossil fuels and its huge requirements for investment in other conventional sources of energy, carries equally staggering environmental implications.

22. In terms of fossil fuel use, for example, it would result in substantial increases in the consumption of coal, oil and natural gas. It is the increase in the first of these, coal, which is most worrisome, since the environmental and health impacts of coal are greater than those of oil. Overall, there would be a more than a doubling of the production of carbon dioxide, which would bring the world much closer to possible major climatic changes. Increased fossil fuel combustion in power stations as well as in automobiles would also aggravate the acid rain problem in industrialized countries and developing countries alike.

23. In developing countries, the indirect environmental impacts of such a high energy future could be disastrous. On the one hand, local energy supplies would have to be substantially increased. Carelessly installed energy development projects, such as the construction of large dams, have greatly contributed to land degradation and consequent environmental impacts.

24. On the other hand, the high energy costs implied by such a high-energy future will require energy importing developing countries to step up commodity production for export (as opposed to production for local consumption) to be able to pay for the higher

debts incurred. More land would have to be devoted to non-food, export oriented agricultural production, which means either the opening up of more forests (i.e., deforestation) or/and the marginalization of even more subsistence farmers onto lower quality lands. In both cases, the environment suffers in the process. Deforested land in the tropics loses its fertility rapidly, and results in eroded topsoils. Marginalized farmers are obliged to overuse the low quality soils, and the results are again the same: soil erosion, silting up of reservoirs downstream, and eventually floods. In all cases, the impacts have tremendous developmental costs, which society as a whole has to pay for.

25. In the case of a low energy future, there will remain a large number of environmental impacts to be avoided or abated. There will, however, be no increases above the 1980 levels. In fact, although fossil fuel use remains essentially constant, there is a small drop in the rate of carbon dioxide production due to changes in the fossil fuel mix (i.e., more natural gas and less coal and oil). This would slow down the rate of climatic change, giving more time for the world community to deal with the problem.

## F. THE CHOICE

26. Given the interrelated economic, environment and development implications of the high and low energy scenarios, the nations of the world should aim for the lowest possible energy future compatible with their economic and social priorities.

27. If the low energy scenario could actually be achieved, it would be sufficient to target future policies on decreasing the energy content of development and controlling the emission of pollutants. But if, as seems likely, substantial increases in energy consumption will take place, then all countries, and particularly developing countries will have to explore urgently all avenues for increasing the supply of energy in environmentally benign ways, particularly from renewable sources.

## II. STABILIZING THE PRICE OF OIL

28. When this Commission was established in 1984, world oil prices stood at $28-$30 per barrel and economic development everywhere was being planned on the assumption of a steady increase in the price of energy. As the Commission completed its report in December 1986, world oil prices stood at around $10-12 per barrel(##To be updated at publication##); and old prophets were announcing a new era of cheap energy.

29. With the breakdown of effective stabilizers, oil prices have become very difficult to predict. Looking to the next decade and the year 2000 and beyond, however, it seems clear that, in the face of increasing economic activity and of constantly rising demand, the supply availability of this non-renewable resource will emerge as the decisive factor in determining prices. It is imperative, therefore, that a period of cheap hydrocarbon energy should not be taken as a permanent phenomenon. Short term gains are always tempting to those in a position to grab them, whether producers or consumers. Such gains may temporarily set back, but they in no way alter the fundamental

character of the transition under way to a broader mix of energy sources, with a steadily increasing proportion of renewables.

30. The world can stumble through this transition, from shock to shock, at a great cost to sustainable development, including the environmental bases of development. Or it can manage the transition, effecting more sustainable mixes of energy supply and patterns of energy consumption. This, however, will require a transformation in energy policies and institutions.

31. An effective arrangement to stabilize the recent wild fluctuations in the world oil price, to a reasonable level and range in real terms is essential to this transformation. In the absence of such an arrangement, oil prices are bound to fluctuate over a wide range. In 1979, the time was ripe to conclude such an arrangement but the opportunity was lost because of myopia among oil exporters and confusion among the importing countries. In 1986 the time is ripe again, but there is a very real danger that the opportunity will again be lost, this time because of myopia among the importers and confusion among the exporting countries.

32. The economic, social and environmental costs of losing this opportunity are much clearer today than they were in 1979. In the western industrialized countries the griplock between energy and development was finally broken during the past decade. The ratio of energy to economic growth fell in many countries, in some from 1.2 to 0.5 units (See Figure 2), resulting in substantial gains in overall economic efficiency and competitiveness and substantial reductions in the

costs of environmental damage. The momentum that produced energy efficiency gains of up to 2 per cent a year is now threatened in transportation, industry, agriculture and other sectors and could quickly be lost.

33. Developments that made sense with oil at $25 per barrel, suddenly make no sense at all with oil at around $10-$15 per barrel. Many oil producers, and new ventures in renewables and conservation, have been devastated. Massive investments in the search for new oil, and in the development of all the renewable energy sources that will be needed through the transition, have been placed in temporary, and perhaps terminal, jeopardy.

34. Developments that need to be sustained through the year 2000 and beyond, and these include most major advances in transportation, agriculture, industry and other sectors, need to be based on a realistic view of the energy transition. Planning the future on the basis of cheap energy will rebound with a vengeance against development and equity when, as happened in the 1970s, prices eventually rise again.

35. The material and commodity content of growth has also fallen during the past decade because of the development of substitutes. A temporary period of cheap oil will enhance the position of oil-based substitutes over naturally produced raw materials, textiles and rubber for example, and further reinforce this process. On this basis, therefore, growth in developing countries will not benefit to the same degree from growth in industrialized countries.

36. Effective attempts to stabilize wild fluctuations in the world oil price will no doubt take some years to negotiate. In the meantime, nations may choose to allow consumer prices to fall to levels dictated by the market or they may deploy various measures to sustain prices at higher levels.

37. At the moment, it is the former course that is generally being pursued. With oil prices falling to around US$ 10 - US$ 15 a barrel, raising the prospect of oil at pre-1973 prices in real terms, confident talk of the market soon finding its own "natural floor" has been silenced. Extreme price uncertainty is leading to unbridled market speculation in oil futures which is imposing severe economic and social hardship on the oil exporting nations. In the longer term, with unrestricted demand gradually overtaking supply, the stage will be set for yet another energy shock, and a repeat of the economic, social and environmental experience of the 1970's.

38. Failure to re-establish world oil prices, and hence consumer prices of energy at a level that sustains annual gains in energy efficiency and a steady shift to renewables will in the long run threaten many nations not only with reduced development potential, but also with reduced security. A period of unreasonably low prices will re-establish high energy supply and consumption patterns, with a higher dependence on fossil fuels. These patterns will reinforce the processes of transboundary air pollution and environmental acidification now proceeding in Europe and North America and will hasten their spread to other regions in Asia, Africa, and Latin America. They will also help accelerate the processes of climatic change now underway.

39. On the other hand, consumer nations and especially the major industrialized countries could take steps to sustain prices at high levels and wherever possible capture in their budgets a major proportion of the gap created by the sudden collapse of world oil prices.

40. This would provide a major source of revenue, enabling governments to reduce their heavy debt burden and return to sounder fiscal management.

41. It would ensure that the momentum producing more sustainable patterns of energy consumption and supply is not lost and that annual gains in energy efficiency continue.

42. It would reduce the rising cost of damage from urban air pollution and the acidification of the environment and it would buy the time needed to develop and apply strategies to reduce and/or adapt to climate change.

43. Moreover, in thus aggregating a portion of the over US$ 100 billion windfall flowing to their consumers, industrialized countries would be in a better position to substantially increase their contributions to bilateral and multilateral agencies. This would support developing countries in establishing the institutions and effecting the policies and environmental regeneration needed to manage the energy transition.

44. This Commission recognizes, however, that action to impose higher consumer prices at the national level would be extremely difficult due to domestic political and international economic constraints. Perhaps the only genuine solution lies in the steadily growing realization that oil is such a crucial raw material in future strategies for environment and development that it is too important to be treated as just another commodity and left to the vagaries of a volatile world market. Instead, both producers and consumers should co-operate to develop policies to build some limited form of global convention for the more orderly production and marketing of oil.

## III. REDUCING FOSSIL FUELS

45. Although all energy systems have environmental impacts, high levels of fossil fuel consumption are a special concern, particularly in industrialized countries and in the industrialized and urban regions of developing countries. They pose three interrelated threats to sustainable development: air pollution[11], acidification of the environment[12] and climatic change[13]. Some of the richer industrialized countries may possess the economic and social resilience and institutional capacity needed to cope with these threats. Most developing countries, however, and especially those who spend a proportionately large part of their national income on energy imports (See Table 2) do not.

### A. AIR POLLUTION

46. During the past three decades of rapid growth, urban air pollution has increased dramatically, more or less in pace with fossil fuel consumption for space heating (and cooling), automobile transport, industrial activities and power generation. Beginning in the late '60s, a growing awareness of the effects of polluted air on human health, property and the environment created a demand for action. Some industrialized countries responded, enacting control measures of various kinds. Most imposed standards that resulted in the development of curative measures, including add-on technologies. Some imposed liability and required compensation for damage, especially damage to human health. While expensive, this react-and-cure approach led, in time, to reduced emissions of some of the principal pollutants and cleaner air over some cities.

47. Many industrialized countries, however, and virtually all developing countries failed to share in this experience. Instead, they witnessed a steady deterioration in the quality of their air with all its attendant effects. Air pollution has reached dramatic levels in most major Third World cities, far exceeding the worst cases of the '50s in western industrialized countries.

48. The fossil-fuel emissions of principal concern include sulphur dioxide, nitrogen oxides, carbon monoxide, various hydrocarbons, fly ash and suspended particulates. They are injurious to human health, damaging body tissue and the nervous system, bringing increased respiratory diseases and cancer, and causing higher morbidity and mortality in sensitive segments of the population. Transformed into acid, they burn and kill vegetation, corrode buildings, metallic structures and vehicles and eventually contribute to land and water pollution. Excepting a few western industrialized countries, studies of the social and economic costs that these effects impose on the economy of communities and nations are non-existent, or unavailable. The few studies available, however, demonstrate that they are enormous, and in most of the world they are growing rapidly.

49. Today, the fossil-fuel sources of air pollution are largely controllable in both industrialized and developing countries. Most are preventable, and at a cost to the community and nation that is usually far less than the damage costs that will otherwise

be incurred, not to mention the eventual costs of retrofitting vehicles, homes and industry, when the effects of air pollution exceed the limits of community tolerance.

50. In a high energy future, however, both prevention and control would be extremely difficult and expensive. Indeed, given projected economic trends on the one hand, and the state of awareness, legislation and institutional capacity in most developing countries on the other, it is doubtful that they could keep up with future sources, let alone catch up with present sources and cure past damage. For similar reasons, this may well be beyond the capacity of many industrialized countries.

51. The most cost-effective means of prevention available, perhaps the only ones available to some industrialized and all developing countries given the high cost of pollute-and-cure processes, are those implicit in a low energy future. Moreover, these and other means would reinforce those needed to prevent and control another major fossil fuel threats to sustainable development: acidification of the environment.

## B. ACIDIFICATION OF THE ENVIRONMENT

52. The measures taken by industrialized countries in the '70s to control urban and industrial air pollution (high stacks, for example) improved the quality of the air in the cities concerned. While reducing human exposure, however, it increased the

problem elsewhere. This was manifest in a rapid rise in transboundary air pollution in Europe and North America and in widespread acidification of the environment. In consequence, the perception of air pollution has shifted from that of a local problem, involving one or more communities, to that of a regional problem involving entire continents.

53. During long distance transport in the atmosphere, emissions of sulphur oxide, nitrogen oxide and volatile hydrocarbons are transformed into sulphuric and nitric acids, ammonia salts and ozone. They fall to the ground, sometimes thousands of miles from their point of emission, as dry particles or in rain, snow, frost, fog and dew.

54. Cryptically accumulating over the decades, damage to the environment first became evident in Scandinavia in the 1960s. Since then, the recognition of damage has mounted at an accelerating pace. Several thousand lakes in Europe and North America have registered a steady increase in acidity levels to the point where they no longer support fish life. The same acids attack stonework and corrode metal structures causing billions of US dollars in damage annually. They enter ground water causing corosion of drinking water piping, and concern has been expressed that they may liberate potentially toxic metals and pose risks to human health.

55. The circumstantial evidence indicating the urgent need for action on the sources of acid rain is mounting with a rapidity that overwhelms the time-frames needed by scientists and governments to assess it scientifically.[14] Up to now, the

greatest damage has been reported over Central Europe, which is currently receiving more than one gram of sulphur on every square metre of ground each year (See Figure 3). There was little evidence of tree damage in Europe in 1970. In 1982, the Federal Republic of Germany reported visible damage to 8 per cent of its trees; in 1983, this rose to to 34 per cent and to 50 per cent in 1985.[15] Sweden reported light to moderate damage in 30 per cent of its forests; and reports from other countries also become extremely disquieting. So far an estimated 5-6 per cent of all European forest land is affected.

56. The evidence is not all in, but many reports consistently show soils in parts of Europe becoming acid throughout the tree rooting layers. The acidity is frequently so high that aluminium comes into solution as a mobile element, toxic in very low concentrations to plant roots. Forest death could be caused by the co-action of acid soils containing mobile aluminium and by direct needle damage in conifers from the interaction of the pollutants mentioned above.

57. If this is true, we may have reached a trip-over point in Europe. We may be witnessing an immense, regional acid-base chemical titration with potentially disastrous results being signalled by widespread tree damage and death, in effect, a kind of "environmental litmus paper", indicating a change to irreversible acidification whose remedial costs are beyond economic reach. Comparatively speaking, forest death on a regional scale would be socially and economically trivial compared to such consequences as erosion, soil slippage and land slides, siltation, flooding of farmlands and towns and local climatic change.

58. The effects of air pollution, such as forest death, acidification of lakes and damage to structures is evident. The sources are multiple, including damage from ozone and sulphur dioxide, deposition of excess nitrogen (nitrate & ammonia), and the deposition of acids and heavy metals. No single pollutant control strategy is likely to be effective in dealing with forest decline - it will take nothing less than a total integrated mix of strategies and technologies, tailored for each region, significantly to improve air quality.

59. Evidence of acidification in the newly industrializing countries of Asia, Africa and Latin America is beginning to emerge. China, Korea and Japan seem particularly vulnerable, given industrialization trends in the former two, as do Venezuela, Colombia, Ecuador and Brazil. So little is known about the likely environmental loading of sulphur and nitrogen and about the acid neutralizing capacity of tropical lakes and forest soils that, at a minimum, a comprehensive programme of investigation should be formulated without delay.[16)]

60. In the US, it has been estimated that reducing sulphur dioxide emissions by half from existing sources would cost an additional US$ 3-4 billion a year, increasing present electricity rates by 2-3 per cent. If nitrogen oxides were figured in, the additional costs might be as high as US$ 6 billion a year.[17)] Estimates of the annual costs of securing a reduction in sulphur emissions in the countries of the Commission of European Communities of 55 to 65 per cent between 1980 and 2000 range

from US$4.6 to $6.7 billion (1982) per year. Controls on stationary boilers to reduce nitrogen levels by only 10 per cent per year by 2000 range between US$ 0.1 and $0.4 billion (1982). While high in absolute terms, even in countries whose energy systems depend heavily on coal-based thermal power, these figures translate into a one time increase of about 6 per cent in the price of electrical power to the consumer.

61. Estimates of damage costs in Europe are less reliable and, given the trends noted above, necessarily very conservative. Nonetheless, studies place damage costs due to material and fish losses alone at US$ 3.0 billion a year; while damage to crops, forests and health are estimated to exceed US$ 10.0 billion per year. But again, the evidence is not yet in. Recent 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.

62. The strategies implicit in the low energy scenario offer the most cost-effective means of reducing future levels of acidification in industrializing and developing countries alike. And they would buy time for the nations of the world to assess and prepare for the implications of global climatic change.

## C. CLIMATIC CHANGE

63. Upon combustion, fossil fuels also emit the gas carbon dioxide, which accumulates in the atmosphere. The pre-industrial concentration was 280 parts of carbon dioxide per million parts of air. This concentration reached 340 in 1980 and is

expected to double (to 560) between the middle and the end of the next century. How soon depends almost entirely on the energy paths followed in the meantime. In contrast to the emissions mentioned above, no technologies exist to control the emissions of carbon dioxide.

64. Other gases are also accumulating in the atmosphere, principally, chlorofluorocarbons (used as aerosol propellants in spray cans and in refrigerators as a coolant); methane (rising from wet, reducing soils, e.g. rice-paddies, or from the earth's surface, especially where oil or gas is exploited); nitrous oxide (derived from the breakdown of nitrogenous fertilizers); and ozone (generated by industry and internal combustion engines).

65. The question of climate warming caused by rising concentrations of these "greenhouse" gases in the atmosphere has been the object of intense assessment, nationally and internationally. The question is enormously complex given the interactive nature of the meteorological, oceanographic and ecological factors conditioning climate, ecosystem and sea level responses.

66. After reviewing the latest evidence in October 1985, however, scientists from 29 industrialized and developing countries concluded that climate change must be considered a "plausible and serious probability".[18] They estimated that the concentration of greenhouse gases in the atmosphere could lead to a rise in global mean temperatures in the first half of the next century "greater than any in man's history". A globally-averaged mean surface rise of 1.5°C to 4.5°C should be anticipated within the next 45 years.

67. Before the warming effect of the other trace gases was appreciated, it was thought that carbon dioxide alone would not generate such a rise until much later - the last half of the next century. The effect of the other trace gases, however, which are increasing rapidly, is to advance considerably the date of significant warming.

68. The great concern, of course, is that a global warming of 1.5 - 4.5$^{o}$C would lead the sea level to rise from 25 - 145 cm, caused mostly by thermal expansion of sea water. This would inundate low lying coastal cities and agricultural areas, and many countries could expect their economic, social and political structures to be severely hit.

69. As rising seas invade and shift the boundaries of coastal states and modify the levels of shared bays, estuaries and international waterways, local disasters could escalate swiftly into international crisis. This would be accentuated by the effects of changing climate on inland crops, forests and ecosystems. Although knowledge about these effects cannot be certain until they occur, experts believe that crop boundaries will move to higher latitudes, and will do so much quicker than forest boundaries because of the longevity of trees. The effects of warmer oceans or marine ecosystems on fisheries and food chains is also virtually unknown. Melting of small glaciers would result in a further rise of more than 20 cm over a century.

## D. SOME POLICY DIRECTIONS

70. Nobody knows how communities and nations will respond to these situations as they evolve. Governments, however, and the world community are in a position to anticipate them and to take certain measures to prevent them or reduce their impact or, in the case of climatic change, at least buy time to facilitate adaptation to the consequences.

71. We seem to be entering an era where sooner or later nations will have to formulate and agree upon long-term policies for all energy-related activities affecting sustainable development and influencing the radiation balance on earth. This will not happen soon, but given the complexities of international negotiations on such issues and the time lags involved it is urgent that the process start now.

72. What is needed for these issues, in fact, marked as they are by varying degrees of uncertainty, is a three-track strategy combining, on the first track, improved monitoring and assessment of the evolving phenomena; on the second, increased research to improve our knowledge about the sources and effects of the phenomena; and, on the third track, the development and implementation of new or modified clusters of economic, finance, trade and sectoral policies. These should be such as to prevent or reduce the avoidable and destructive impacts of these phenomena on human health, resources and ecosystems, especially those which involve a high risk of irreversibility and transgenerational transfers.

73. No single nation has the institutional, professional and resource capacity needed to undertake the research, monitoring and assessment that is now required. And no nation has the political reach to entertain the changes in the structure of policies that will be necessary. Increasingly sophisticated forms of international burden sharing to address these issues are required at both the regional and global levels. This should include an immediate start on an internationally-binding convention covering all energy-related environment and development questions.

74. While this proceeds, more immediate policy measures can and should be adopted. The most urgent, as mentioned earlier, is an effective arrangement to stabilize wild fluctuations in world energy prices and hold them at levels which will maintain steady gains in energy efficiency and a shift in the energy mix towards more renewables. A wide range of specific measures is available to increase energy efficiency in housing, industry, transportation, agriculture and other sectors. Most such measures are cost-effective and their potential has scarcely been touched. There is good prima facie evidence that carbon dioxide output globally could be halved by energy efficiency measures over the next 50 years or so without any reduction of the tempo of GDP growth. And, as noted earlier, these measures would also serve to reduce other emissions and thus reduce acidification and air pollution. In addition, they would also improve balances of payments, reduce debt burdens and provide rich sources of revenues for countries to improve sound fiscal management.

75. Many other mutually reinforcing measures should also be entertained. Measures deliberately to switch the fossil fuel mix, are one example. The current global energy mix (per cent) is oil 41; coal 24; gas 17; other 18. One TWyr of energy from oil or coal or gas liberates 0.62; 0.75; 0.43 gigatons of carbon respectively. Consequently, gaseous fuels should be promoted at the expense of solid ones. Gaseous fuels should be the fuels of choice for cooking and other residential uses, in particular, since it is generally more difficult to implement pollution control at the domestic level.

76. Apart from fuel cleaning and fuel switching, financial mechanisms should be established that build the external costs of different energy sources into their prices. Strengthened economic incentives and disincentives favouring environmentally attractive energy investments are needed; as are emission limits, with licences to reflect them; and flexible trading in such licences; and improved regulatory measures.

77. Some measures would serve to control or reduce still other problems. Nitrogen oxides, for example, could be reduced by more careful nitrate fertilizer controls. This may also help to reduce the chronic problem of eutrophication and the growing problem of nitrates in drinking water, currently an important health hazard in many areas worldwide.

78. 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. Two chlorofluorocarbons[19] alone are thought to be

responsible for 20 per cent of the present day temperature rise[20], which should rise to about half by the turn of the century, and since they are produced by one large manufacturer worldwide, they might be an obvious starting point for management.

79. On the one hand, the chemical industry should make every effort to urgently find a replacement for chlorofluorocarbons for use in refrigerators and heat pumps. In the case of spray cans, on the other hand, since replacement gases already exist, the use of chlorofluorocarbons should be banned everywhere, and as soon as possible.

80. A roughly four-fold increase in chlorofluorocarbons is expected before 2050 at present rates of emission; this is estimated to cause a reduction in the stratospheric ozone shield of 10-30 per cent, thus allowing greater ultraviolet radiation to reach the earth's surface.

81. Nuclear energy could also have an important role to play in attacking all fossil-fuel related issues. The conditions under which its development can be maximized are discussed below. They need to be established and implemented through a new and binding international agreement.

82. Much of the uncertainty concerning the future global energy path could be cleared away if negotiated agreements could set "ceiling" levels for the quantities of the principal transboundary air pollutants, including carbon dioxide and work backward to map out exactly what energy strategies would be needed in future to peg them below these ceilings. The available range of strategies can

provide ample room for national priorities and for the energy supply conditions that are unique to each nation, but a lot of policy development work is needed to obtain them. This should proceed hand in hand with accelerated research to reduce remaining scientific uncertainties.

83. What is needed urgently is a concerted act of political will. The uncertainty about where we shall finally end up globally says more about policy irresolution at the political level than any shortcoming in the science of these issues.

## IV. SUSTAINING WOOD FUEL RESOURCES

### A. THE FUELWOOD CRISIS

84. Although wood ranks only fourth in the world's energy budget after coal, oil and natural gas (See Figure 4), almost half the world's population relies on it, mainly for cooking, and its use has been expanding at 2 per cent annually. Wood fuels, such as fuelwood or charcoal are the most important energy source for over 2 billion people in developing countries, where 30 - 98 per cent of all energy consumed comes from biomass.

85. Although wood fuels are in adequate supply in many countries, 1,300 million people live in areas that can satisfy minimum needs only through unsustainable over-cutting; and over 110 million people live in areas where even with such over-cutting minimum needs cannot be satisfied. By the turn of the century, unless counter measures are taken now, 3 billion people will suffer from a severe or absolute scarcity of wood fuel. Figure 5 shows the fuelwood situation in Africa.

86. The "fuelwood crisis", as it is called is particularly hard-hitting for the vast number of poor, rural and urban households, whose livelihoods and well-being depend on access to local supplies of traditional fuels like fuelwood, cow dung and crop residues.

87. There is no simple way of measuring the amount of wood fuels consumed due to the enormous diversity even within countries and local areas. Different kinds of wood are used, often supplemented by biomass wastes. Moreover, most fuelwood transactions take place outside formal markets, and consequently the quantities involved are difficult to measure. Recent studies and surveys seem to indicate, that on the average 70 per cent of the people in developing countries use wood, and, depending on the availability, burn anywhere between 350 to 2900 kg of air-dried wood, with the average being around 700 kg per person per year.

88. Given present trends, in the next few decades the fuelwood crisis will undoubtedly worsen and the theoretically renewable supply of trees will become increasingly non-renewable. Populations will grow substantially, and even if per capita consumption remains steady, total wood fuel demand will grow. Proportionately more of this population increase will take place in urban conglomerations, where charcoal use is generally higher. Overall, given the inefficient charcoal kilns now widely used, charcoal requires twice as many trees as straight fuelwood to deliver the same energy at the point of end-use. Consequently, per capita wood requirements will grow, even if per capita energy consumption remains. All in all, 1980 wood fuel demand potential of at least 2 billion cubic metres will grow to well over 3 billion cubic metres by the year 2000, and this at a time when, in many places, wood is already being harvested at levels higher than the sustainable yields.

89. At the same time unprecedented pressures are being placed on the same biomass base from the agricultural and urban-industrial sectors.[21] Forests are being cleared at a rapid rate to open up new agricultural land and much of this is induced by the need to produce more goods for export (tea, coffee, meat, etc.) to pay debts incurred to import or develop new sources of energy.

90. Some forest loss is inevitable, of course, to make way for human settlements, agriculture and industry. The continued rapid loss of forest cover, however, will be ecologically, environmentally and consequently economically disastrous for the regions concerned. Many of society's most important values are locked up in forests and disappear with them. But apart from that deforestation causes soil degradation and erosion, siltation of reservoirs, reduced electricity production, flooding and loss in agricultural yields.[22]

91. Furthermore, the scarcity of fuelwood represents more than just a lack of an energy source. Trees in rural communities are an important source of livelihood for people, in addition to being sources of fuelwood. In particular, trees supply fruits, fodder, fertilizer, medicines, poles for construction, shade and raw materials for a host of artisanal activities.

92. Yet, the fuelwood crisis and deforestation - although related - are not the same problems. On the one hand, wood fuels destined for the commercial markets for urban and industrial consumers tend to originate from forests. There are, therefore clear connections between urban-industrial wood fuel use and deforestation. On the other hand, however, fuelwood used in the rural areas comes from a mixture of sources, such as from scattered trees around villages, along roadsides, and so on. In general only a small proportion comes from forests, and even in those cases not as a result of clear felling of whole trees, but rather from the collection of dead wood or cutting off of branches from trees.

93. When fuelwood is in short supply, people respond by economizing in consumption; and when it is no longer available in an area rural people turn to burning biomass wastes, such as cow dung, rice husks and cotton stalks. In some cases these practices do no harm, since a true waste product is incinerated (e.g., cotton stalks). In other cases, however, much needed organic nutrients are diverted from the soil (e.g., animal manure, some wet biomass, etc.), and their diversion for energy purposes may result in problems, such as, in particular, the diversion of nutrients from agricultural lands (See Figure 6). It must be emphasized, however, that people will respond to the increased demand potential.

94. Poor rural people have no option other than cutting down on consumption in the face of fuelwood scarcity. It has been observed that the absolutely minimum consumption level necessary for survival is at around 350 kg of wood per person per year[23]. This can be achieved by very careful tending of fires and by accepting much hardship and poorer lifestyles. Eventually, however, the obligation to use so little energy means cutting down on the number of cooked meals, and shortening the cooking time for individual meals, which at the end means more malnourishment.

## B. SOME POLICY DIRECTIONS

95. The resolution of the fuelwood crisis in developing countries is a necessary condition for their sustainable development. On the one hand, energy needs both in the rural and urban areas must be met, either with additional wood, or other biomass and other alternatives. On the other hand, the disappearance of the trees and forests must be stopped and reversed, so that this valuable natural resource can sustainably supply fuel and other needs for the development process.

96. During the last 10 years there has been a significant effort by governments and aid agencies to resolve the fuelwood crisis, but unfortunately mostly in vain. It seems that failure has been, at least in part, due to a misunderstanding of the role of fuelwood in rural communities, and in not making sufficient distinction between rural and urban end-uses, and also in not distinguishing between the main actors responsible for deforestation. There is, however, a new

opportunity to tackle the problem afresh, and thereby to ensure that the developing countries will have a sustainable source of wood by the turn of this century. Given the completely different nature of the fuelwood crisis in the urban and the rural areas, different sets of policies are required for their resolution.

97. In urban areas where wood fuels are extensively used, most consumers purchase their requirements. Recently, as the price of wood fuels has been going up, poor families have been obliged to spend increasing proportions of their income on wood fuels (in Addis Ababa and Maputo families spend a third to a half of their incomes on wood!). This also means that any fuel saved translates into money saved, and if the cost of saving fuel is sufficiently lower than the avoided cost of wood fuel purchase, then people might just adopt fuel saving measures.

98. Over the last 10 years a great deal of work has been done on the development of fuel-efficient stoves. Many acceptable ones have been developed, which can save 30-50 per cent on fuel. These, as well as aluminium cooking pots and pressure cookers, which can also save a great deal of fuel should be made available much more widely in urban areas. Governments should make available credits or even outright grants to induce people to purchase them.

99. Charcoal conversion is presently a great wood waster. A major impact could be made on deforestation rates surrounding urban areas if more efficient charcoal conversion methods could be introduced. There are a large number of proven

technologies available. The main problems seem to be social and political in character. Charcoal is usually made and marketed through informal networks of small-scale producers and suppliers. What is needed is their replacement with new style charcoal co-operatives or boards which could be involved in the planting of trees, selecting technologies and marketing the product.

100. In addition to charcoal, there are other ways to transform wood into more efficient and practical fuels through chipping and briquetting. These should be promoted much more, particularly where forestry operations produce wood chips or sawdust.

101. Efficiency measures, however, will only buy time. Wood use rates must be lower than sustainable growth rates, and if they cannot be brought down sufficiently, then the supply has to increase. As is the case with efficiency measures, if the expansion of supply can be made sufficiently low-cost, the consumers themselves will be able to pay for it, particularly if the price of the alternatives is sufficiently high. There are a large number of policy options available for governments to increase wood fuel supplies.

102. The most important and urgent task is to improve the management of existing forests, including control of cutting and of encroachment.

103. In as much as commercial forestry operations do not generally make sense for the provision of fuelwood in rural areas, they do so for urban and industrial needs. Commercial farm forestry, or on a larger scale dedicated energy plantations, can be viable enterprises. Greenbelts around large

urban areas can be planted to provide wood fuels for the urban consumers. The additional environmental benefit of having a green zone around the city is not negligible either.

104. It is in these dedicated energy plantations that the high-efficiency charcoal kilns operate best. Given the high throughput of wood, their high cost can be justified. In Brazil some iron and steel industries are based on charcoal produced from wood in such dedicated energy plantations. Unfortunately, most still depend on wood supplies from native forests, without caring about their reforestation.

105. Sometimes, especially in the initial stages, fiscal and tax incentives are necessary to get projects going. In a second stage the subsidy or fiscal help can be tied to success rates for tree growth, and can eventually be phased out.

106. In urban areas, there are also relatively good prospects of increasing the supplies of alternative energy sources, such as coal, kerosene and in some countries, even electricity.

107. A combination of the measures proposed in the paragraphs above may be able to increase wood fuel supplies in sustainable ways to urban and industrial consumers, that is consumers who can pay. The above strategies, however, will not be able to help most rural people, particularly the poor, who collect most of their fuelwood needs. In their case, fuelwood is a "free good" until the last available tree is cut down. For the rural

populations totally different strategies will be required. It is here in this area, that the need is stronger than ever not to consider the fuelwood problem in isolation from other issues as a problem of energy, but rather as one of many in a set of problems of overall development.

108. Given the basic need for domestic fuel, and the low level of substitution possibilities, it seems, at least in the short and medium term, that the only way out of this problem is to treat fuelwood like food, and grow it as a subsistence crop. In the subsistence sectors, the need is to make available food and fuelwood together, locally where the demand is and not in distant countries and forests respectively. The definition of what is local is site-specific, but presumably extends to that boundary within which distribution is still feasible.

109. Large, centrally organized, World Bank funded projects to increase fuelwood supplies for rural areas have on past experience, been shown to fail. Even if the projects themselves are not very expensive, the resulting fuelwood is always more expensive than that which rural people can afford. Again, recent experience shows that better results can be obtained by decentralized, small-scale action through NGOs and other local organizations, where the planting and growing of trees is taken care of by the people themselves.

110. The best way to do this is by employing various agroforestry techniques, some of which have, in fact, been used for generations. These allow the growing of a few trees around the house, in the fields or in grazing areas, in combination with

food and fodder plants. The combined food/fuel/fodder output is higher than if the land were used only for one or the other activity.

111. In places, where local community organization is strong, the potential of village or community level social forestry programmes is large. India has been one example, where small initial help from a central government can start off very successful projects.

112. In most rural areas, however, simply growing more trees does not necessarily solve the problem. Often the picture is further complicated by complex socio-political factors. In many areas, in spite of a relative abundance of trees the availability of wood fuels is very low. One finds that the reasons tend to include problems like access to and ownership of trees, or the role of women in society.[24] Suitable solutions will have to be worked out for such local problems by the communities concerned.

113. One message which comes through is that governments, aid and development organizations who want to help the fuelwood situation in developing countries have to make a much more intensive effort to understand the role fuelwood plays in rural areas, and the social relations governing its production and use.

114. The particular problem of women and the fuelwood crisis needs much more attention than hitherto. In fact, women are the main actors involved in the collection and use of fuelwood. Consequently, development projects related to fuelwood must have women as the main targets.

## V. INCREASING RENEWABLE ENERGY

### A. THE POTENTIAL FOR RENEWABLES

115. Renewable energy sources provide more than 20 per cent of the energy consumed worldwide, of which 14 per cent is comprised of biomass and 6 per cent of hydro. However, most of the biomass is in the form of fuelwood and agricultural and animal wastes used by the majority of rural people and urban poor in developing countries, and in many cases it has become a non-renewable resource because use rates have overtaken sustainable yields. In this sense, although worldwide reliance on these sources has been growing by more than 10 per cent a year since the late 1970s, the world is still far off the point when renewable energy sources make up a substantial portion of the world's energy budget.

116. Wood as a renewable energy source is usually thought of in the context of the traditional sector. This, however, is far from correct. Wood is an important feedstock for advanced energy conversion processes in both developing and in industrialized countries, including for the production of electricity and potentially for other fuels, such as combustible gases and liquids.

117. The challenge ahead of developing countries is tremendous: to stabilize, and increase sustainable wood production to satisfy all legitimate demands in all sectors, at a time when unprecedented, and increasing pressures are exerted on these same resources from agriculture and urban and industrial energy consumers.

118. Hydropower, second to wood among the renewables, has been expanding at nearly 3 per cent annually. Although hundreds of thousands of megawatts of hydro power have been harnessed throughout the world, the remaining potential is huge, especially in the Third World.

119. Solar energy is currently of small importance globally, but it is beginning to assume an important place in the energy consumption patterns of some countries. In many parts of Australia and Greece, for example, solar water and household heating is widespread. Prior to the recent price shock, Israel expected that 60 per cent of its water would be heated by solar energy by 1990. 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 substantially increase.

120. Wind energy use has been growing tremendously in some countries, such as off the California coastline. In this case the wind turbines are used to generate electricity, to be fed into the local electricity grid. Wind power, however, has been used for ages for mechanical power - mainly for pumping water. Many countries have successful wind programmes, but the untapped potential is very high in all countries.

121. The Brazilian alcohol programme in 1984 produced about 10 billion litres of ethanol from sugar cane and replaced about 60 per cent of the gasoline that would have been required in the absence of the programme.[25] The cost has been estimated at US$ 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.

122. Although with the present oil glut the programme has become temporarily uneconomic, the programme saves the nation a great deal of hard currency, and provides additional benefits of rural development, employment generation, increased self-reliance, and reduced vulnerability to future crises in the world oil markets.

123. The Brazilian ethanol programme is particularly efficient at generating jobs - requiring an investment of $6,000 - $28,000 per job, which compares with an average of $42,000 for the Brazilian industry sector, and $200,000 for the oil-refining, petrochemical complex at Camarcari.[26]

124. The alcohol fuel cycle is not without environmental impacts either, but they are generally much smaller than those resulting from the fossil fuel cycle. The distillation process produces a lot of effluent wastes which have to be managed. In addition, the combustion of ethanol fuel does not appear to be perfect, and in addition to steam and carbon dioxide, small quantities of other chemicals are also

produced, whose impacts on the environment and on human health have not been fully researched.

125. Another promising option is the production of methanol from wood. Like ethanol, methanol has many advantages over gasoline. It produces a clean exhaust gas consisting of carbon dioxide and steam. However, some health aspects of using alcohol fuels need careful monitoring. The use of methanol has particular problems. For developing countries, methanol from wood is a viable option only if it is linked to large scale forestry programmes. An added bonus of such programmes is that it is possible to obtain charcoal as a byproduct, a nearly smokeless fuel, able to satisfy a number of end-uses in developing countries, including cooking and artisanal requirements.

126. The use of geothermal energy has been increasing rapidly, more than 15 per cent per year, in both industrialized and developing countries. Exploration is expected to uncover a world geothermal capacity exceeding 10 gigawatts by 1990 and the engineering and other experience gained during the past decades could provide the basis for a major expansion in geothermal-rich countries.

127. Globally the potential for renewable energy sources is huge. Quantitative projections are difficult, both at the global or at regional or national levels. However, one estimate placed the long-term global potential at at least 10 TW (See Table 3), a value equal to the 1980 level of

energy consumption worldwide.[27] This level could be substantially increased, however, with new technologies. While the extent and rate at which renewables are developed will depend on technology, it will depend even more in the short run on policies that attack certain economic, environmental and institutional constraints.

128. Not only is the potential huge, but so are the additional benefits from the use of renewable energy. They are inherently less polluting than their fossil counterparts. Consequently, the avoided cost of pollution control should act in their favour. Most renewable energy systems operate best at small to medium scales, ideally suited for rural and sub-urban applications. They are also generally labour intensive, which should be an added benefit in situations of surplus labour. Finally, since most nations have some renewable resources, their use can help nations move toward the goal of self-reliance.

129. Yet, in spite of all these advantages, renewables are taking off very slowly, much slower than desirable. Now, given the low oil, and other energy prices, it is even less likely that renewables will increase faster than hitherto. Governments have not been considering these new energy sources sufficiently seriously in their plans. Renewables are still being measured with the same yardsticks as their non-renewable counterparts, which invariably means narrowly calculating the quantity of energy produced at a certain cost, and conveniently leaving out the environmental and social externalities.

130. This does not mean that renewable energy production does not have to make economic sense as does any other activity. It does mean, however, that the evaluation of renewables has to be much more comprehensive. The cost/benefit calculations must include all aspects, including avoided pollution costs, job creation, achievement of social goals, subsidies for non-renewable systems, etc.

## B. SOME POLICY DIRECTIONS

131. The policies required for a steady transition to a broader and more sustainable mix of energy sources are beginning to emerge. Those associated with a high energy future, however, with their emphasis on fossil fuels and other conventional sources would have a negative effect on this essential process. National and international institutions would remain attached to supply-side planning and the promotion of conventional fuels. The limited budgets available for energy research and development would continue to focus almost entirely on improving conventional sources.

132. In contrast, radically different policies could favour the promotion of renewables. A low energy future, for example, would require decentralized energy systems, able to satisfy a wide range of end-uses, employing the most economically available sources. Very often, this will be various forms of energy saving measures: insulation for space heating and cooling; fuel-saving vehicles; energy efficient production machinery or processes; co-generation;

etc. Or, it could be various forms of locally available renewables: active or passive solar; biomass; etc.

133. With the exception of large-scale hydro, most renewable energy sources are compatible with the less intensive, decentralized systems that now exist in most developing countries and that will emerge in other parts of the world. In fact, most renewables are characterized not only by decentralization, but also by diversity. Unlike non-renewables, this enables each country to tailor its energy economy to its indigenous resources. Although every country possesses some sun, wind and biomass, some are better endowed with certain renewables than with others. Some may wish to rely on one locally abundant form of renewable energy; hydro power, for example. Others may be able to develop highly diversified renewable energy economies. Biomass gasifiers, biogas plants, small hydro installations, and most solar and wind systems work well in small to medium scale and are often the best match for family and village or community use, especially in developing countries. Some large countries or regions, Brazil, India, North America, may be wise to develop the entire panoply of renewable sources: from energy crops, including alcohol and wood fuel plantations through to wind, solar and photovoltaics.

134. As they evolve, renewable energy economies will also reinforce the self-reliance goals of most developing countries. Certain renewable energy systems could either displace imported fuels, or satisfy new demands without the need to import

additional energy. This is particularly true of hydro-electric plants, biomass gasifiers, biogas plants, ethanol distilleries, various solar electric and solar heat systems.

135. For developing countries, reliance on locally available energy sources should improve the balance of payments and reduce debt loads. The outlays of foreign exchange are negligible, particularly if conversion hardware is locally manufactured. In addition, many renewable sources are virtually inflation-proof. Once the initial investment is made, the cost of running hydro and solar is tied to maintenance.

136. The economic, social and environmental consequences of renewables require serious evaluation and comparison with non-renewables. Sustainability is the limiting factor with some renewables. Using them above sustainable limits will render them non-renewable, and consequently unsustainable. It is very important that these limits be continuously assessed and monitored in every country. Countries should undertake a full assessment of their potential for renewable energy, and the economic, social and environmental consequences of a steady shift to renewables.

137. The influence of unreasonably low fossil fuel prices has already been noted. The high level of hidden subsidies for conventional fuels built into the legislation and energy programmes of most countries also distorts choices against renewables. These subsidies are legion, including not only research and development, but also

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 publish the results.

138. Beyond that, given the advantages of a renewable energy economy to their development, countries should also reorient certain fiscal and tax policies that now penalize renewables. At a minimum, they should be neutralized and in some cases they should be re-cast to give individuals, entrepreneurs, private companies and parastatals the promise of a gain sufficient to induce them to invest in new energy technologies that improve both economic efficiency and the environment. Developing countries should consider the establishment of small venture capital funds at national, regional or global level to finance renewable energy projects. International development assistance agencies and financial institutions should assist in this.

139. Both industrialized and developing countries should critically evaluate the feasibility of shifting the basis of thermal power generation from the combustion of fossil fuels to gasification. Where available, biomass fuels should be included in the assessment. Following comprehensive economic analyses, wherever feasible, countries should step up the pace of the shift from coal and oil to gas and renewable energy sources, such as solar thermal, solar photovoltaic and biomass. In particular, the transport-fuel base should be shifted from

gasoline and diesel to alcohol fuels, such as ethanol and methanol where a full socio-economic and environmental comparative analysis shows this to be worthwhile under local market conditions.

140. Progress in renewable energy technologies depends on a much greater level of research and development. The current effort has registered some success, but in most countries it is dwarfed by the effort put into fossil fuels and nuclear. In addition to increasing the level of direct support, countries should offer high tax write-offs or other similar benefits to corporations that undertake research into new energy technologies and high investment write-offs for tax purposes for investment in energy-saving or new energy technologies.

141. The shift to a renewable energy economy in developing countries must include strategies for the stabilization and increase of sustainable wood production to satisfy growing demand, both in the traditional and in the modern sectors. This has to be carried out in environmentally favourable ways, which enhance and not reduce the countries' agricultural priorities.

142. In particular, existing trees and forests will have to be managed in environmentally and economically sustainable ways. Additional trees and forests should be planted in different ways; agroforestry programmes, large- or small-scale dedicated energy plantations, village- and community-scale woodlots or as conventional forests. The aim should be to make tree growing financially viable. Where possible, wood conversion processes should be made more efficient, particularly in charcoal making.

143. In examining their current structure of energy subsidies, the governments concerned should therefore pay special attention to the fuelwood crisis. Those fiscal, tax and other policies that induce practices adding to pressures on fuelwood should be reversed and special programmes of incentives to farmers to augment fuelwood resources should be introduced.

144. Institutional barriers to renewables are formidable in many countries. Electrical utilities, for example, often have enjoyed a complete monopoly not only in power distribution (which is historically perhaps justifiable) but also in power generation. In some countries, a relaxation of these powers, requiring utilities to buy power generated by industry, small systems and individuals at avoided costs, has created many 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. All countries should consider this urgently and international development agencies should support it.

# VI. MAKING NUCLEAR ENERGY ACCEPTABLE

## A. THE NUCLEAR DILEMMA

145. The large number of public demonstrations against nuclear power in various countries, as well as the delaying or alteration of nuclear programmes by a number of governments in the light of the Chernobyl accident, indicate that nuclear power has not yet reached full maturity as a publicly acceptable technology. Even in countries where it has reached an appropriate level of technical maturity, socially and politically, attitudes to nuclear energy have not matured enough for it to be considered a fully acceptable energy supply option for the future in its present state.

146. This is unfortunate because the pressure for increased electrical energy is great in many countries, because nuclear energy could be one of the most important sources of centralized electricity production, and because increasing nuclear sources of electricity could reduce significantly the environmental impacts of fossil fuel. If nuclear power is to achieve its promise, however, much needs to be done. Nuclear reactors will have to be made inherently safe, and methods of nuclear waste disposal will have to be not only fully developed but also put in place and made operational. Safety standards will have to be mutually agreed within and between nations, and the siting and operation of nuclear facilities will have to be brought under appropriate forms of international control.

147. In many countries, nuclear power agencies have lost the confidence of the public. Regaining this confidence will take time and an open approach to information disclosure alien to the original attitudes of most nuclear agencies. The nuclear establishment much show a far greater sensitivity to the concerns expressed by people from all walks of life than it has displayed in the past.[28] It will also take a demonstrated record of safe operation of the nuclear fuel cycle, much more "transparency" in all sectors of the nuclear fuel cycle, and resolution of outstanding questions of decommissioning of nuclear reactors and radioactive waste management, including sites for the permanent disposal of high-level radioactive wastes. The clear separation of civilian and military nuclear activities in all countries is also a necessary condition for making nuclear energy acceptable technically and socially.

148. Nuclear safety returned to the headlines following the Chernobyl accident. The post-accident analysis has shown that human error was the original and, perhaps, the major cause. In this connection, it is interesting to note that the risk of a signifant reactor accident, which as a result of an engineering calculation had been put at one in a million reactor years, has now been revised downwards in the light of practical experience to one in twenty reactor years. This reinforces the Commission's view that a new generation of "fail-safe" and operationally fool-proof reactors is needed, in which the risk of catastrophic accidents would be reduced

significantly. Various designs of fail-safe reactors have been developed and in the future they should be the reactors of choice.

149. "Absolute" proof of the safety of any disposal of high-level radioactive wastes is impossible, of course! Only time will tell if a disposal configuration chosen today will function as designed and that time may be measured in the hundreds of thousands of years. Even within reasonable and practical limits, however, resolving the problem of radioactive waste disposal will not be easy due to the extreme complexity of the proposed or potential disposal methods. Nonetheless, some governments in co-operation with the IAEA and NEA are working strenuously to this end.

150. A few countries (e.g., Sweden, Switzerland etc.) 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. This has intensified the search for environmentally acceptable forms of management of these wastes, and has brought some nations closer to solutions for their final disposal. As a result, the technology of disposing of even the long-lived, high-level wastes in environmentally acceptable ways has now reached the stage of technical feasibility in a number of nations.[29] Technical feasibility, however, has been demonstrated mostly in the form of paper studies[30], at least in part due to substantial opposition from towns and regions to the

designation of their lands as a potential repository. This "not-in-my- backyard" syndrome will have to be overcome before "technical feasibility" can be translated into actual "disposal" of the wastes.

151. The extremely long time horizons involved in nuclear radiation create particularly difficult issues. The question arises, for example, as to whether this generation has the right to bury wastes in geological formations which may harm future generations, however small that probability may be. In a real sense, geological disposal of long-lived radioactive wastes is an attempt to bypass the polluter pays principle, by transferring some of the potential costs and radiation harm of the back-end of the nuclear fuel cycle to generations not yet born. This is more than a theoretical question since, at least in principle, it is possible to transmute the long-lived nuclides to ones with much shorter half lives - although at higher cost.[31)]

152. Governments and the international community should fully adopt the goal of working toward "closing" energy cycles. The ideal of achieving clean-up at exactly the same time as energy production will probably remain ellusive, but efforts should be made to reduce the time delay as much as practically possible, preferably within the same generation. In particular, the "transmutation option" for the elimination of long-lived radioactive wastes should be further studied and developed to reach the stage of technical feasibility in order to allow full cost/benefit comparison with the "geological disposal option" presently practised.

153. The disposal of radioactive wastes is one area which lends itself well to international co-operation. Large internationally supervised repositories may have some technical and environmental advantages. Small nations do not possess all the scientific and technical capability to carry out the necessary research and development work. Some nations have superior or inferior geologies for the disposal of radioactive wastes. Consequently, the scope for international co-operation on the development of waste disposal methods is great.

154. However, there are a number of difficulties with international co-operation. Problems of agreeing on the location of such repositories seem so great as to make them unlikely, before a number of national repositories are brought into successful operation. International co-operation under binding conditions and strict supervision, probably through an authority accountable to some clearly neutral body would seem imperative for the siting and operation of any repositories in the international commons.

155. Something similar may be desirable should proposals to site nuclear repositories on the territory of developing countries be seriously entertained. Recently, some developing countries (e.g. People's Republic of China, Sudan, Ethiopia, etd.) have shown an interest in agreements with nuclear countries (e.g. FRG, Switzerland, etc), under which they would take the nuclear wastes of the former for hard currency or access to technology. Although no such agreements are known to have been signed, the possibility is very dangerous indeed.

156. Radioactive wastes should be disposed on the territory of the country enjoying the benefits of nuclear power. On the rare occasions, when this is not possible, for geological or other technical reasons[32] disposal in another country should be subject to the same strict safeguards as for the disposal in the international commons, and should be conducted under an appropriate international authority.

157. The nuclear industry is going through a tremendous change in this decade. A host of entirely new types of reactors, including relatively small ones (10 - 300 MW) are now under development, many of which are designed either for district heating or for electrical power generation for potential markets in developing countries.[33] Some industries are planning 100 per cent package deals, where the reactor could be assembled at the factory location, and then shipped to final location on rail or on barges, where it would simply be hooked onto a national grid.

158. The problems as well as the potentials in these developments are tremendous. On the one hand, standardized construction could enable manufacturers to ensure higher safety. On the other hand, technological dependence, the need for highly skilled operators and other issues would need to be addressed by the receiver countries.

159. The Chernobyl accident strengthens the Commission's general view that in the future no nation should arrogate decisions on energy matters entirely to itself. In as much as the fossil fuel emissions from a plant may cause harm in a

neighbouring or even a distant country, or the damming of a river may have implications in a neighbouring country, so the siting of nuclear reactors, of nuclear waste repositories and the routine releases of radioactive materials into the environment have regional and even global implications. A sovereign nation may decide to site a nuclear reactor or repository near their frontier as, indeed, many have, or to permit a nuclear reactor with lower safety levels, but should a catastrophic accident ensue, the released radioactive fall-out will invade neighbouring countries, and expose their people, animals, crops and land to perhaps very high risks. The right to advance notification and consultation on these decisions needs to be recognized with prior and binding international agreement on matters of site selection criteria, safety standards, releases into the environment and compensation in the event of a catastrophic accident.

160. The role of the International Atomic Energy Agency in this regard needs to be revised to reflect the new requirements which are being placed upon it. Presently the IAEA is mandated to promote and to regulate nuclear energy and its other civilian applications. In practice, however, it is difficult to play both roles simultaneously and effectively. In particular, its regulatory role needs to be greatly strengthened, and if possible be brought under different management than its promotional role.

## B. SOME POLICY DIRECTIONS

161. The Chernobyl accident will, no doubt, create a de facto moratorium on nuclear energy in a number of countries. This Commission is of the view, that new nuclear plant construction should be phased out in all countries, until the most important technical, legal and socio-political problems are resolved at national as well as international levels. During this period, governments should make every effort to develop concrete plans to close the nuclear fuel cycle, and to bring the safety of their nuclear installations up to internationally agreed standards, and to conclude appropriate international conventions on nuclear energy.

162. The response of IAEA and its member countries to Chernobyl, while encouraging, only begins to reflect the lessons of that tragedy and the changes required if nuclear power is to become a fully acceptable option. By August 15, 1986, only .....days after the accident, experts meeting at IAEA headquarters had reached consensus on the texts of two draft conventions. The first would commit parties to provide early notification and information about nuclear accidents with possible transboundary effects. The other would commit parties to endeavour to provide assistance in the event of a nuclear accident. (This paragraph on the negotiations underway at IAEA will be revised after Harare).

163. These measures, important though they are, would trigger co-operation after the fact of an accident. Anticipation and prevention require that the international dimensions of a nuclear

plant be recognized much earlier in the design, siting and operation. Negotiations on a more comprehensive internationally binding convention on the peaceful uses of nuclear energy should commence immediately. Such a convention should include:

163.1 an obligation by member states to notify in advance and to co-ordinate with neighbouring states the siting of all future nuclear installations, including reactors, reprocessing plants and radioactive waste storage and repository locations;

163.2 an obligation on all signatoies to communicate routinely operational details such as fuel loading timetables;

163.3 an obligation by all signatories not only to notify automatically all neighbouring states of all nuclear accidents on their territory, but also an obligation to provide information concerning the quantity and types of radioactive materials released into the environment both during normal operations and as a result of accidental releases;

163.4 the advance preparation of regional contingency plans to deal with nuclear accidents, and the obligation to co-ordinate clean-up efforts at a regional level.

163.5 the progressive adoption of mutually agreeable reactor safety and radiologically protection criteria.

164. Chernobyl has also highlighted the need to strengthen the regulatory functions of IAEA and to separate them from the promotional role of the agency. At the national level, during the past two decades, several countries have moved in this direction, separating nuclear power development, manufacturing and sales from regulation of the nuclear industry. Ideally, at the international level, similar steps should be taken. This would require agreement to revise the statutes of the IAEA, however, and that would undoubtedly take many years, if it could be achieved at all. In the meantime, until such agreement can be realized, the IAEA should consider a separation of its functions into two major branches, with the promotion of nuclear power institutionally divorced from the promotion and regulation of nuclear safety, safeguards and environmentally sound nuclear waste disposal.

## VII. INCREASING ENERGY EFFICIENCY

165. Energy efficiency should be the cutting edge of national energy policies and sustainable development; and measures to achieve it deserve the highest priority on national agendas. Although impressive gains in energy efficiency have been made since the first oil shock, the results have been uneven. Some countries have made great progress, others have gone backwards. The latter's potential is not limited to the achievement of the former; in both cases, the opportunities for future gains are enormous. But both will require deliberate policies.

166. The cost effectiveness of efficiency as the most environmentally benign source of energy is well established. There are many cases where the energy consumption per unit of output of "best practice" technologies is less than half of typically available equipment. This is true of lighting, refrigeration and space cooling, which are growing rapidly in most developing countries and putting severe pressures on electricity supply systems. It is true of cooking fires and cooking equipment, with all their impacts on tree cover, the recycling of crop and animal residues now burnt for fuel, and soil erosion. It is true of cultivation and irrigation systems, of the automobile, and many industrial processes and equipment.

167. These claims are often rejected by developing countries, and the poor generally, as concerns only of the extravagant and well-to-do. Nothing could more grievously misrepresent the truth. It

is the poorest who are most often condemned to use energy - and other resources - least efficiently and productively; and who can least afford to do so.

168. The woman who cooks in an earthen pot over an open fire uses perhaps eight times more fuel than her 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 hundredth of the illumination of a 100-watt electric bulb and use just as much energy to do so. The cement factory, automobile or idling irrigation pump in a poor country is no different from its equivalent in the rich world. In both cases there is roughly the same scope for reducing the energy consumption (or peak power demand) of these devices without any loss of output or welfare. But in a poor country the benefits thus gained will mean much more.

169. This, however, is the tragic paradox of poverty. It is not energy, but rather poverty which is the limiting factor for the poor. They are forced to live on a meagre current account, and thus use inefficient equipment, because they have no savings for investment capital to purchase energy efficient devices. Consequently they end up paying many times over for a unit of delivered services.

170. While there are countless examples of successful energy efficiency programmes in industrialized countries, these programmes face a large number of barriers in developing countries. In all countries, ignorance tends to be the most important constraint. Many consumers, including

large industries, do not know how they use energy, what it costs them, how costs can be reduced, or how to set about reducing them. Information campaigns in the media, technical press, schools, etc.; demonstrations of successful practices and technologies; free energy audits; energy "labelling" of appliances; training in energy-saving techniques; and other techniques have been used successfully to increase awareness and they need to be extended.

171. Indifference is equally widespread. Apart from transportation and the most energy-intensive industries, energy typically accounts for only 3-5 per cent of total costs of an enterprise. The figure is much the same for middle to high income families in industrialized countries. It represents only 1-3 per cent of the family budgets in the warmer developing countries where there is little need for space heating. Where budgets are tight, therefore, investments in energy savings may be postponed regardless of the potential pay-off.

172. This tendency is reinforced by energy pricing policies, which may reflect subsidies and almost never reflect the real costs of producing or importing the energy, including the external health, property and environmental damage costs. Countries should evaluate the overall cost to government and society of different energy options, both renewable and non-renewable, with all hidden and overt subsidies included. Economic pricing of energy - perhaps with safeguards for the poor - needs to be extended in all countries.

173. Developing countries face particular constraints in this area. They are generally in the throes of foreign exchange difficulties which make it hard to purchase efficient, but costly energy conversion devices. Often such technologies are new, not yet fully tested, and poor developing countries cannot take the risks of experimenting, and possibly failing with such technologies. Finally, many measures for energy savings tend to be the "fine tuning" of already functioning systems. These do not appear as attractive as new, large scale energy supply projects to aid agencies or to local government officials.

174. There are more subtle but no less important price and cost distortions. The economic benefits of improved energy efficiency, for example, may be captured by parties other than the industry or consumer who has to bear the investment costs. Energy efficiency measures which reduce peak electricity demand and thus postpone the need for investment in additional capacity are a case in point. Frequently, the ratio of the cost of avoided supply to the cost of the efficiency measure is two or three to one. In these and similar cases, there are strong arguments for systems to enable those who invest in energy efficiency measures to capture more of the financial rewards.

175. Many energy efficiency measures cost nothing to implement. Where investments are needed, they are frequently the main barrier to action, even when pay-back times are short. These barriers are often absolute for the poor consumer or for small informal sector entrepreneurs. In these latter cases, subsidies will be necessary. Where

investment costs are not insurmountable, there are many mechanisms for reducing or spreading the initial investment hurdle which can be adopted by the public or private sector, ranging from subsidies, tax credits and loans to "invisible" measures such as payment through the (reduced) energy bills.

176. Mandatory efficiency standards for equipment and appliances have a number of advantages over strictly market measures. They can be relied upon to produce predictable energy savings, thus greatly assisting energy supply planning which must often be based on expected demand some 10 - 15 years ahead. They overcome the reluctance of manufacturers to take a gamble on producing more energy efficient technologies for uncertain consumer markets. They can induce both the spread of existing and the innovation of new technologies, processes and products as automobiles, chemicals, steel and other industries demonstrate. They can induce and push research and development efforts towards socially desirable goals.

177. The imposition of minimum energy consumption standards on the manufacture, import or sale of equipment is one of the most powerful and effective tools in promoting energy efficiency. Where the equipment concerned is traded internationally, these may require international action. Countries, and where appropriate, regional organizations, should introduce and or extend increasingly strict minimum efficiency standards for equipment and mandatory labelling of appliances.

A. IN TRANSPORT

178. 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 the majority of developed and developing countries. It is a major source of local air pollution and regional acidification of the environment.

179. Looking to the year 2000 and beyond, vehicle markets will grow much more rapidly in developing countries, adding greatly to potential air pollution in cities where international norms are already exceeded. Indeed, unless strong action is taken, air pollution could become a major factor limiting industrial development in many Third World cities. In this context, fuel economy emerges as the most cost-effective means both to prevent further growth in air pollution from vehicle transport and to preserve a region's capacity for sustainable development.

180. With higher prices, fuel economy becomes a high-visibility issue for consumers as well as governments. It can continue to be a driving force behind technical innovations directed at dealing with a changing operating environment and gaining competitive advantage in the market place. In the absence of higher prices, however, mandatory standards providing for steady increase in fuel economy may be necessary. Either way, the potential for substantial future gains in fuel economy is enormous; improved body design, material substitutions, and engines and power trains are some of the technical paths now being pursued. If the momentum can be maintained, the

current average fuel consumption of approximately 10 litres per 100 kilometres in the fleet of vehicles in use in developed countries could be cut in half by the turn of the century.[34)]

181. A key issue is how developing countries can secure similar improvements in the fuel economy of their fleets. Those countries that import their fleets, could mandate standards for new vehicles. In those countries where vehicles are assembled under licence with industrialized country manufacturers, however, the situation is different. The designs are frequently old and predate energy efficiency improvements. These countries should give priority to the reforms of licensing and import agreements under which they will have access to the best available fuel efficient designs and production processes.

182. The issue goes deeper, however. Transport is the one sector of demand where there are at present few substitutes for oil. While the scope for increases in energy efficiency in road haulage are immense, and will lead to very significant savings in energy, fleet life in developing countries is nearly twice that in industrialized countries. Thus the rate of improvement in energy efficiency will be much slower, and will almost certainly fall behind the rate of growth in total transport demand, at least if historical trends in the latter are any indication of what will happen in the future. Thus, even under the most optimistic assumptions, developing countries could face a significant rise in the total demand for transport fuels over the next three to four decades.

183. In view of this, certain developing countries should explore the potential in non-oil based transport fuels. Some actually have: Brazil being the outstanding example. The obvious candidates are alcohol-based fuels such as ethanol and methanol. Both can be obtained from biomass, and the latter may also be obtained from coal and natural gas. In fact, in principle, their combustion yields only steam and carbon dioxide. But some recent research and experience indicates the possibility of other health hazards. As a result, there is an urgent need to monitor them closely, and to conduct research on their elimination.

184. The encouragement of more energy efficient modes of transport is another option. In developing countries - and historically in the industrialized countries - the trend has been the other way. In particular, rail has given way to road and the bus to private vehicles. But reversing this trend is not easy, since the least energy-efficient transport modes are the most convenient and flexible. And the provision of quality services that attract customers - in particular, more frequent and less crowded buses or trains - inevitably reduces overall fleet energy efficiency.

185. Changes of this kind are easiest if they are built-in to development strategies. If city growth is centred on multiple cores, or on new towns within an expanding metropolitan region, efficient and rapid mass transit systems can be used to link the centres in which most travel can be non-mechanized. Such major shifts in development patterns can often be achieved by simple legislative measures such as zoning and floor space regulations.

B. IN INDUSTRY

186. Industry is also a major source of energy demand accounting for 40 - 60 per cent of all energy consumed in industrialized countries and 10 - 40 per cent in developing countries. Like transport, it is a major source of pollution, especially in those countries that have not enjoyed strong environmental programmes over the past two decades.

187. Most trends point to a very rapid growth of industry through the turn of the century, but the form and pattern could be markedly different between industrialized and developing countries. Industry in the former has been undergoing a massive restructuring marked by a shift toward higher technologies, a substitution of synthetics for primary inputs, and a growing dematerialization of the economy.

188. At the same time, there has been significant improvement in the energy efficiency of production equipment, processes and products. The innovation behind these improvements has been driven, in part, by higher energy prices. As a result, every industry sector is now marked by plants that are comparatively energy efficient and, hence environmentally efficient and economically competitive.

189. During this period, there has also been significant shift of industrial capacity in the basic and traditional sectors of developing countries in industries that tend to be more energy intensive and polluting. Moreover,

developing countries have tended to attract older technologies and processes which are comparatively inefficient and internationally non-competitive. While in some cases they do not have an other choice, it must be admitted that some developing countries actively seek to buy old plants as a part of their industrial strategy. If these trends continue, developing countries could end up with industrial sectors that are not only economically uncompetitive but also highly polluting, imposing heavy health, property and environmental damage costs on their cities and economies.

190. In this context, energy efficiency again emerges as the most cost-effective means both to prevent further growth in such damage costs and to promote a competitive and sustainable industrial sector.

191. The key issue, again, is how can developing countries ensure that future industrialization reflects the most advanced and resource efficient technologies available in each of the sectors concerned. Several measures seem within reach. Those countries that permit nationals or parastatals to import plants on a turn-key or other basis, or that permit multinationals to establish plants on their territories, should ensure that all permits, licences and contracts provide for the best available energy and environmentally efficient technologies and processes. Moreover, such contracts should require registration of complete plans for the safe management and disposition of all emissions

inside and outside the plants, and of all wastes. Development assistance, export credit and other international financing agencies involved should ensure that both are included in the financial plans of the industry.

192. Developing countries often need to decide on the comparative advantage of domestic production of industrial components. In these cases, the most energy intensive and polluting components might be imported, leaving the others to be made domestically, thus achieving a far lower overall energy intensity for the final product. Energy saving of as much as 20 - 30 per cent could be achieved by such skillful forms of industrial development.

193. The proper maintenance of industrial plant, especially older equipment, can also save much "down-time" and can pay real dividends in terms of energy saving. Industry-oriented energy conservation programmes, managed perhaps by an "energy service utility" with incentives to help existing industries to identify cost-effective opportunities for saving energy, could reduce energy demands by a further one third. Saving of this order cannot only improve the competitiveness of a nation's industrial sector, but also improve its balance of payments, reduce its debt requirements and increase the capacity of the environment in Third World cities to accept more development.

194. Where the latest industrial designs are transferred to developing countries, either through retro-fitted process improvements or through embodiment in new plant designs, the improvement in energy efficiency can be truly dramatic. This improvement is vitiated only by the much longer life of plant and equipment in developing countries. This longer life stems only partly from the scarcity of capital and foreign exchange. An equally important reason is the existence of protected home markets and monopolistic structures of production which make such improvements unnecessary for raising or retaining high levels of profits. This means that even a modest package of fiscal and monetary incentives can significantly accelerate the pace of technological renewal, even within the given capital constraints.

C. IN AGRICULTURE

195. Globally, agriculture is only a modest energy consumer, accounting for about 3.5 per cent of commercial energy use in the industrialized countries and 4.5 per cent in developing countries as a whole. A strategy to double food production in the Third World through massive increases in fertilizers, irrigation and mechanization would add only 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 fraction of the energy that could be saved in other economic sectors in the developing world through appropriate energy efficiency measures.

196. Agriculture is usually the least energy-intensive sector in national economies and the one with the highest economic and social return for each extra unit of energy input. The western industrialized countries have established clearly that the "high food - high energy" linkage can be broken. While energy use has grown, energy efficiency has grown even faster permitting a significant rise in productivity.

197. Much of the increase has taken the form of chemical fertilizers and pesticides. Failure to manage them properly, however, is now threatening the sustainability of agriculture in many areas. Increased pest resistance, loss of soil fertility, eutrophication of lakes, contamination of streams and nitrate pollution of water supplies are some of the effects undermining the potential for future gains in production at the rates enjoyed in the past. Measures for more effective management are dealt with in Chapter V of this report.

198. Agriculture in developing countries, on the other hand, suffers from low levels of energy use and productivity and the potential for increasing both is enormous. It is hard to find examples where increasing levels of energy use does not bring more than proportional increases in yield, income and profits.

199. Fertilizers are perhaps the most significant case in point. Increasing yields through higher applications of appropriate nutrients is perhaps the most important means available to developing countries to secure the annual gains in food production needed for their growing populations. In this regard, locally available sources of

organic fertilizer can be more fully exploited. Some 10-15 million tons of nitrogen and 5 million tons each of potassium and potash could be had in the Third World if only half the available human and animal manure were used. A comprehensive composting or biogas programme in the Third World could provide an estimated 50 - 100 million new jobs and in the latter case produce high-grade energy for cooking, lighting and irrigation pumping.

200. Selective mechanization with small machines and improved use of animal draft power are also important energy interventions to break labour bottlenecks, significantly improving productivity and, in many cases, allowing double or even triple cropping. Access to more conventional sources of power would also pay high dividends in increased productivity. Farmers, for example, require energy to pump water for irrigation and other uses, or diesel for tractors, and they require it at precise times of the year. If they do not get it because of priorities elsewhere, yields suffer or crops may fail entirely.

201. The main constraints to increasing energy for agriculture in developing countries can be traced to unbalanced and inequitable development policies. Although there are vast differences in the political and economic power of rural societies to command energy resources, and genuine problems of resource distribution in rural areas, a balanced development strategy could achieve much in minimizing these problems.

## VIII. STRENGTHENING INSTITUTIONAL CAPACITY

202. Attention has already been drawn to the ways in which the oil price rises of 1973-74 and 1979 actively stimulated a movement away from oil into other energy forms and towards a concern with energy saving and efficient usage practices. Many countries began to review their national energy polices and there was great interest in coal, nuclear, natural gas and renewable forms of energy. In the early 1980s, after the initial economic upheavals had settled down, many began to see the steady transition from oil into other energy forms as a healthy sign in a world that formerly had been too heavily dependent on oil products.

203. At about that time, predictions and forecasts about the future of oil abounded, most of them expressing pessimism about future prices. Those few analysts who prophesied drastic falls in oil prices as producers competed for a share in a shrinking world market were quickly dismissed. Nowadays, with prices dropping almost as dramatically as they originally rose, once more approaching the 1973 prices in real terms, most serious analysts have a much healthier respect for uncertainty and many feel that the journey to any energy future involving oil may well mean a very bumpy ride for consumers and producers alike, unless radical action is taken now.

204. In spite of this, at the moment, energy seems to have slipped off the global agenda and many are asking whether worldwide preoccupations with conservation, renewables and coal are really necessary nowadays in a world of oil-glut.

205. And yet, for reasons connected with more stable and sustainable pricing policies and production arrangements, and for longer term oil availability, the transition must somehow be encouraged to go on. Already, many countries are learning that rapidly falling oil prices can be economically very dangerous. The ground lost towards transition must somehow be regained and more orderly oil pricing and disciplined production somehow restored. Increasing diversity in fuel use must be revived. This is in everybody's interest. But in the current climate, it is becoming ever clearer that at present, the world lacks the economic and financial structures, as well as the institutional arrangements and, above all, the mental attitudes to do so decisively.

206. After the price debacles of the last decade or so, many analysts would argue that oil is too important in the global economy to be treated as a mere commodity, competitively traded on volatile world markets. Instead, both producer and consumer countries should develop policies designed to build some form of limited but appropriately effective convention for the more orderly production and marketing of oil to the year 2000 and beyond.

## A. NATIONAL ENERGY AGENCIES

207. An important aspect of the transition is the use of alternative energy sources in ways which are environmentally benign and developmentally sustainable but also cost-effective. Despite the immense amount of recent work done on the

health/environment risks attached to various energy sources, very little attention has been paid to the true total costs to society of fuel production, and transport, energy liberation and satisfactory management of the solid, liquid and gaseous waste products. In short, we still lack genuinely comprehensive systems analyses of complete energy cycle costings with the result that integral components of the energy production process, usually waste management, are not folded into the pricing of the resultant energy.

208. This produces serious price distortions between energy sources. Thus coal, or electricity from coal, without waste management costs included, are bound to appear less expensive than the gas option which is hence dearer, but cleaner in health/environment terms.

209. Another important feature is that energy sources vary widely, from wood fuels, crop-wastes, animal dung, through fossil fuels (gas, coal, oil) to electricity produced by hydraulic, nuclear, thermal or solar power. In many countries, responsibility for each of these is placed in separate utilities with little or no contact between them. And when, as has happened recently in many countries, a Ministry of Energy is formed, there are still serious and apparently insoluble demarcation disputes about such issues as whether fuel wood and crop-wastes should be handled by Energy, or should be lodged with Agriculture, Forestry or the Environment. It is also quite often unclear as to who has the responsibility for managing the environmental impacts of energy production, which through lack of action usually results in reinforcing the pricing distortions referred to above.

210. Again, the young Ministry of Energy often has an inadequate budget and may lack the power to devote funds to timely energy projects or to determine energy taxes, subsidies, extended credit facilities and pricing policies or other instruments of financial management control over the energy mix. Often, the Ministry is so stretched professionally with day to day management imperatives that it also lacks the time to develop a comprehensive energy plan for the country, which is an essential starting point for the implementation of all the recommendations in this report. Furthermore, it is unable to develop the marketing of energy services as opposed to fuels in various sectors of the energy economy. Nor is it usually able to promote energy saving by fostering such important conservation procedures as energy audits, energy intensity analyses or the thermal insulation of buildings.

211. All these shortcomings are so serious in terms of prudent energy management that governments should give the highest priority to designate a lead agency or authority with a broad mandate for the development of energy policy and its co-ordination, covering all energy sources and uses, and with clear responsibility to assess and to take into account the effects of energy strategies on economic growth and on sustaining the environmental basis of that growth. All single fuel agencies, including nuclear, should be subordinate to its advice.

212. This lead agency should also be required to effect meaningful co-ordination with finance, economic development, environment, transport, agriculture, and other relevant ministries, and vice versa.

213. To be effective, the agency must have access to some level of fiscal authority and become a primary source of advice on energy consumption taxes, subsidies, credit and other financial instruments used to influence energy development in favour of sustainable supply and consumption patterns

214. This agency should have a special mandate to remove institutional barriers to the transformation of electrical supply and distribution utilities into "energy service" utilities, responsible for purchasing supplies from all sources, including renewables, at remunerative prices; and for marketing these supplies, tailored to specific end-uses in households, industry, agriculture, and other sectors.

215. In developing countries, it is essential that these agencies develop realistic national energy plans, and that any proposals or demand for foreign aid for energy development be made in its context.

## B. REGIONAL ENERGY AGENCIES

216. Air, river or marine pollution from waste products following energy production may cross national boundaries and cause problems for adjacent states of a world region, leading to damage and political embarrassment. The acid rain problem is a well

known example of this, as are certain effluent accidents from nuclear installations. Another such issue is the regional identification of sites for the disposal of nuclear waste. They usually require collaboration by adjacent states for their solution which may involve mutually agreed or harmonized abatement and emission control codes of practice and standards.

217. Where many states are involved, detailed policy optimization practices based on overall least-cost solutions need to be worked out. Additional surveillance, monitoring and early warning practices developed by member states of the region could be made conformable and inter-comparable so that regional exchange of comparable data can be used to strengthen the power of the regional management process.

218. On the more positive side, individual states with similar energy management problems may develop specialized technical skills for energy planning, hardware production or other expertise which they could more easily share if regional energy information exchange networks were developed. The activities of the SADCC Regional Energy Centre in Luanda is a good example of a step in this direction.

219. In fact, the advantages of regional energy commissions are so numerous that a series of such commissions should be developed globally to carry out the above activities and similar collaborative functions. States sharing common borders or similar socio-economic and bio-climatic conditions should strengthen existing and/or establish new regional organizations with broad mandates for

regional co-operation and joint action to deal with interrelated economic, energy, environment and development problems. Thus they may manage the energy transition in a co-ordinated and cost-effective way.

220. These agencies would provide a much needed capability to identify and seize opportunities for regional co-operation in financing, developing and exploiting new technologies for energy supply, energy saving and for environmental regeneration. They would also enable nations to develop regionally comparable economic and environmental statistics; baseline quantity and quality surveys of shared resources and an early warning capability to reduce and/or prevent an increasing range of environment and development hazards.

## C. GLOBAL ENERGY-ENVIRONMENT CONVENTION

221. Most energy-related problems, like the energy policies which induce them, reach across national boundaries, becoming regional and even global problems. Consequently, some form of international action is required for their resolution. Moreover, it is often more efficient for a number of countries with similar geographical, economic and other characteristics to join forces and tackle regional problems in a regional forum.

222. International action, however, cannot be, and is not a substitute for national action. In general, effective international action should be based on similar and parallel action at the national level.

223. It is abundantly clear from the discussion above, that no solution to these problems will be possible unless developing countries have access to assured finance from international sources. Now that the World Bank is giving up its energy accounting activities for developing countries, the idea of a "World Bank Energy Affiliate", or some similar organization, with specific concerns for developing countries is more relevant than ever. Such a bank should increase overall energy related lending over present levels, with particular emphasis for projects involving energy efficiency measures.

224. The line of argument developed in the previous sections could be extended to problems that represent generally global externalities, such as the carbon dioxide and climate-warming issues or the release of radioactive gases to the atmosphere. These and similar global problems should form the basis for the creation of a global energy-environment commission, in co-operation with the United Nations Environment Programme and the proposed regional energy agencies. The tasks of this commission should include the development of internationally agreed abatement and/or adaptation strategies of the problem as it develops in tandem with policy development.

225. Such a commission would strengthen institutional capacity at the global level in order to enable national governments to deal effectively with a growing range of energy-based environment and development problems that transcend regional boundaries. These include: climatic change; the acidification of the environment; air pollution,;

marine and coastal water pollution; and the problems posed by heavy metals; fuelwood; deforestation and so on. A three-track approach is recommended to these issues:

225.1 The first involves an acceleration of monitoring and assessment to improve our knowledge base, strengthen our capacity for anticipation, prevention and adaptation and reduce the level of uncertainty. To this end, existing arrangements for co-ordinated monitoring, assessment and research in the UN system need to be streamlined and broadened to include other sectors (e.g. agriculture, transportation, urban development) and other regions and countries likely to be severely hit by acidification or by shifts in climate, rising sea levels, or other phenomena.

225.2 The second involves policies to induce a several-fold research on energy and related strategies for the transition, including more effective instruments to influence energy demand and barriers to their implementation, more energy-efficient technologies, alternative sources of energy, the economic costs of health, property and environmental effects of alternative sources of energy, the geo-political implications of energy-induced climate change, etc.

225.3 The third involves an immediate start on negotiations for an international convention on critical environment and development problems related to energy, including those mentioned above. To this end, the Secretary

General of the United Nations should convene a special conference not later than 1989, and charge it with drafting such a convention, potentially as embracing and binding as that of the Law of the Sea.

CONCLUSIONS

226. The patterns of energy consumption and supply, their environmental impacts and their implications on the economy and development in the year 2000 and beyond are being determined today. Moreover, the aggregate results of today's choices by governments, industries and individuals are energy patterns which are not sustainable. Some, such as the overuse of natural resources, such as biomass in developing countries and the acidification of the environment in industrialized countries are already causing environmental catastrophes today. Others, such as climatic change will only manifest themselves in the medium- to long-term future.

227. The major underlying forces favour continuing the higher levels of energy consumption per unit of growth, and the massive investments in traditional sources of supply, which are wasteful of resources, pollute the environment and inhibit economic development. If this goes on, the world will lurch from avoidable crisis to avoidable crisis, both developmental and environmental.

228. It is possible to develop environmentally favourable energy strategies which will enhance, rather then diminish the potential for economic development. The changes required to make it possible to implement such strategies, however,

face enormous obstacles, economic, institutional and political. Governments, industries and individual energy users must make a total commitment to enable a transition to such sustainable energy patterns.

229. Environmentally favourable energy strategies would aim to secure a major shift from present to more productive patterns of energy consumption and improved forms of production, including a much greater emphasis on benign sources. They must include strategies to increase energy efficiency in all sectors; reduce the use of fossil fuels wherever possible, and use them in environmentally favourable conversion systems; stabilize the wood fuel resource base in developing countries; increase the role of renewables substantially ; and make nuclear energy an acceptable source of power.

230. Although these actions will have to be carried out within national jurisdictions, no individual country can solve these issues on its own. At a time when multilateral co-operation is being neglected everywhere, much more regional and international co-operation will be required for effective solutions.

231. The world has been living on energy capital for a long time now, and the capital is running out. The transition to living off income, that is renewable energies is inevitable, and the earlier it comes the better. Countries of the world can join forces and make it happen, or they can sit back, go on as before and accept the consequences. The choice is ours, and we should act accordingly.

## A. NOTES AND REFERENCES

1) FAO-1981 and FAO-1983

2) Villach-985

3) Keepin - 1985

4) For a more detailed discussion see Keepin - 1985 and Keepin 1984

5) IIASA - 1981

6) The group consisted of Jose Goldemberg of Brazil, Thomas B. Johansson of Sweden, Amulya K.N. Reddy of India , and Robert H. Williams of the USA. The initial findings of the group have been published in Goldemberg et al, - 1985a

7) World Bank - 1983

8) World Bank - 1983

9) Goldemberg - 1985b

10) The study was made by H. Geller of the Companhia Energetica de Sao Paulo, Brazil. Quoted by Goldemberg - 1985b

11) For more detailed discussion see the background papers Lohani - 1985, Weidner - 1985, Hashimoto - 1985, and CETESB - 1985

12) For more detailed discussion see the background papers Torrens - 1985, Zhao - 1985, Rhode - 1985 and Goodman - 1985

13) For more detailed discussion see the conference report Villach - 1985, and the contributions to various public hearings of the WCED, such as Mintzer - 1985 and Hare - 1986

14) For a detailed discussion of the state of acidification in various European countries see WRI - 1986

15) WRI - 1986

16) Rodhe - 1985

17) Quoted from page 224 of WRI-1986

18) Villach - 1985

19) The two chlorofluorocarbons are Trichlorofluoromethane or F11, and Dichlorodifluoromethane or F12.

20) From Chapter I of the Preparatory Material prepared for the 1985 Villach Conference on Climatic Change, written by B. Bohlin, et al.

21) There exists a large amount of literature on this. See for example: Chidumayo-985, Ambio-985, Beijer - 1985-86.

22) See for example, Bandyopadhyay - 1986

23) See the detailed discussion of this in the article: Wood Fuel and Conventional Fuel Demand in the Developing World, written by Gerald Foley, on pages 253-258 of AMBIO-1985.

24) See for example Fernandes & Kulkarni - 1983, Chidumayo - 1985, Bradley - 1985.

25) Goldemberg - 1985b

26) Goldemberg - 1985b

27) Deudney & Flavin - 1983

28) For a more detailed discussion of this issue see KASPERSON - 1986.

29) Parker, et al. - 1984, and IAEA - 1983, etc.

30) As in Sweden, Switzerland, FRG, etc., as described in detail in Parker et al. - 1984

31) Castaing - 1983, and Parker et al. - 1984

32) For example, a number of nuclear reactor supplier countries also supply the nuclear fuel, which after use is returned to the supplier country for recycling or direct disposal. This is for example the case for nuclear reactors and fuel supplied to the CMEA countries by the USSR.

33) For a more detailed analysis see Egan - 1986.

34) MIT - 1984

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| Region | 1980 | | | | 2000 | |
|---|---|---|---|---|---|---|
| | Acute scarcity | | Deficit | | Acute Scarcity or Deficit | |
| | Total Population | Rural Population | Total Population | Rural Population | Total Population | Rural Population |
| Africa | 55 | 49 | 146 | 131 | 535 | 464 |
| Near East and North Africa | | | 104 | 69 | 268 | 158 |
| Asia and Pacific | 31 | 29 | 832 | 710 | 1,671 | 1,434 |
| Latin America | 26 | 18 | 201 | 143 | 512 | 342 |
| Total | 112 | 96 | 1,283 | 1,052 | 2,986 | 2,398 |

**Note:** a. Total population and rural population (total population less that of towns with more than 100,000 inhabitants) in zones whose fuelwood situation has been classified.
**Source:** Adapted from Food and Agriculture Organization, 1983, Reference 67.

Table 1: POPULATIONS EXPERIENCING A FUELWOOD DEFICIT 1980 and 2000 (in millions).
(Source WRI-1986)

| Country | 1983 | Country | 1983 |
|---|---|---|---|
| **Central & S. America** | | **Africa** | |
| Argentina | 9% | Algeria | 2% |
| Brazil | 56 | Burkina Faso | 50 |
| Chile | 24 | Cameroon | 4 |
| Colombia | 21 | Egypt | 12 |
| Costa Rica | 22 | Ivory Coast | 16 |
| Dominican Republic | 71 | Madagascar | 32 |
| El Salvador | 57 | Morocco | 57 |
| Guatemala | 68 | Niger | 17 |
| Honduras | 28 | Senegal | 58 |
| Nicaragua | 46 | Sudan | 57 |
| Panama | 82 | Togo | 18 |
| Paraguay | 1 | | |
| Peru | 2 | **Asia** | |
| Trinidad & Tobago | 4 | Bangladesh | 20% |
| Uruguay | 28 | Hong Kong | 7 |
| Venezuela | 1 | Indonesia | 20 |
| | | Korea, Rep. of | 28 |
| **Europe** | | Malaysia | 16 |
| Greece | 59% | Pakistan | 49 |
| Portugal | 48 | Philippines | 44 |
| Turkey | 66 | Singapore | 40 |
| Yugoslavia | 33 | Sri Lanka | 40 |
| | | Thailand | 39 |
| | | **Middle East** | |
| | | Jordan | 101% |

*Source:* World Bank *World Development Report 1985.*

Table 2: ENERGY IMPORTS AS A PERCENTAGE OF MERCHANDISE EXPORTS IN DEVELOPING COUNTRIES
(Source: Miller - 1986)

| *Source* | *1980* | *2000* | *Long-term potential* |
|---|---|---|---|
| | | | *(exajoules)* |
| Solar energy: passive design | <0.1 | 3.5–7 | 20–30 |
| Solar energy: residential collectors | <0.1 | 1.7 | 5–8 |
| Solar energy: industrial collectors | <0.1 | 2.9 | 10–20 |
| Solar energy: solar ponds | <0.1 | 2–4 | 10–30+ |
| Wood | 35 | 48 | 100+ |
| Crop residues | 6.5 | 7 | — |
| Animal dung | 2 | 2 | — |
| Biogas: small digesters | 0.1 | 2–3 | 4–8 |
| Biogas: feedlots | <0.1 | 0.2 | 5+ |
| Urban sewage and solid waste | 0.3 | 1.5 | 15+ |
| Methanol from wood | <0.1 | 1.5–3.0 | 20–30+ |
| Energy crops | 0.1 | 0.6–1.5 | 15–20+ |
| Hydropower | 19.2 | 38–48 | 90+ |
| Wind power | <0.1 | 1–2 | 10+ |
| Solar photovoltaics | <0.1 | 0.1–0.4 | 20+ |
| Geothermal energy | 0.3 | 1–3 | 10–20+ |
| Total | 63.5 | 113–135 | 334–406+ |

+ indicates that technical advances could allow the long-term potential to be much higher; similarly, a range is given where technical uncertainties make a single estimate impossible.

< means less than.

Source: Worldwatch Institute

Table 3: WORLD USE OF RENEWABLE ENERGY, 1980, 2000 AND POTENTIAL (Source: Deudney & Flavin - 1983)

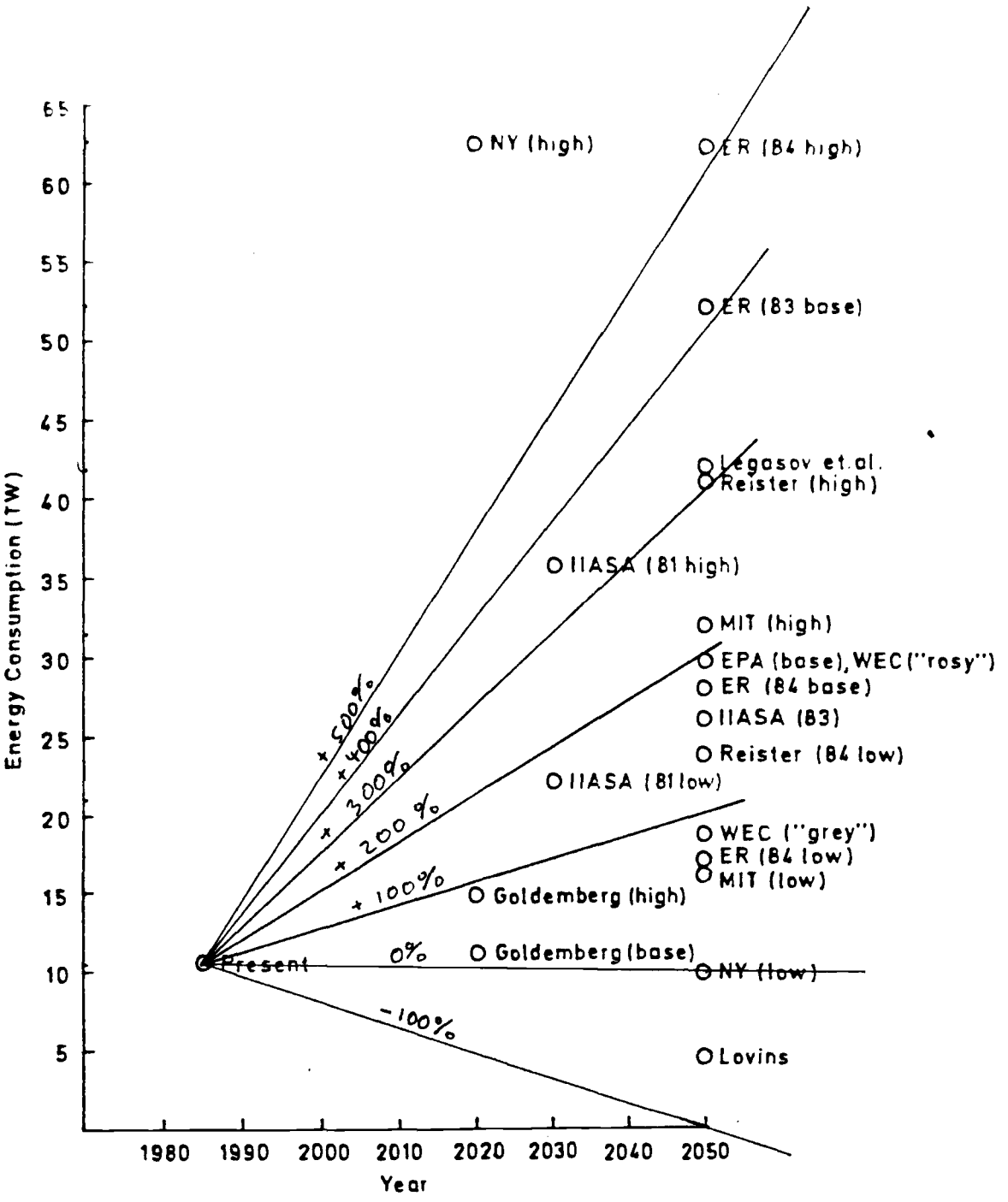
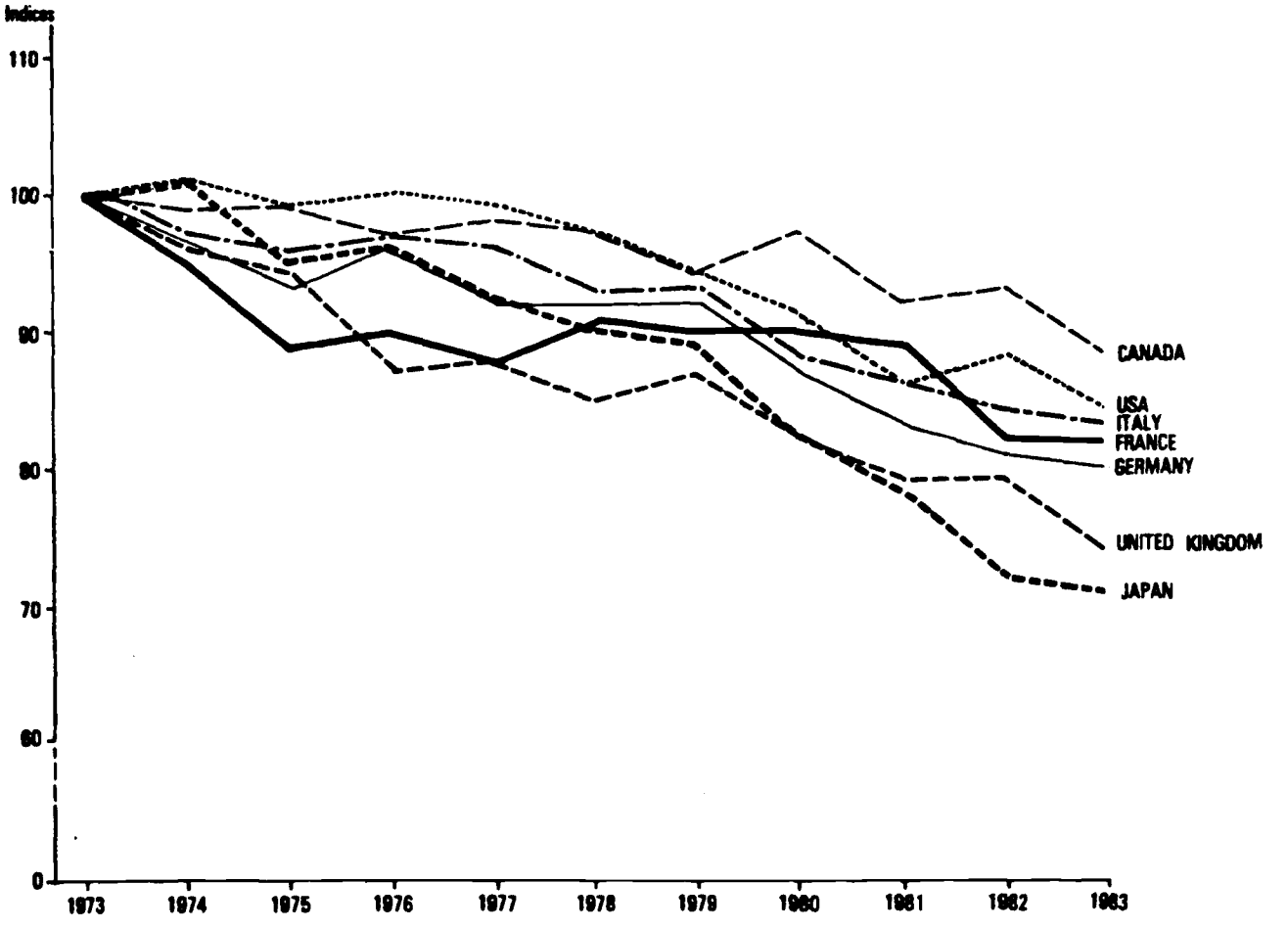



FIGURE 1: PROJECTIONS OF PRIMARY ENERGY CONSUMPTION IN THE FUTURE

The circles represent actual projections, while the lines show percentage variation from the 1985 (actual) level, in units of 100%.
Source: After Keepin-1985




*Note : Indices (base 100 in 1973) are calculated from values of ratio*

$$\frac{\text{Total Primary Energy Requirements}}{\text{Gross Domestic Product}}$$

*Source:* OECD - 1985

Figure 2: TOTAL ENERGY REQUIRED PER UNIT OF GROSS DOMESTIC PRODUCT (Source: OECD - 1985)

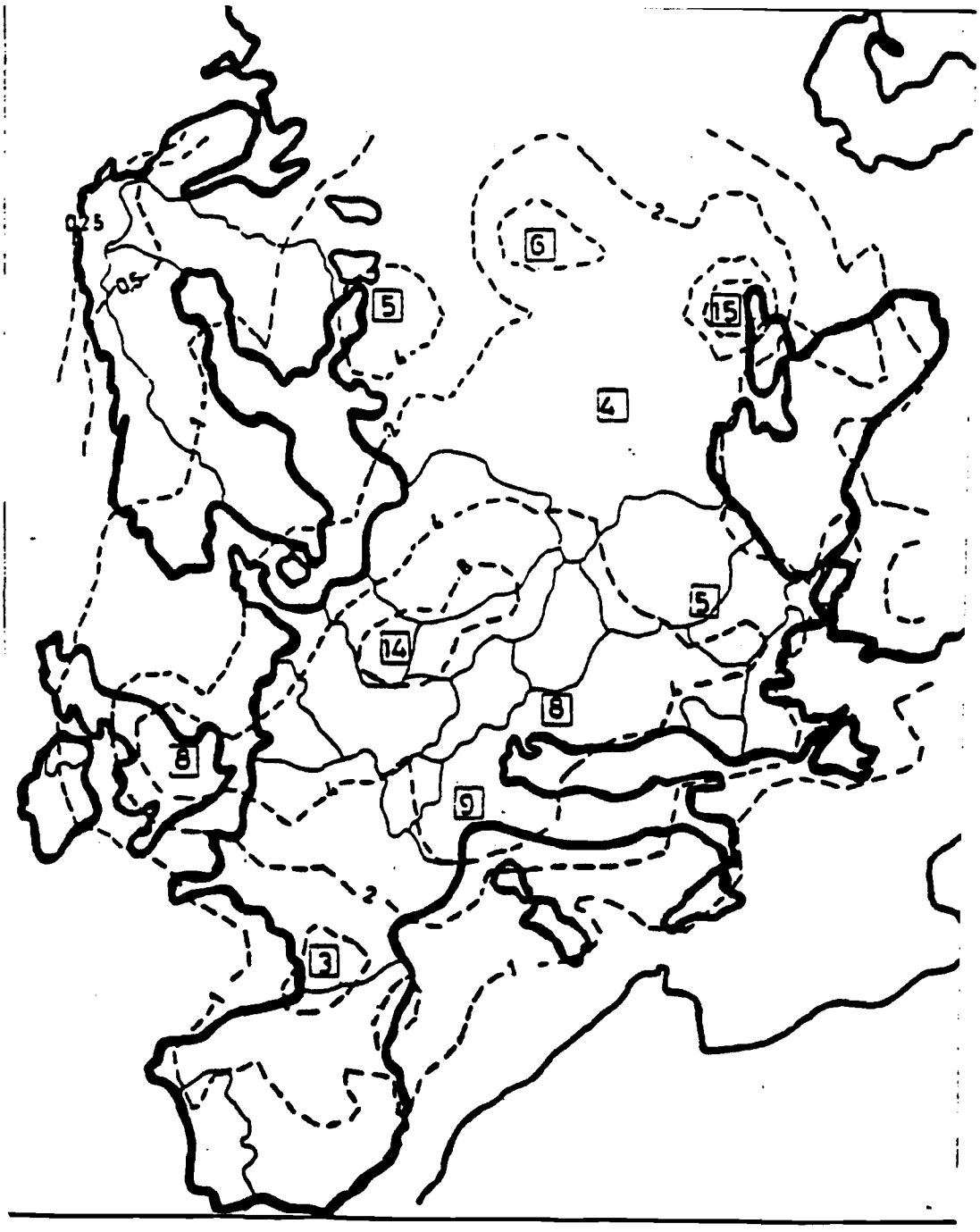
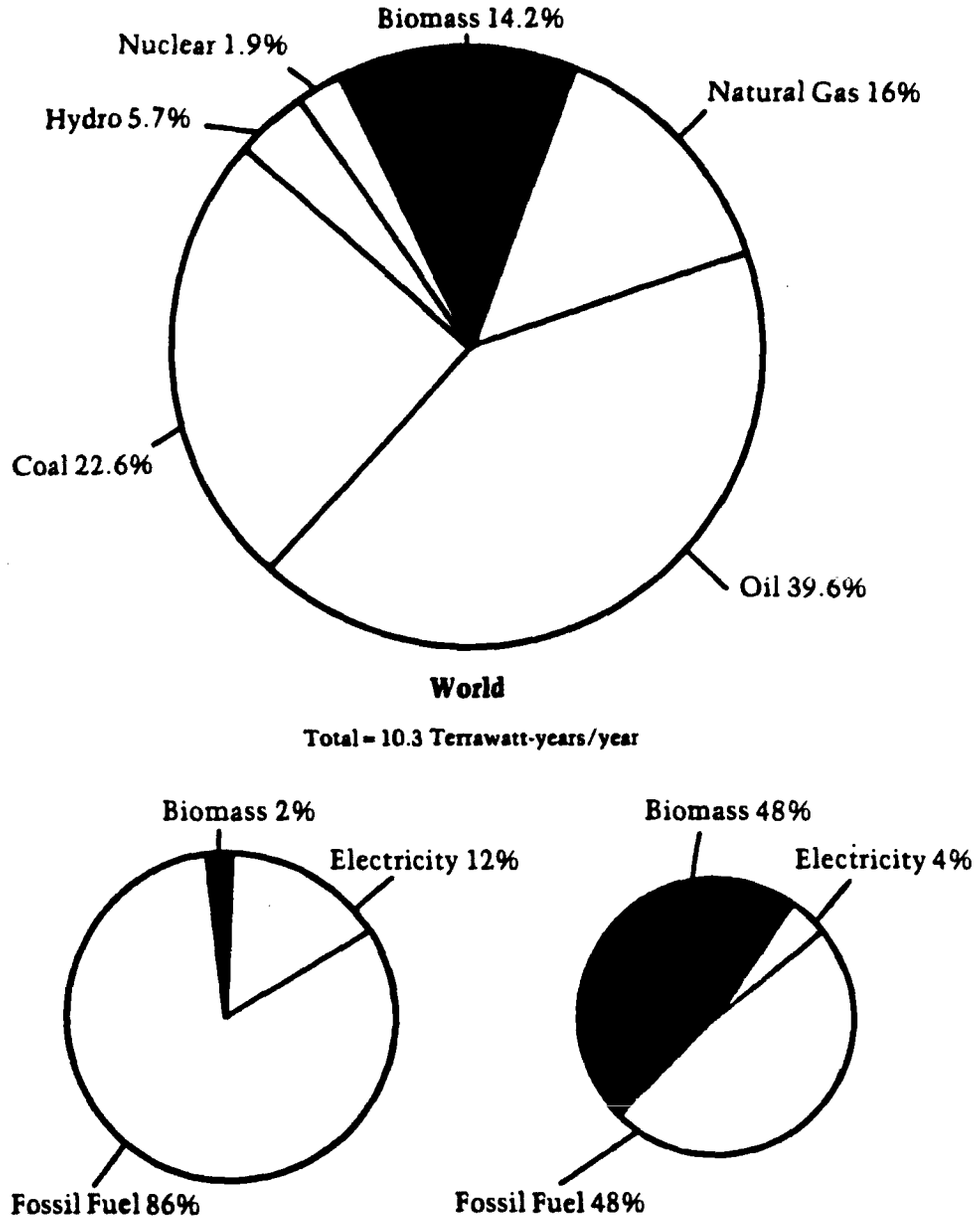



Figure 3: ACID DEPOSITION ON EUROPE (Isolines of Average Annual Total Deposition of Sulphur, expressed as grams of sulphur per square meter of ground per year, based on the period October 1978 - September 1982. Maxima are shown as boxed numbers. Source: adapted from EMEP/MSC-W Report 1/85)




*Source:* Robert Williams, "Potential Roles for Bioenergy," presentation at the WRI/RBF symposium; Goldemberg, Johansson, Reddy, and Williams, "End-Use Oriented Global Energy Strategy."

Figure 4: GLOBAL DISTRIBUTION OF PRIMARY ENERGY USE, 1980

(Source: Miller - 1986)

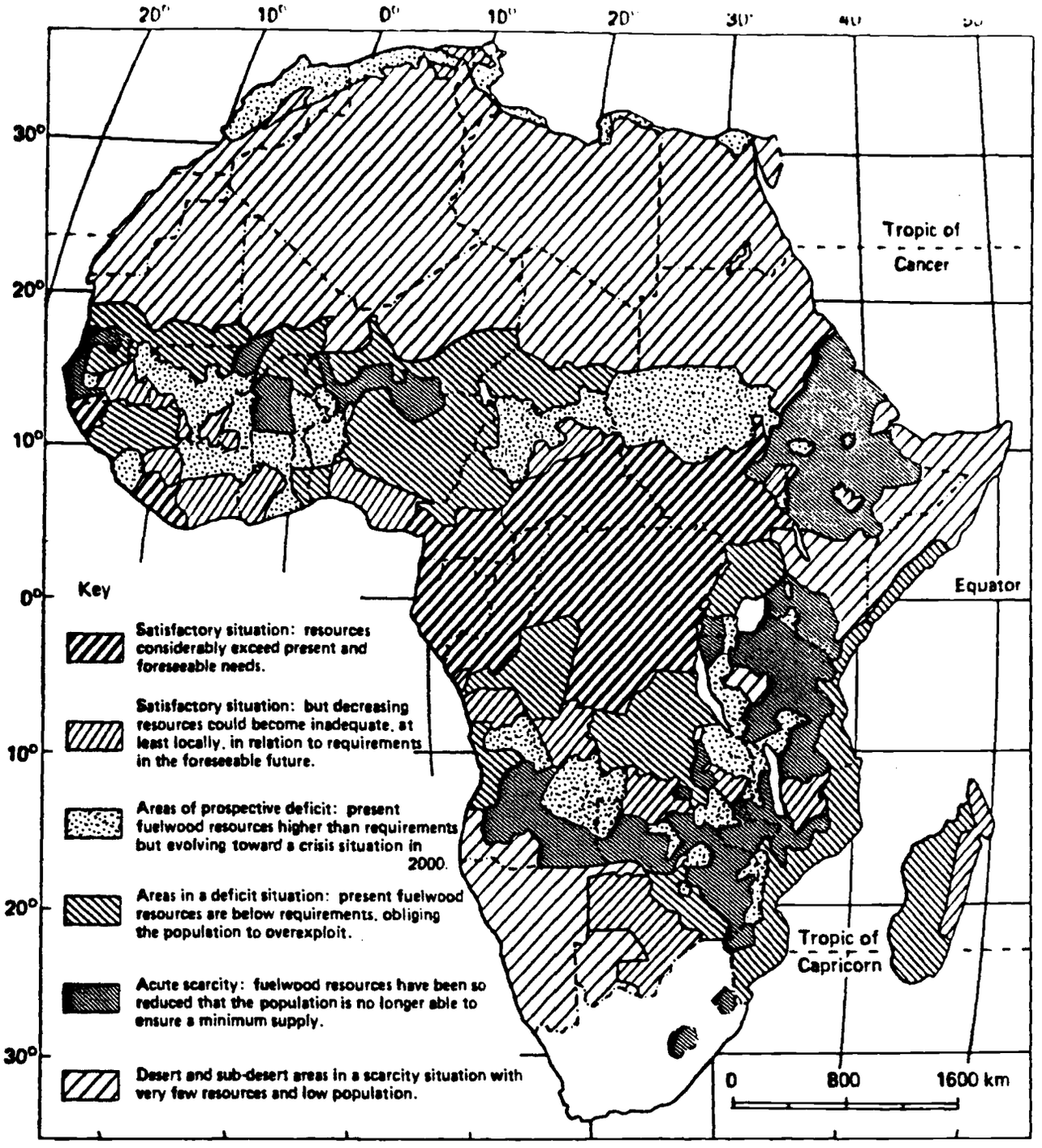



**Figure 5. Firewood availability in Africa, present and future.**

SOURCE: ENERGY POLICY, JUNE 1986

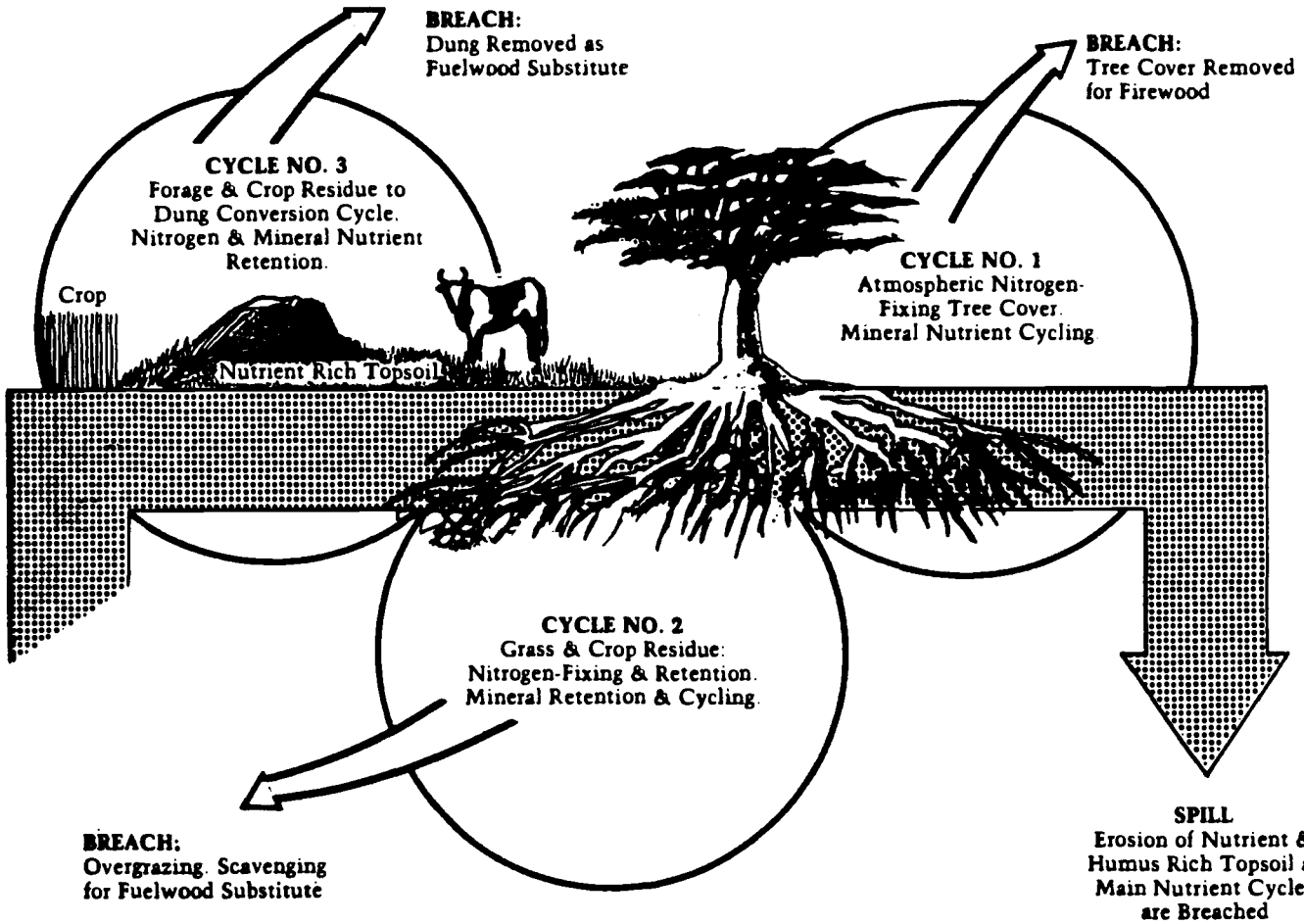



Figure 6.: PATTERN OF DETERIORATION IN ETHIOPIAN AGROECOSYSTEMS (Source: Miller - 1986)