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# ENERGY

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CHAPTER 7

# ENERGY: THE POWER TO DEVELOP

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## ENERGY: THE POWER TO DEVELOP

### I. ENERGY CHOICES FOR SURVIVAL AND DEVELOPMENT

1. The provision of energy is not automatically an end in itself; it is important only if it can supply "essential services" for society as cost-effectively as possible and with minimal risks to human health and the environment. Energy services such as those for keeping warm, or cool, cooking food, providing artificial lighting as well as powering the working-services for industry, agriculture and transport, all depend on the right forms and amounts of energy being available at the right places and times to run the appropriate, service-delivering, end-use equipment - stoves, furnaces, lamps, generators, motors and engines. If these essential energy services are inadequately delivered or if energy is seriously wasted in their production, future development and even the day-to-day survival of human societies may be jeopardized. Various complex technical, economic and institutional systems and arrangements are needed: (a) to provide the right forms of primary energy supply; (b) to produce suitable efficient end-use equipment and (c) to connect the supply unwastefully to the end-use appliances so as to deliver the services most productively when and where they are needed. All these systems and arrangements have become finely tuned to suit societal demands. But they will continue to evolve as

societies world-wide update their requirements for energy services and gear them to the new opportunities and constraints of exploiting the primary energy supplies available and of producing new end-use equipment. Thus, when dealing with energy issues it is not enough to think only in terms of fuels and other energy sources. It is also essential to pay careful attention to the role and suitability of end-use appliances and in particular to the efficiency with which they perform their function of delivering the energy-services demanded from them as productively as possible.

2. Thus, although the vitally important energy productivity linkages between primary source supply and efficient energy-services provision are often neglected, a point that will be developed later, there is still a major questionmark over the basic adequacy of primary energy sources for future development. Clearly, some of today's primary sources of energy are not everlasting. They are non-renewable and effectively finite (unsustainable). Fossil fuels such as natural gas, oil, coal, and peat or conventional nuclear power come into this category. By contrast, there are sources which are either renewable or extremely large and effectively infinite (Table 7-1).[1/, 6/] Geothermal sources (tidal energy), direct solar energy (trapped by photovoltaic cells, flat-plate and other thermal collectors), or indirect solar energy are in this category. Examples of indirect solar energy are wind, waves, falling water, ocean-thermal gradients and woody plant material or animal dung (biomass) as well as human and animal muscle-power. In future, nuclear breeder- and fusion-reactors will also be considered for adoption. In theory at least, all of these sources can contribute to the future energy mix worldwide. They each have their own economic, health and environmental costs and benefits. But perhaps it is axiomatic that wherever

TABLE 7-1

Global Primary Energy Sources:

Present Supply and Future Potential

| SOURCE | | Present (1984)[a/] TWyrs/yr [g/] | Present (1984)[a/] Per Cent | Future Potential[b/] Reserves TW years | Future Potential[b/] Resources TW years |
|---|---|---|---|---|---|
| (Finite) | | | | | |
| Gas | DC[e/] | 0.2 | 2 | 76 | 333 |
| | IC[e/] | 1.8 | 15 | | |
| Tar Sands & Oil Shale | | 0.0 | 0 | 99 | -- |
| Oil | DC | 0.9 | 7 | 125 | 365 |
| | IC | 3.1 | 25 | | |
| Coal | DC | 1.0 | 8 | 591 | 9405 |
| | IC | 2.3 | 18 | | |
| (Effectively Infinite) | | | | | |
| Geothermal | | +[f/] | (<0.1) | Very large *if* "hot rock" used | |
| Wind | | + | (<0.1) | 1.2 TW (continuous)[d/] | |
| Hydropower | DC | 0.2 | 2 | 2.2 TW (continuous)[c/] | |
| | IC | 0.5 | 4 | | |
| Biomass | DC | 1.8 | 15 | 4.6 TW (continuous)[d/] | |
| | IC | + | (<0.4) | | |
| Solar (Photo-voltaic etc) | | + | ( 0.1) | Extremely large | |
| Nuclear Fission | DC | + | (<0.3) | Unlimited *if* "Breeders" used | |
| | IC | 0.3 | 3 | | |
| Nuclear Fusion | | 0 | 0 | Unlimited *if* developed | |
| TOTAL | | 12.1 | 100 | | |

Table 7-1
continued

Notes: a/ Based on BP Statistical Review, 1985[1] except figures for Biomass which have been extrapolated from [16]; b/ Based on IIASA, 1981[2]; c/ Based on WEC, 1983[3]; d/ Based on Rose *et al*., 1983[4] and 1984[5]; e/ DC = developing countries, IC = industrialized countries; f/,+= < 0.05TW; g/1TW= 1000 000 000 ($10^9$) Kilowatts; 1TW emitted continuously for 1 year (1TWyr) is approximately equivalent to the quantity of energy liberated by burning 1 billion ($10^9$) tonnes of coal; 1TWyr/yr is equivalent to burning 1 billion tonnes of coal annually.

Source: Adapted from Keepin *et al* 1985[6] feasible, societies will tend to develop their long-term dependence on those primary energy sources which they perceive as: most economic and readily available; safe; environmentally benign and in particular sustainable (and most efficiently converted into energy-services).

3. It is not possible to formulate one uniform set of criteria for this selection process because every society will wish to choose in accordance with its prevailing socio-economic, political and cultural background as well as its locally available primary energy sources. It is, however, very important that all the basic factors conditioning economic costs, health- and environment-safety, availability, sustainability, and efficiency are made clear so that the ultimate choice of energy mix is made under conditions of minimal uncertainty. There is no time to be lost in doing this because the patterns of primary energy supply and consumption today, and the ways they are changing, are already influencing those which will prevail to the year 2000 and beyond. The same is true, of course, of current patterns of population growth, urbanization, industrialization, agriculture and transport. But growth in all these latter factors which normally accompany development directly places such an additional burden on the demand for energy services that it is fairly natural to expect developmental problems to show up early in the energy sector. These usually take the form of harmful effects on the quality of life and the environment, caused by shortages of primary energy, especially in developing countries. Undesirable or harmful effects on health and/or the environment - via pollution - may also arise from the intensive use of energy, especially in cities and industrial regions. These two problem areas connected with too little or too much energy are particularly aggravated if, as at present, primary energy is inefficiently or wastefully used to provide the energy services needed.

4. But these two questions related to primary supply have much deeper ramifications than this. They are interactively connected to a whole set of fundamental issues, dealt with at length throughout this report, each having its "energy dimension" as touched on in the ensuing treatment in this Chapter:

* poverty;
* the global (debt-related) economic crisis;
* periodic food scarcity;
* woodland loss, soil degradation and drying; water shortages;
* rapid population growth and urbanization;
* landlessness, human refugees and population migrations;
* proliferation of nuclear weapons and nuclear war;
* pollution causing health and environmental damage;
* global climatic change.

The first six affect developing countries particularly seriously, but all of them prejudice social equity, endanger basic human rights, threaten socio-economic and environmental sustainability, aggravate "North versus South" polarization, and destabilize peace and security worldwide. It is, therefore, not enough to supply environmentally benign, low health-impact energy systems in amounts adequate to provide energy services for development. All this must be done in a manner that as far as possible contributes minimally to the above global problems. We believe that this challenge, although very difficult, is by no means impossible.

## II. ENERGY IMPACTS ON THE GLOBAL ECONOMY AND ENVIRONMENT

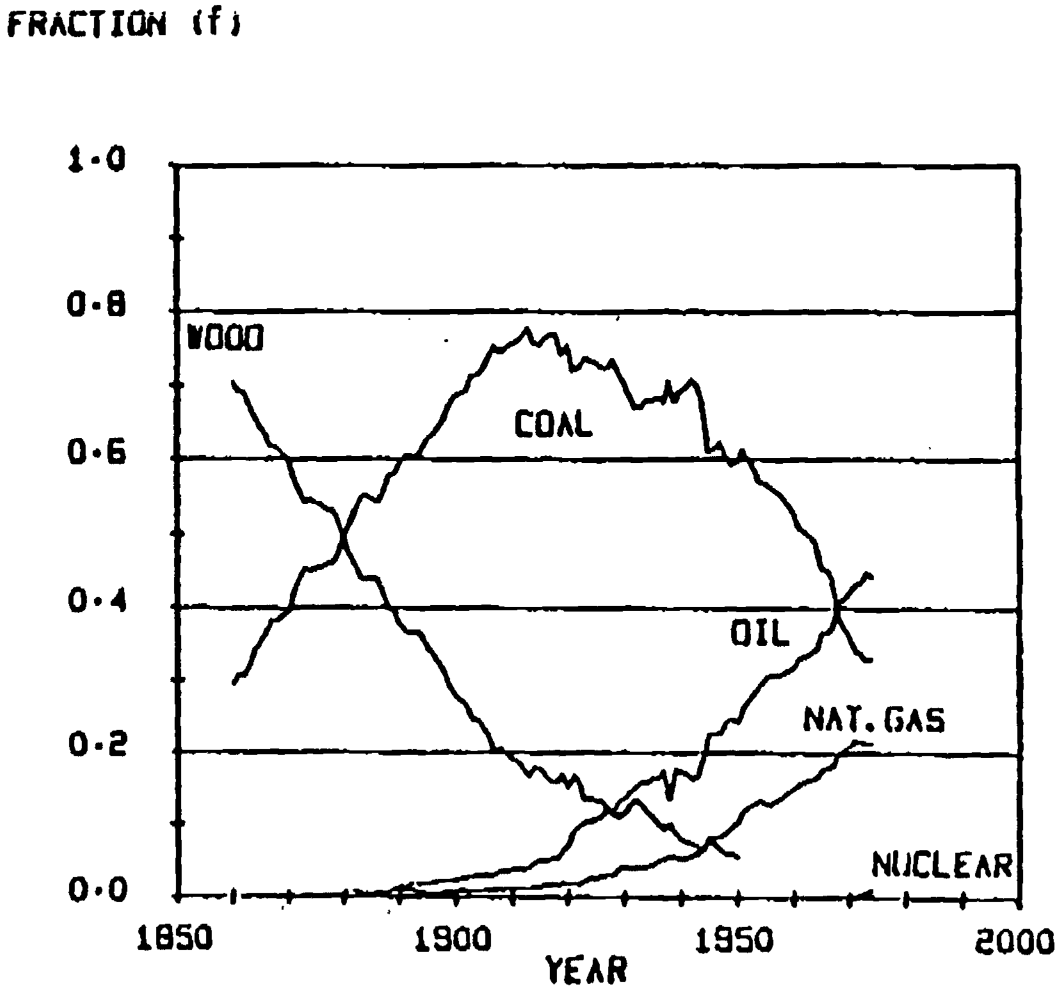
### 1. Energy and the Economy

#### 1.1 Supply Sources

5. Ever since antiquity, the original energy supply sources for cooking, space-heating and even lighting were the old, traditional fuels: wood, leafy shoots, charcoal and the dried dung of grazing animals (biomass sources). These slowly became partially commercialized and were only superseded in the relative quantities being used when coal became dominant in the mid-19th Century. But biomass is still the prevailing domestic fuel for most people, being burned mainly non-commercially, even today by about half the world's population for cooking and warmth. Figure 7-1 [2/] shows this historical substitution of commercially traded wood by coal, followed in the second half of the 20th Century by oil and natural gas as these two latter fuels dominated the rapid expansion of the market. Nuclear energy can also be seen starting at this time. This selective process of market shares moving in favour of more convenient and energy richer fuels as the demand expanded was also accompanied by a tendency to increasing centralization of supply. Figure 7-1 also shows that the time period for primary energy sources to grow to a large market fraction seems to be circa. 50 years, with a corresponding 50 years decline. This has led many to wonder whether the market share of oil will be replaced by some other fuel by around the year 2020 and if so, what? This speculation presumes an energy market which continues to grow - perhaps not a good assumption under present-day conditions in industrialized countries. A more important question regarding oil is raised by Table 7-1 which suggests that at present rates of consumption, the ultimately recoverable reserves and resources may run out

FIGURE 7-1

Global Commercial Primary Energy
Consumption as a Fraction of Market Shares




Source: Häfele (1981) [1/]

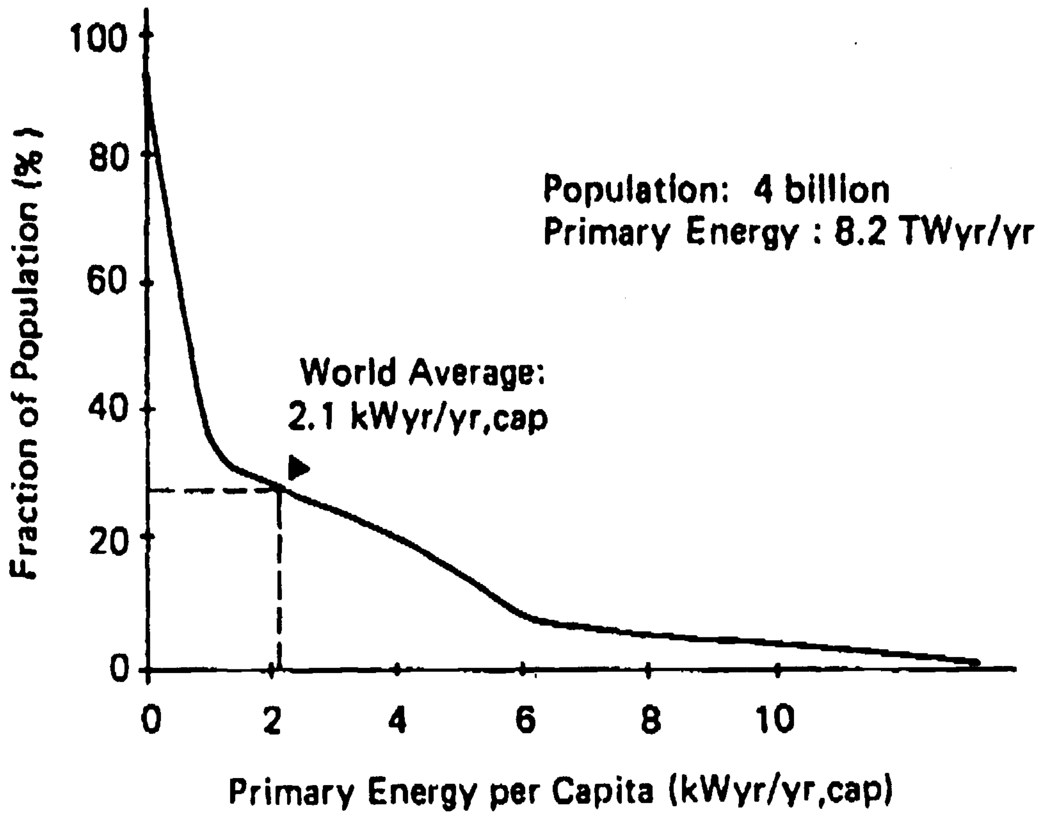
in about 100 years from now. This widely held belief, together with the present-day political and economic tensions worldwide caused by heavy dependence on Middle-East supplies, indicates that great care is needed when planning the role of oil in energy futures.

6. The fossil fuels shown in Figure 7-1 were successively added to the supply menu, largely in response to increasing wood shortages and to the rising demand for more concentrated energy to satisfy the greatly intensified consumption of the spreading industrialization, urbanization and later on, societal affluence. Non-industrialized countries still exhibited very low demand patterns. This has led today to the extremely uneven distribution of primary energy consumption worldwide, as shown by Figure 7-2[2/] where in 1975 about 5 per cent of the world's population consumed 8KW years/year or more and as much as 60 per cent used 2KW year/year or less. (1KW is one kilowatt - a thousand watts of energy, which if emitted continuously for a year is 1KW year. Consuming 1KW year/year is equivalent to the energy liberated by burning 1050 kilogrammes - approximately 1 tonne - of coal annually). This situation is not much different today, as indicated by Table 7-2[8/] which shows that average consumption per head in the "Northern" industrialized countries is circa x80 greater than in Sub-Saharan Africa. Half the global population averages 2KW. Thus about a quarter of the population worldwide consumes three quarters of the primary energy.

7. What do these per capita consumption figures tell us about future global demand? If per capita use remained at the same levels as today, by 2025, a global population projected at 8.2 billion [8/] would need 13.79TW years/year (4.47TW in developing and 9.33TW in industrialized countries). (1TW - Terawatt - is a

FIGURE 7-2

Global Commerical Primary Energy Consumption
per capita in 1975




Source: Häfele (1981) 2/

TABLE 7-2

Global Primary Energy Consumption
per Capita in 1984

| World Bank GNP Economy Category | Total Population in mid-1984 (millions) | Energy Consumption (KW per capita) | GNP per US$ 1984 |
|---|---|---|---|
| 1. Low Income | 260 | 0.414 | 2389.5 |
| (Sub-Saharan Africa) | ( 210) | ( 0.08) | ( 257.7) a/ |
| 2. Middle Income | 1250 | 1.068 | 1187.6 |
| (Lower-middle) | ( 740) | ( 0.572) | ( 691.1) |
| (Upper-middle) | (1950) | ( 1.756) | ( 496.6) |
| (Sub-Saharan Africa) | ( 680) | ( 0.252) | ( 148.4) |
| 3. High Income Oil Exporters | 11250 | 5.166 | 18.6 |
| 4. Industrial Market Economies | 11430 | 7.013 | 733.4 |
| 5. East European Non-Market Economies | - | 6.269 | 389.3 |
| Total (World) | - | 2.11 b/ | 4718.4 |

Notes a/ Figures in parentheses are sub-sets of main category.
b/ Population-weighted average Energy Consumption (KW/Capita)

1-3 = 0.655; 4+5= 6.76; World = 2.11

Source: World Development Report 1986[8/]

billion kilowatts and 1TW year/year is equivalent to the energy liberated by consuming circa 1 billion tonnes of coal annually). If, however, energy consumption per head was uniform worldwide at the level currently used in industrialized countries (6.75KW year/year), by 2025 the global population would require 55.4TW (years/year). If the average energy consumption for the "Low Income" and "Middle Income" economies trebled and doubled respectively, with the "High Income Oil Exporters" and the high consumption "Northern" industrialized countries (Categories 3, 4 and 5 in Table 7-1) remaining the same as today - a very much more modest assumption - the energy needs of the "Low-" and "Middle-" income categories would be 10.5TW and the three "High" categories would sum to 9.3TW, totalling 19.8TW globally. These "low" and "high" figures give a rough idea of the range within which energy futures might move, while the "intermediate" figure indicates what might happen to global consumption if energy supply was improved in developing countries. All pre-suppose that primary energy is used at the same levels of efficiency as today. Is there any evidence that any of these three hypothetical situations could be realizable in practice? There have been many detailed analytical studies of global energy futures up to the year 2030. These have been carried out to obtain a clearer understanding of how all the various factors conditioning changes in energy supply and demand might function and interact. They have also been used to clarify at what demand levels the various energy resources themselves, their economic costs or their environmental impacts might start to limit supply potential. Thus, they have not in any sense tried to predict or forecast energy futures, but rather, to clarify the relative influences which the various assumptions being made can exert on the outcome. They also attempt to explore how far a chosen scenario would be technically feasible at least, and thus try to demonstrate some form of "existence proof" of its possibility of happening in theory.

8. The six scenarios selected in Table 7-3 [2/, 7/, 9/ 12/] have been taken from a larger number of detailed studies which have been carried out by different energy analysts at various times in the last few years. They have been analysed comparatively by Goldemberg et al (1985)[7/] and by Keepin et al[6/]. They are compared in Table 7-3 with the energy situation in the world in 1980 as the "reference year".[7/] Although the world's total primary energy use in 1980 was 10.3TW (years/year), the scenarios A-F shown in Table 7-3 range from 5.2TW by 2030 (A), to 35.2TW by 2030 (F). The remaining scenarios shown (B-E), are intermediate in consumption and are sometimes constructed for the year 2020 or 2025. In all scenarios, population growth, projected for both developing and industrialized countries were used to allow for increasing demand. They are all very instructive in that, as will be seen in the ensuing sections, D, E, and F all have extremely important technical, economic or environmental constraints seriously limiting their realization. Moreover, A, B, and C can only be effectively realized if the current linkages between primary energy supplies and the delivery of energy services are steadily discarded and replaced by a radically new and productive, energy-efficient approach to providing energy services. The highest global consumption shown here is F. It is indicative of the direction in which energy consumption and supply patterns are heading if existing policies and institutions remain

TABLE 7-3
A Comparison of Selected Global Energy Studies

| | | 1980[7/] | A[9/] | B[7/] | C[10/] | D[11/] | E[12/] | F[2/] |
|---|---|---|---|---|---|---|---|---|
| | GDP Growth per capita | – | 1.1 | 3.0 ca | 1.2 | 1.6 | 2.0 | 2.1 |
| Total Primary Energy Consumption | World | 10.3 | 5.2 | 11.2 | 14.4 | 18.8 | 24.7 | 35.2 |
| | Indust. Countries | 7.0 | 3.6 | 3.9 | 7.2 | 12.7 | 14.8 | 20.1 |
| | Developing Countries | 3.3 | 1.7 | 7.3 | 7.2 | 6.1 | 9.9 | 15.1 |
| Per capita Primary Energy Consumption (KWyrs/yr) | World | 2.3 | 0.65 | 1.61 | 1.81 | 2.55 | 3.2 | 4.41 |
| | Industr. Countries | 6.3 | 2.28 | 3.15 | 4.64 | 8.52 | 9.67 | 12.9 |
| | Developing Countries | 1.0 | 0.26 | 1.28 | 1.12 | 1.04 | 1.59 | 2.35 |
| | World Population (billions) | 4.43 | 7.98 | 6.95 | 7.98 | 7.36 | 7.72 | 7.98 |
| | Projection Year | – | 2030 | 2020 | 2030 | 2025 | 2020 | 2030 |

essentially unchanged. It is a normative trend scenario. It is the "High" scenario included in a carefully analysed study published in 1981 by the International Institute for Applied Systems Analysis[2/] and projects more than a tripling of global energy consumption over 1980 levels by 2020. This would necessitate an enormous increase in supply levels which the study demonstrates to be technically feasible in theory. Additionally, there would be at least a consequent tripling of potential environmental impacts.

9. The energy supply implications of a "high" energy future are alarming. By the year 2020, oil and natural gas would have to be produced at x1.5 and x2.9 the 1980 rates respectively, while coal production would need to increase by a factor of x4.0. With all the attendant increases in resource exploitation, cleaning and transport, these tasks are regarded by most as well beyond our logistical capacity during the present century. This increase in fossil fuel use implies a capacity equivalent to bringing a new Alaska Pipeline (2 million barrels of oil equivalent -mboe-day) into production every two to three years even if existing oil production is maintained. (It should be noted that the 1980 level of oil consumption carried through to 2020 would exhaust known reserves, and would require the discovery of 20 per cent more proven reserves than existed in 1985.[12/]) More than 6TW of nuclear capacity would also have to be installed by the year 2020, an increase of 3,000 per cent over 1983 levels!. This is equivalent to installing one new 1-GW(e) nuclear electricity generator every 2-3 days. In fact, the immense organizational effort needed globally to build this supply infrastructure means that in practical terms, this scenario is at the absolute limit, if not beyond present or expected technical capacities. Even so, the scenario's global level of 35.2TW annual consumption

falls well below the 55.4TW needed for an energy future which universally adopts per capita energy consumption levels currently needed in the "Northern" industrialized countries (see para 7 (?) above). Such a future is thus not even achievable, let alone sustainable, within the next 50 years.

10. This conclusion is confirmed by a World Bank Study [13/] which stressed the need for developing countries to reduce their external energy dependence by investing in indigenous energy resources. The study indicated that the production of local energy could rise from 1.7 billion tonnes of oil equivalent in 1980, to 3.1 by 1995.

11. This rate of increase (4.1 per cent annually over 15 years) is close to what would be needed for developing countries in scenario F (3.9 per cent annually over 40 years) to effect the growth of their aggregate energy supply by a factor of x4.6 by 2020. World Bank figures indicate that this 4.1 per cent growth could be achieved at an average annual investment of US$ (1982) 130 billion, or a doubling of the share of energy investment in aggregate GDP (2-3 per cent in the late 1970s) to circa 4 per cent. About half of this would have to come from foreign exchange requirements, as compared with the US (1983) 25 billion used to finance energy investment in 1982. This would require a 15 per cent increase in real terms of foreign exchange allocations to energy supply expansion over the ensuing decade, which in turn would mean a major shift in the level of external funds flowing into the energy sector from all sources, private, public, equity and debt. This would also have to be accompanied by a vigorous mobilization of local resources via energy pricing policies.

12. The study estimated that this ambitious level of investment would remain advantageous if oil prices stayed about US$ (1983) 25 per barrel. But even so, the study further indicated that oil imports by the oil importing developing countries would most likely still need to increase by 1995 to almost one third more (circa 400 million tonnes oil annually). Commenting on the results of this study in the context of the overall difficulties of improving energy services by building greatly increased supply capacity, Goldemberg et al[7/] stated "The staggering costs of providing these energy services would lead many to believe (but rarely to state) that it is not feasible to improve living standards substantially in developing countries."...by large supply expansion efforts.

## 1.2 Oil Prices in the 1970s and 1980s

13. In developing countries, the close linkage between the viability of investing in the production of indigenous energy supplies and the fate of future oil prices makes the decision to go ahead with local energy development particularly difficult, even if done at much more modest levels than outlined in paragraphs 9 and 10 above. This is because of the extreme uncertainty of oil prices since 1973. The foreign exchange content of the investment varies, depending on the type of source being exploited and also on the maturity of the local capital goods industries - oil and gas development are particularly consumptive of foreign exchange. But all local energy investment comes into direct competition with the external currency earnings needed to pay for other imported energy (Table 7-4). This is only one reason why oil market volatility has a destabilizing effect on decisive energy policy making. Many other energy developments worldwide that made sense with oil above $25 per barrel, suddenly made no sense at all with

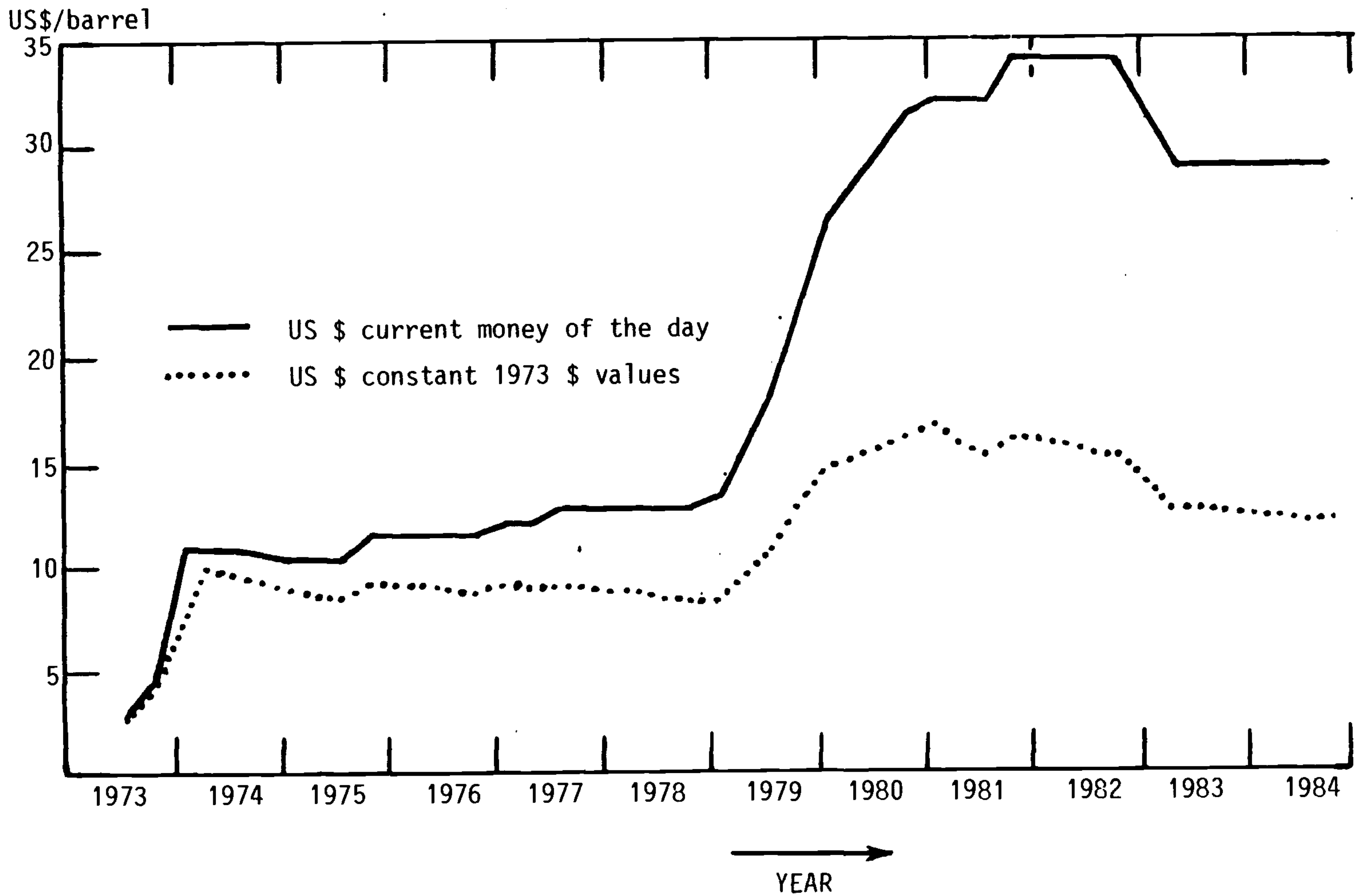
TABLE 7-4
Energy Imports as a Percentage of Merchandise Exports, 1984

| Per cent | Per cent | Per cent | | | |
|---|---|---|---|---|---|
| Over 100 | Panama | 30-39 | Brazil | 10-19 | Austria |
| | | | Czechoslovakia | | Colombia |
| 90-99 | - | | Italy | | Cote D'Ivoire |
| | | | Japan | | Denmark |
| 80-89 | Burkina Faso | | Madagascar | | Egypt |
| | | | Singapore | | Germany |
| 70-79 | Dominican Rep. | | Sri Lanka | | Ireland |
| | Jordon | | Thailand | | Liberia |
| | | | Yugoslavia | | Malaysia |
| 60-69 | Sierra Leone | | | | New Zealand |
| | | 20-29 | Bangladesh | | Sweden |
| 50-59 | Benin | | Belgium | | Switzerland |
| | El Salvador | | Costa Rica | | Tunisia |
| | Greece | | Finland | | U.K. |
| | India | | France | | |
| | Jamaica | | Honduras | 0-9 | Algeria |
| | Kenya | | Hungary | | Argentina |
| | Pakistan | | Indonesia | | Australia |
| | Turkey | | Israel | | Cameroon |
| | | | Korea | | Canada |
| 40-49 | Ethiopia | | Mauritius | | China |
| | | | Netherlands | | Ecuador |
| | | | Papua New Guinea | | Hongkong |
| | | | Poland | | Mexico |
| | | | United States | | Nigeria |
| | | | Uruguay | | Norway |
| | | | | | Oman |
| | | | | | Peru |
| | | | | | Trinidad/Tobego |
| | | | | | United Arab Emirates |
| | | | | | Zambia |

Source: World Bank 1986 "World Development Report 1986" oil at around \$10-\$20 per barrel. New ventures in renewables, conservation and energy services have been delayed or maybe lost altogether. 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 retarded or placed in jeopardy. In short, it would seem that the supply and pricing of oil is crucial in planning the type of energy supply future to be desired and in determining how fast it can be achieved.

14. The fivefold increase in world oil prices initiated by OPEC during 1973 (Figure 7-3) raised the market price of one year's oil output from 0.5 per cent to 2.5 per cent of gross world product. It led to very large monetary transfers away from the oil consumers, especially in the industrialized countries, and over to the oil producers. This created serious economic dislocations, aggravating stagflation in many oil importing countries worldwide, a number of which were already exhibiting recessionary tendencies. There was much anxiety over whether the international economic system could contain the extra liquidity generated or even function adequately. This generated a considerable interest in importers in the idea of a producer - consumer dialogue to see if any ways could be found of avoiding sudden, rapid oscillations in the supply and pricing of oil by some form of mutually agreeable regulatory mechanism. This interest, strong at first, led to a number of international meetings, but gradually died away inconclusively by the later 1970s as it was realized by consumers that the international monetary system was resilient enough to absorb the shock. This also satisfied producers who felt they had control over supply and pricing in the foreseeable future. Oil prices rose again, effectively doubling during 1978-80 following the Iran-Iraq war. Tough financial policies by the

FIGURE 7-3
Oil Prices (Arabian Light Crude) 1973-84 (Quarterly Averages)




Source: Redrawn from BP Statistical Review, 1985.[1]

industrialized countries largely contained the problem for them. The oil importing developing countries, however, were hit hard, especially after the 1980-82 period, when commodity prices fell by 20-30 per cent. Their indebtedness became chronic and for many debt-service costs and repayment problems have endangered their economies since that time and caused anxiety among lenders in industrialized countries.

15. Prices, although very erratic, began to drift downwards again in 1982 and the third oil shock began when prices collapsed in early 1986, falling to around US$ 10 per barrel in early April, followed by a period of considerable market volatility. This has meant that in terms of constant US dollars, oil fell back to around pre-1979 price levels, which has had the completely opposite effect. It has led to economic dislocation among even the best-placed exporters and has stalled development particularly severely among those producers whose economies are heavily dependent on oil export revenues. Additionally, further lender anxiety developed when the poorer oil exporters now faced difficulties in repaying the large loans made to them when their oil revenues were high. Most consumers have seen this fall as a welcome relief, particularly the developing countries who benefitted from lowered import bills and debt burdens. But cheap oil is not an unmixed blessing. During the oil boom, many Middle- and Far-Eastern countries supplied the Gulf States with skilled and unskilled workers and as a consequence their economies greatly benefitted from wages remitted home. Much of this migrant labour has now returned back home. Egypt, itself an oil producer, has had 500 000 workers return home jobless from the Gulf. Jordan, Syria, Tunisia, Morocco, and Turkey have all gained from lower oil prices. It is doubtful whether these gains have outweighed the loss from the now failing employment and

commercial links which had grown up between these countries and the Gulf. Many Islamic countries have also received aid in the form of oil at concessionary prices. All this disturbance has reduced stability in the Middle Eastern region - a longer term factor which must be set against the short term price gains.

16. The U.S.S.R. received about 70 per cent of its foreign exchange from oil exports, now jeopardized by lower prices. Transient nuclear electricity shortfalls there may need to be made good from oil-powered generators. These factors may affect Soviet international oil policies.[14/] Considering the U.S.A. government's involvement in oil and gas leases and taxes, it is expected that the U.S. Treasury will have lost US $ 30 billions in 1986 (about half the loss expected by OPEC) [15/] Another factor of importance is the slower rate of drilling and exploration under the softer market conditions. By early 1987 it is estimated that the U.S.A. will be losing circa 1 million barrels daily in higher-cost oil production, and it is expected that there will be a further 1 million barrels per day lost worldwide if prices remain below US$ 17/barrel. Overall, it appears that by early 1989, world demand for imported oil may rise by 2 - 2.5 million barrels daily[15/]. This will solve the current problem of OPEC in allocating future market shares to its members. Once these national production quotas are satisfactorily resolved, the scene is again set for decisive production control and another round of price rises. This, once again would inevitably lead to a period of global economic readjustment which will often be difficult and painful for many importing countries.

17. But perhaps the greatest longer term loss to producers and consumer alike is caused not so much by the low or even the high price of oil, but by the

unpredictable volatility of price fluctuations. It is this factor which plays an important part in constraining clear-cut policy development towards a more sustainable energy future. The catalytic effects which higher oil prices have had in stimulating further often successful oil exploration are in the longer term less important than their dramatic effect on promoting widespread interest in energy efficiency, energy services, and research and development into alternative and renewable energy sources, thus easing the transition to a more safe and sustainable energy supply beyond this century. This latter development needs a long-term uninterrupted effort to succeed a situation economically impossible to maintain under the present disorientating swings of a vacillating oil market. At the present time, oil producers, not unnaturally, want to obtain the best price they can for their product on world markets. Likewise, importers try to stabilize supplies to their own advantage, either by more a less large domestic taxes (or even in many cases, by subsidies) on oil products. Import tariffs or bilateral concessionary pricing arrangements with oil producers are sometimes used. This latter arrangement is a consumer - producer agreement between interested parties in a restricted form. All these strategies are in one sense de facto illustrations of some form of "conservation pricing", where the policy adopted is judged to be in the best short-term interests of the producer or consumer government.

18. What is needed for the future is an attempt worldwide to lengthen the time horizons over which costs are weighed against benefits. This does not mean that any of the four mechanisms outlined above should not continue to operate:

* concerted producer pricing policies;
* national taxes on domestic oil products;

* import tariffs;
* import subsidies and other consumer - producer arrangements.

19. It does mean, however, that they should become more widespread and operate more stably throughout longer time horizons, thus acting as buffers, bringing greater steadiness to the world oil market. All these features are to a greater or lesser extent an interference with the free market in oil and as such are regarded as counter-productive by proponents of the "free-market" philosophy. The last item - consumer-producer arrangements - if broadened into a continuing and generic consumer-producer dialogue outside the market place is particularly distrusted. But even the first item - producer pricing policies - is often regarded as monopolistic or at worst, simply crude price-fixing.

20. But a glance at the trade in oil in the first half of this century seems to indicate that there has rarely been a genuinely free market. Following the declaration of the "open-door" policy by the U.S.A. in 1922, the oil market was chaotic until the large international oil companies brought stability to it under the "Achnacarry" agreement. The American Petroleum Institute performed the same service for national production and consumption in 1928-29 using similar market regulation principles. And again, following the collapse of prices in the Gulf after new finds in Texas in 1933, the "Interstate Oil and Gas Compact Commission", the "Connally Act" and the "Texas Railroad Commission" all played an important regulatory and stabilizing role. In fact, it is generally agreed that crude oil prices would have fluctuated far more violently during 1935-1970 had not output been regulated by these and similar institutional mechanisms.[15/] The role of OPEC must also be acknowledged when, during the 1970s and early 1980s, it

kept prices much lower than they would otherwise have been by producing oil beyond the economic needs of its members.[16/]

21. Formal consumer - producer discussions would be much more difficult to arrange today because of powerfully held differences in production and pricing philosophy between OPEC and non-OPEC states. They would also run into anti-trust and other legislative difficulties which would require intervention at the highest levels to clear the way forward. But oil will continue to play a crucial role not only as a fuel in its own right but as a dominant factor controlling any transition to a new energy future. If any progress is to be made towards such an energy transition in the coming century, there will have to be wide-ranging discussion globally between producers and consumers to develop consensual thinking around the most effective deployment of producer pricing policies, as well as the most effective levels of implementing domestic taxation, import tariffs and other price management policies among consumer countries. No international forum currently exists for ventilating these issues. Such issues should include the feasibility of price "floor" and "ceilings" both at national and international levels between which: (a) economic stability for all countries is not jeopardized; (b) an appropriate level of new oil exploration remains feasible, particularly in developing countries, and (c) a strong start can be made and its momentum maintained to a future energy transition involving efficient energy utilization and the development of energy services as well as major programmes of research and development on renewable energy. Although action is difficult and risky, the costs of doing nothing are too high to let the unique opportunity presented by the global oil situation today pass by unheeded. Given the fact that oil is a finite

fuel, this "conservation pricing" strategy should lead to prudent and responsible oil consumption thus extending its future life as a crucial energy source.

## 2. Energy and the Environment

### 2.1 Present-day Environmental Impacts

22. Paragraphs 7-9 above drew attention to the technical and logistic problems of building a large primary supply capacity over the next 30-40 years and also touched upon associated capital investment problems in developing countries. Other, less ambitious primary supply scenarios may also have these problems, but in less acute forms. However, they may still pose environmental dangers and health risks which may well be sufficiently serious to prevent their implementation. Such health-environment drawbacks are also implicit in the large scenarios but are swamped by the major difficulties involved in mounting them. There is at present a scientific consensus worldwide that there now exists a "plausible and serious probability"[17/] of climate change, generated by the "greenhouse" effect of trace-gases emitted to the atmosphere. The most important of these trace-gases is carbon dioxide produced from the combustion of fossil fuels. Significant climate warming is now thought to be likely by the 2030's. It could subsequently disrupt ports and coastal cities by causing a rise in sea-levels. It may well influence rainfall, run-off and soil water-table regimes and even affect the geographical boundaries of forests, crops, and the species diversity of ecosystems, especially in mid-latitudes. Such impacts would place heavy pressures on national environmental security and may even unsettle regional political stability. Atmospheric pollutants from the combustion fossil fuels seem to be the cause of acidification of the environment in North America[18/]

and, particularly, in Europe. The largely unnoticed accumulation of damage by acidic and oxidizing substances from fossil fuel combustion has led to the widespread sterilization of lakes in Scandinavia[19/] and, to an impoverishment of forest soils in parts of Southern Sweden [20/]. Soil degeneration may also be an important contributory cause of the accelerating tree damage and death in some of Central Europe's forests and the consequent erosion, soil slippage and attendant flooding in steep-sided valleys there.

23. Nuclear energy poses problems that are not yet adequately solved. The risks of a reactor accident, although small, are not insignificant. A solution to the problem of how to dispose of nuclear waste safely has not yet been demonstrated. Neither has the safe method of dismantling reactors at the end of their service-lives. Above all, there still remains great concern over the proliferation of nuclear weapons secretly manufactured via the possession of civil nuclear reactors for electricity generation.

24. These risks to health and environment from the pollutant impacts of energy use are qualitatively different from the problem posed by woodfuels. The evidence that wood is being collected faster than it can regrow is coming in from many developing countries that still rely predominantly on biomass for cooking, space heating and even for lighting. FAO[21/, 22/] have published estimates suggesting that in 1980, circa 1300 million people lived in wood deficit areas and that if these population driven overharvesting trends continued, by the year 2000, circa 3 billion people will be living in areas where wood is "acutely scarce or has to be obtained elsewhere". This will lead to much more widespread hardship. Precise data on this problem are not available because a large part of the woodfuels

consumed is not commercially traded, but directly collected by the users, principally women and children. But there is no doubt that finding widely available substitute fuels present intractable problems. Although it is ultimately feasible to replace woodfuels by kerosene, liquid propane gas, coal or electricity in cities, where the economy is monetized, it is virtually impossible to supply these commercial fuels to remote country districts, particularly in Africa where in very many rural areas virtually little or no monetized economy exists. This "informal sector" fuel is used by as much as 70 per cent of the population in developing countries and may well account for circa 40 per cent of energy consumption in these countries. It is the "joker in the energy-planning pack" because its widespread failure will completely destroy all the energy planning arrangements and revolutionize the energy supply scene in many developing countries.

## 2.2 Future Environmental Impacts

25. Clearly, if future primary energy demand rises by the increased used of fossil fuels, nuclear energy or fuelwood, these problems may become dangerous enough to prohibit their further use unless radical measures are taken which are guaranteed to solve them. Will the various hypothetical figures for global primary energy supply automatically mean a large increase in some or all of these fuels? Under present day energy efficiency regimes, the current per capita amounts of primary energy would require a global total of 13.79TW by 2025. Therefore, any fall below 13-14TW by 2025, at present-day efficiencies, would mean a supply reduction. This would be completely unacceptable retrogression in terms of the energy services delivered. Scenario F has already been seriously questioned as a viable future prospect (para 9 above). This leaves three scenarios above this level in

Table 7-3: C at 14.4TW; D at 18.8TW and E at 24.7TW. Because scenario C involves a fundamental change in energy efficiency arrangements, it is not valid for discussion at this point. This leaves D and E as illustrative of the type of problem we are treating. Scenario D is close to, and E above the "intermediate" supply requirement of 19.8TW obtained by trebling and doubling "Low-" and "Middle-" income categories respectively whilst leaving high income categories unchanged (para 7 above).

26. The high level of dependence on increased fossil fuels and nuclear energy supplies over and above 1980 levels (see Table 7-5) in scenario E raises technical and engineering supply - delivery problems similar to those encountered with scenario F but in a somewhat less acute form. But it should be noted that the time horizon is 2020 - ten years shorter. Scenario D depends heavily on coal and hydropower with a tripling of nuclear energy. Whether a virtual quadrupling of coal requirements and the scaling up of hydropower by a factor of x5.5 is logistically and economically feasible by 2025 is doubtful but open to question. The high level of fossil fuel use has been estimated, by the original authors of the study, to bring forward a doubling of atmospheric carbon dioxide from circa 2080 (under present fossil fuel usage rates) by 30 years, to circa 2050. No state-of-the-art method exists for the removal of carbon dioxide from fossil fuel combustion gases. So this acceleration of the onset of potential global warming is an important problem which will inevitably be aggravated by other trace-gas pollutants such as chlorofluoro-carbons, methane, etc.. This is likely to mean that significantly problematic climate change could occur in the 2020s or 2030s under this scenario. Additionally, the high coal use will generate air-pollution problems from oxide of sulphur and nitrogen which will be only containable at a significant cost. If there are pollution problems from fossil fuel use which cast serious doubts on the wisdom

TABLE 7-5

A Comparison of Primary Supply Sources for Energy Studies Selected in Table 7-3

| | 1980[7/] | A[9/] | B[7/] | C[10/] | D[11/] | E[12/] | F[2/] |
|---|---|---|---|---|---|---|---|
| Total World Energy Supply TW | 10.3 | 5.2 | 11.2 | 14.4 | 18.8 | 24.7 | 35.2 |
| Oil (TW)<br>x1980 supply | (4.18)<br>x1.0 | –<br>– | x0.8 | x0.7 | x1.0 | x1.4 | x1.6 |
| Gas (TW)<br>x1980 supply | (1.74)<br>x1.0 | – | x1.9 | – | x2.1 | x2.6 | x3.4 |
| Coal (TW)<br>x1980 supply | (2.44)<br>x1.0 | – | x0.8 | x2.0 | x3.9 | x3.9 | x4.9 |
| Hydropower (TW)<br>x1980 supply | (0.19)<br>x1.0 | – | x2.4 | x4.0 | x5.5 | x3.7 | x2.7 |
| Nuclear (TW)<br>x1980 supply | (0.22)<br>x1.0 | – | x3.4 | x7.9 | x3.1 | x14.6 | x36.8 |
| Other (TW)<br>x1980 supply | (1.49)<br>x1.0 | – | x1.1 | x2.9 | x – | x 1.8 | x1.2 |
| Total (TW)<br>x1980 supply | (10.3)<br>x1.0 | – | x1.1 | x1.4 | x1.8 | x2.4 | x3.4 |
| Projection Year | – | 2030 | 2020 | 2030 | 2025 | 2020 | 2030 |

of implementing this scenario (D) the same strictures must apply even more to scenario E which relies to a much greater extent on fossil fuels.

27. The general conclusion seems to be that it will be very difficult if not impossible to increase global primary consumption much above 14-15TW years/years without encountering prohibitive health and/or environmental problems (the $CO_2$ problem being currently insoluble) or running into difficulties of engineering logistics or economic problems. This provisional conclusion needs closer examination. The following questions are raised:

1. Since circa 80 per cent of global primary energy currently comes from fossil fuels, an important question is: "For how long in the future can these sources be relied upon?"

2. If fossil fuel use appears to be associated with environmental and health problems from pollutant emissions following combustion: "Is there good evidence that significant problems already exist at present-day usage level?" If so, any increased rate of consumption will only aggravate this situation, maybe to unacceptable levels.

3. If the answer to question 1. above is that we can relay on them long-term and the answer to question 2. suggests a significant pollution problem, the next question is: "Can their pollution problems be contained at costs which make their future use worthwhile?"

4. If the answers to the three questions above raise uncertainty or doubts we need to ask: "What other, less troublesome sources of primary energy are available to us worldwide?" - compared with fossil fuels.

5. Maybe as much as 15 per cent of primary energy worldwide comes from biomass fuels, representing almost half the energy consumption in developing countries, with much of it "outside the market place". If it is collapsing as a source, and no substitute is at hand, this is a development disaster threatening the day-to-day stability of many nations. But where users have the monetary capacity to buy alternative fuels, this is a serious challenge as to how and where to find the extra fuels needed (see question 4 above) within the commercial system.

## III. FOSSIL FUELS

28. Table 7-1 suggests that oil is a finite resource, lasting no longer than towards the end of the next century at present usage rates. More pessimistic forecasts of the recoverable reserves and resources suggest that oil production will level off or even decline by the early decades of the next century. These estimates persuade many analysts to the view that the world should embark on an oil conservation policy, in order that it can be used sparingly, responsibly and thus, for as long as possible. Gas supplies, spanning about 200 years, and particularly coal appear to be much longer lasting. It is generally agreed, however, that in terms of pollution risks, gas is by far the cleanest fuel with oil next and coal coming a very poor third. But they all pose three closely interrelated atmospheric pollution problems: urban industrial air pollution

[23/, 24/, 25/, 26/]; acidification of the environment[27/, 28/, 29/, 30/] and the induction of climatic change.[17/, 31/, 32/] 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 7-4), do not.

## 1. Reducing Urban-Industrial Air Pollution

29. During the past three decades of rapid growth, urban air pollution potential has increased dramatically, more or less in pace with fossil fuel consumption. Beginning in the late 1960s, a growing awareness of the effects of polluted air on human health, property and the environment in urban and industrial areas resulted in the development of curative measures, including air-quality criteria, standards and add-on control technologies. Some imposed liability and required compensation for damage, especially to human health. This led, in time, to greatly reduced emissions of some of the principal pollutants and cleaner air over many cities. Several 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 serious levels in the cities of several industrialized countries and in those of most developing countries, often far exceeding the worst cases of the 1950s in industrialized countries.

30. The fossil-fuel emissions of principal concern include sulphur dioxide, nitrogen oxides, carbon monoxide, various volatile organic compounds (VOCs), fly ash and other suspended particulates. They are potentially injurious to human health, bringing increased respiratory complaints, some potentially fatal in segments of the population, specially sensitive to lung trouble. Transformed into acid in the air, they damage vegetation, corrode buildings, metallic structures and vehicles, causing billions of US dollars in damage annually, and 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. What few studies are available, however, demonstrate that they are very large, and suggest that they are growing rapidly.

31. In most of the world today, the fossil-fuel sources of air pollution are avoidable or largely controllable at a cost to the community and nation that is now widely believed to be usually less than the damage costs that will otherwise be incurred. In a high energy future, however, both prevention and control would be extremely expensive, particularly in developing countries.

## 2. Preventing Acidification

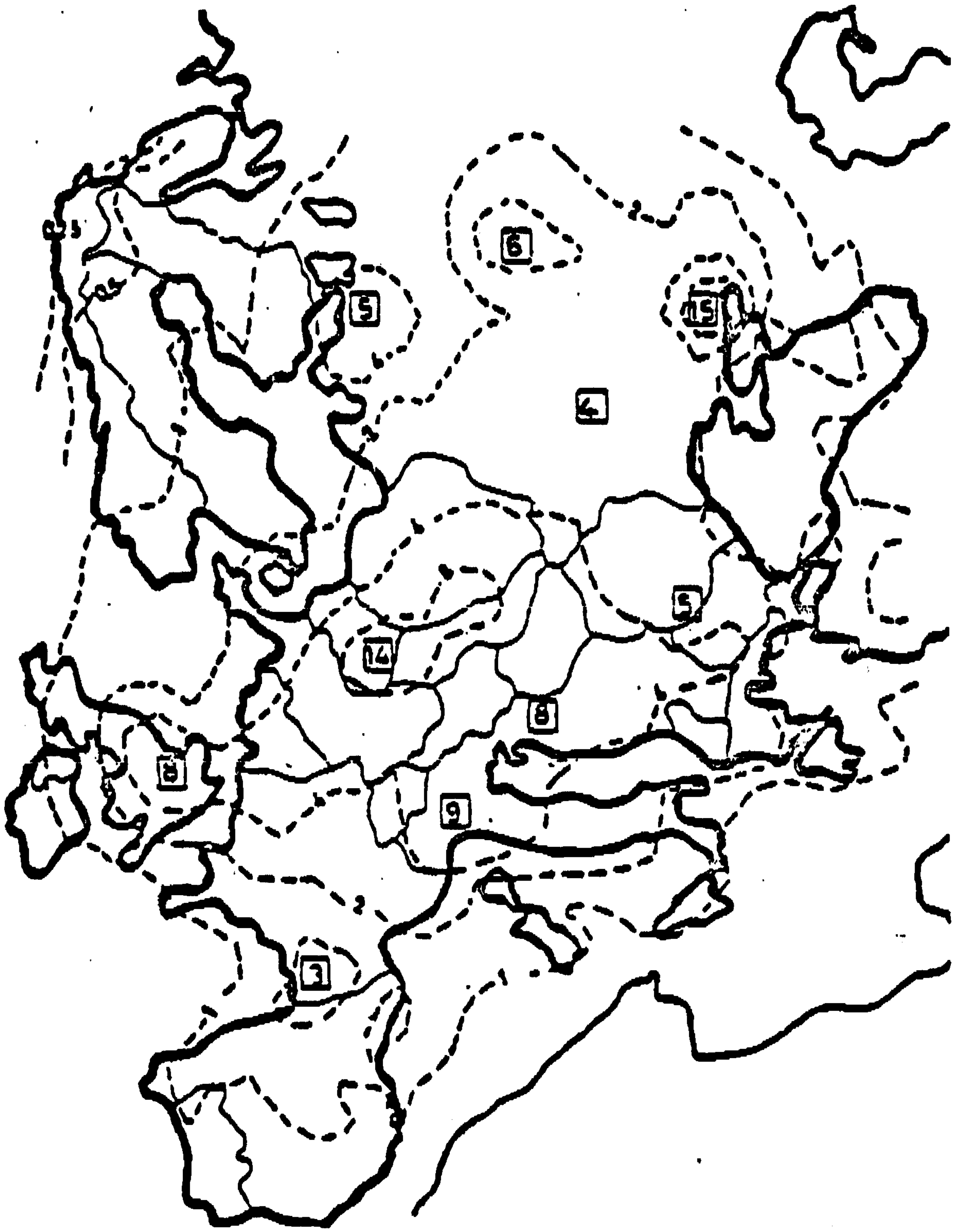
32. The measures taken by many industrialized countries in the 1970s to control urban and industrial air pollution (high chimney stacks, for example) greatly improved the quality of the air in the cities concerned. While reducing local human exposure however, it quite unintentionally increased the problem to soils and communities of plants and animals elsewhere. This was manifest in a rapid rise in transboundary air pollution in Europe and North America and an increasing

acidification of the environment. In consequence, the perception of atmospheric pollution has widened from that of a local urban-industrial problem involving the health of human communities, to that of a much more complex problem involving both people and ecosystems regionally over many hundreds or even thousands of kilometres. During long distance transport in the atmosphere, emissions of sulphur and nitrogen oxides and volatile hydrocarbons are transformed into sulphuric and nitric acids, ammonium salts and ozone. They fall to the ground, sometimes many hundreds of kilometres from their point of emission, as dry particles or in rain, snow, frost, fog and dew.

33. Gradually accumulating over the decades, damage to the environment from air pollutant transport over long distances 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, particularly in Southern Scandinavia, and several in North America[18/] have registered a steady increase in acidity levels to the point where their natural fish populations decline or die out. The same acids enter the soil and ground water, increasing the corrosion of drinking water piping in Scandinavia, and concern has been expressed that they may possibly liberate potentially toxic metals and pose risks to human health. The circumstantial evidence indicating the 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.[27/, 28/] Up to now, the greatest damage has been reported over Central Europe, which is currently receiving more than one gramme of sulphur on every square metre of ground each year (Figure 7-4). There was little evidence of tree damage in Europe in 1970. In 1982, the Federal Republic of Germany reported visible leaf damage

FIGURE 7-4

Acid Deposition on Europe




Note : 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[29] in 8 per cent of its sample of forest plots nationwide; in 1983, this rose to to 34 per cent and to 50 per cent in 1985.[30/, 33/, 34/] Sweden reported light to moderate damage in 30 per cent of its forests; and various reports from other countries in Eastern and Western Europe are extremely disquieting. So far an estimated 5-6 per cent of all European forest land is affected.

34. The evidence is not all in, but many reports show soils in parts of Europe becoming acid throughout the tree rooting layers, particularly the nutrient-poor soils of Southern Sweden.[20/, 31/] The acidity is frequently so high that aluminium comes into solution as a mobile element, toxic in very low concentrations to plant roots. Although several theories exist, the precise damage mechanism is not known. However, all include an air pollution component. Root and leaf damage appear to co-act, both affecting the ability of the trees to take up water from the soil and retain it in the foliage, so that they become particularly vulnerable to dry spells.

35. We already may be witnessing an immense, regional acid-base chemical titration in Europe, 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.[30/, 31/]

36. 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.[29/]

37. In the eastern United States, where a great deal of emission control has already been successfully achieved, it has been estimated that reducing the remaining sulphur dioxide emissions by half from existing sources would cost an additional US$ 5 billion a year,[18/] 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.[34/] Other estimates for the whole U.S.A. would add up to a doubling of this figure. Materials corrosion damage is estimated to cost US$ 7 billion annually in 17 states in eastern U.S.A.[35/] Estimates of the annual costs of securing a reduction in the remaining sulphur emissions in the countries of the European Economic Community of 55 to 65 per cent between 1980 and 2000 range from US$ 4.6 to 6.7 billion (1982 $) per year. Controls on stationary boilers to reduce nitrogen levels by only 10 per cent per year by the year 2000 range between US$ 0.1 and 0.4 billion (1982 $).[36/] While high in absolute terms, even in countries whose energy systems depend heavily on coal-based thermal power, these figures translate into a one time increase of about 6 per cent in the price of electrical power to the consumer. Estimates of environmental damage costs are much less reliable and, given the trends noted above, necessarily very conservative. In Europe, studies place damage costs due to material and fish losses alone at US$ 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[35/] indicate that air pollution and acid rain can reduce some wheat and rice crop production, perhaps by as much as 30 per cent.

38. Modern equipment and technologies such as powdered coal-liquid mixtures, fluidized bed combustion, low $NO_x$ burners, gasification and secondary smoke condensers can remove sulphur, nitrogen and also many other troublesome pollutants quite adequately and cost-effectively, either before, during or after combustion.

## 3. Managing Climatic Change

39. Upon combustion, fossil fuels also emit the gas carbon dioxide, which accumulates in the atmosphere. The pre-industrial concentration was circa 280 parts of carbon dioxide per million parts of air by volume (ppmv). This concentration reached 340 in 1980 and is expected to double (to 560) between the middle and the end of the next century. No proven technologies exist to control the emissions of carbon dioxide. Other gases are also accumulating in the atmosphere, principally, chlorofluorocarbons (used as aerosol propellants in spray cans, for the foaming of plastics and in heat-pumps and refrigerators as a heat transfer medium); methane (emitted from wet, reducing soils, e.g. marshes, rice-paddies, or from herbivores, or the earth's surface, especially where oil or gas is exploited); nitrous oxide (derived from cold, moist soils and the breakdown of nitrogenous fertilizers); and ozone (generated by industry, internal combustion engines and photochemical oxidations in the atmosphere). Apart from these, there are at least a further 28 gases released by human activity in trace amounts, any of which could be significant in future. Although these other gases are not emitted from energy generation, they have a decisive influence on the energy policies developed for carbon dioxide emissions.

40. After reviewing the latest evidence in October 1985, scientists from 29 industrialized and developing countries concluded that climate change must be considered a "plausible and serious probability".[12/] They further concluded that: "Many important economic and social decisions are being made today on ... major water resource management activities such as irrigation and hydropower; drought relief; agricultural land use; structural designs and coastal engineering projects; and energy planning - all based on the assumption that past climatic data, without modification, are a reliable guide to the future. This is no longer a good assumption since the increasing concentrations of greenhouse gases are expected to cause a significant warming of the global climate in the next century. It is a matter of urgency to refine estimates of future climate conditions to improve these decisions." They estimated that if present trends continue, the combined concentration of $CO_2$ and other greenhouse gases in the atmosphere would be radiatively equivalent to a doubling of $CO_2$ from pre-industrial levels, possibly as early as the 2030s, and could lead to a rise in global mean temperatures "greater than any in man's history". Current modelling studies and "experiments" show a rise in globally averaged surface temperatures, for an effective $CO_2$ doubling, of somewhere between 1.5$^{o}$C and 4.5$^{o}$C, with the warming becoming more pronounced at higher latitudes (during winter) than at the equator. This temperature rise may take some decades to reach full equilibrium with the increased trace-gas concentrations.

41. The great concern, of course, is "that a global warming of 1.5 - 4.5$^{o}$C perhaps with a x2-3 greater warming at the poles would lead the sea level to rise from 25 - 140 cm". A rise in the upper part of this range would inundate low lying coastal cities and agricultural areas, and many countries could expect their

economic, social and political structures to be severely hit. It would also slow down the "atmospheric heat-engine" which is driven by differential equatorial and polar heating, thus influencing rainfall regimes.

42. Unless pre-planned adaptation strategies were readily available globally, local disasters could escalate swiftly into international crisis. This would be accentuated by the effects of changing climate and water-regimes 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. The effects of warmer oceans or marine ecosystems on fisheries and food chains are also virtually unknown.

43. 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 abate emissions and so avoid these problems or at least reduce their impact. In the case of climatic change, this latter strategy would buy time to facilitate adaptation to the consequences. We seem to be entering an era where sooner or later nations will have to formulate and agree upon long-term policies for all industrial- and energy-atmosphere interactions 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.

44. What is needed for these issues, in fact, marked as they are by varying degrees of uncertainty, is a three-track strategy combining:

* improved monitoring and assessment of the evolving phenomena;

* increased research to improve our knowledge about the origins, mechanisms and effects of the phenomena;

* the development and implementation of new or modified clusters of economic, finance, trade and sectoral policies. These latter policies 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 impacts.

Above all, the question remains: "How much certainty do we need before acting?"

45. No nation worldwide has either the political legitimacy or the economic power to implement this three track strategy. If it is to be started up, the only body likely to be successful is the United Nations. However, the consensus statement issued at Villach[17/] recommended such a strategy for climate change to be promoted by governments and the scientific community via the World Meteorological Organization, the United Nations Environment Programme and the International Council of Scientific Unions. The Villach Statement further recommended that if deemed necessary, consideration be given to the need for a global convention. While this strategy is being developed, more immediate policy measures can and should be adopted. The most urgent, as mentioned earlier, is a careful consideration of how to continue the steady gains in energy efficiency and a shift in the energy mix towards more renewables. There is detailed 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.[4/, 5/] And, as noted earlier, these measures would also serve to reduce other emissions and thus reduce acidification and urban-industrial air pollution.

46. Many other mutually reinforcing measures should also be entertained. Measures deliberately designed 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. As far as possible, gaseous fuels should be the fuels of choice for cooking and other domestic uses, in particular, since it is generally more difficult to implement pollution control at the domestic level. 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.

47. 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. Some of these, notably chlorofluorocarbons may be more easily controlled than carbon dioxide. 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.

## 4. Conclusion

48. Although oil supply seems to be more finite, there is little doubt that gas and particularly coal reserves are available if needed as part of a longer term energy future. There is equally no doubt that the world is already experiencing serious health, environmental and materials corrosion damage, from oil and coal use. These damage effects are becoming more widespread, with their environmental repercussions not as yet fully appreciate, particularly in tropical and sub-tropical regions. Although its seems in general that the pollutant damage can be contained at costs which appear to be less than the damage costs themselves, the important exception is carbon dioxide and its role in global warming. No widely-available proven technology currently exists to remove it from combustion gases. Clearly, if all these pollution problems are difficult as the present usage levels of fossil fuels, their heavier use will only increase pollution damage and/clean-up costs and will inevitably aggravate the problem of global warming. The relative transience of oil supplies and the global warming risks of carbon dioxide make heavy future reliance upon fossil fuel use very problematic. This immediately raises the fourth questions posed in paragraph 24: "Are there any less troublesome sources of primary energy available to us worldwide?". This brings up the issues of moving away from finite resources to effectively infinite primary energy supply. The two

large sources of outstanding interest are indicated in Table 7-1 direct solar (thermal and photovoltaic); indirect solar (particularly biomass) and nuclear energy. Both are in theory more widely available than geothermal sources. Although a special problem of shortages exists with naturally occurring wood, which can be avoided by the cultivation of "energy forests".

## IV. RENEWABLE ENERGY: UNTAPPED POTENTIAL

### 1. Improving Future Prospects

49. Renewable energy sources provide almost 22 per cent of the energy consumed worldwide, of which 15 per cent is biomass and 6 per cent hydropower. However, most of the biomass is in the form of fuelwood and agricultural and animal wastes used by about 70 per cent of the populations of developing countries. In many cases fuelwood has already become a non-renewable resource because usage rates of naturally occurring wood have unfortunately overtaken sustainable yields, a point discussed later on. Table 7-1 shows the overall relationship of renewable to non-renewable sources; Table 7-6 [37/] provides a more detailed breakdown of the future prospects for renewable energy. Although worldwide reliance on all 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 potentially renewable energy sources used in a truly renewable manner make up a substantial portion of the world's energy budget.

TABLE 7-6

World Use of Renewable Energy, 1980 and Potential

| Source | | 1980 TWyrs/yr | Long-term Potential TWyrs/yr |
|---|---|---|---|
| Solar energy: | passive design | + | 0.6-1.0 |
| | residual collectors | + | 0.2-0.3 |
| | industrial collectors | + | 0.3-0.6 |
| | solar ponds | + | 0.3-1.0* |
| Wood | | 1.1 | 3.2* |
| Crop residues | | 0.2 | - |
| Animal dung | | 0.1 | - |
| Biogas: | small digesters | + | 0.1-0.3 |
| | feedlots | + | 0.2* |
| Urban sewage and solid waste | | + | 0.5* |
| Methanol from wood | | + | 0.6-1.0* |
| Energy crops | | + | 0.5-0.6* |
| Hydropower | | 0.6 | 2.9* |
| Windpower | | + | 0.3* |
| Solar photovoltaics | | + | 0.6* |
| Geothermal energy | | + | 0.3-0.6* |
| Total | | 2.0 | 10.6-12.9* |

Notes: + = less than 0.01 TWyrs/yr;
* indicates that technical advances could allow the long-term potential to be might higher; similarly, a range is given where technical uncertainties make a single estimate impossible.

Source: Worldwatch Institute, Deudney & Flavin - 1983[37/]

50. Wood as a renewable energy source is usually thought of in the context naturally occurring trees and shrubs harvested for the traditional domestic sector. However, wood is becoming an important feedstock, specially grown 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.

51. Hydropower, second to wood among the renewables, has been expanding at nearly 4 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.

52. Solar energy use is currently small globally, but it is beginning to assume an important place in the energy consumption patterns of some countries. In many parts of Australia, Greece and the Middle East for example, solar water and household heating is widespread. 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. The cost of photovoltaic equipment has fallen from the original of circa. US$500 - 600 per peak watt to a current US$5. This optimistic evolution is approaching the US$1 - 2 where it can compete with normal electricity production. But even at US$5, it is still more cost effective than ranging power lines to remote places.

53. Wind power has been used for centuries - mainly for pumping water. Recently its use has been growing tremendously in some countries, such as off the California coastline and in Scandinavia. In these cases the wind turbines are used to generate electricity, to be fed into the local electricity grid. Wind generated electricity costs have fallen dramatically in California in the last five years and will probably be very competitive with other power generated there within a decade. Many countries have successful wind programmes, but the untapped potential is very high in all countries.

54. The alcohol programmes in Brazil in 1984 produced about 10 billion litres of ethanol from sugar cane and replaced about 60 per cent of the gasolene that would have been required in the absence of the programme. 7/, 38/, 39/ The cost has been estimated at US$ 50-60 per barrel of gasolene replaced. When subsidies are removed, and a true exchange rate is used, this is competitive at 1981 oil prices. 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. It 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. 39/, 40/

55. Geothermal energy use 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.

56. These energy sources are not without their health and environment risks. Some of the commonest difficulties with solar energy is somewhat surprisingly, the injuries from roof falls during solar thermal maintenance and the nuisance of sun-glare off their glass surfaces. A modern wind turbine can be significant noise nuisance to people living nearby. But these are small problems compared with the fundamental ecosystem modification downstream of a hydropower site or the uprooting of homesteads in the areas to be flooded, as well as the health risks from such toxic gases as hydrogen sulphide generated by amoebically rooting submerged vegetation and soils. Hydrodams also act as an important barrier to fish migration and sometimes to the movement of land animals. Perhaps the worst problem they pose is the danger of catastrophic rupture of the dam-wall and the sweeping away or flooding of human settlements downstream. This risk is small but not insignificant. There have been many such tragic accidents. One of the most widespread chronic problems is the eye and lung irritation caused by woodsmoke in developing countries.[41/] When agricultural wastes are burned, pesticide residues inhaled from the dusts or smoke of the crop material can be a health problem. Modern biofuel liquids have their own special hazards. Apart from competing with food crops for good agricultural land, their production generates large quantities of organic waste effluent, which if not usuable as a fertilizer, can cause a water pollution problem. Such fuels, particularly methanol, may produce irritant or toxic combustion products.

57. 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 years continuously (see Tables 7-1 and 7-6), a value equal to the 1980 level of energy consumption worldwide.[7/] This level could be substantially increased with new technologies, but it will depend overwhelmingly in the short run on policies that attack certain economic, environmental and institutional constraints to their use. Most renewable energy systems operate best at small to medium scales, ideally suited for rural and suburban applications. They are also generally labour intensive, which should be an added benefit in situations of surplus labour. Additionally, they are less susceptible to wild price fluctuations and foreign exchange costs than fossil fuels. Finally, since most nations have some renewable resources, their use can help nations move toward the goal of self-reliance. 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. This does not mean that renewable energy production need not make economic sense. It does mean, however, that the evaluation of all energy sources has to be much more conformably inter-comparable and 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.

## 2. Conclusions

58. The need for a steady transition to a broader and more sustainable mix of energy sources is beginning to become accepted. But the fiscal and institutional

barriers to renewables are formidable in many countries. The influence of temporarily 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 in research and development, depletion allowances, tax write-offs and direct support of consumer prices. Countries should undertake a full examination of all subsidies and other forms of support to various sources of energy and publish the results. Additionally, electrical utilities often have a supply monopoly on generation which allows them to arrange pricing policies which discriminate against other (small) suppliers.

59. Renewable sources are still in a rather primitive state of development. What is needed is a major series of well co-ordinated research, development and demonstration programmes, funded on a par with the levels of expenditure put into nuclear energy. With a potential delivery of 10 TW or so, even if 3-4 TW were realized, it would make a crucial difference to future primary supply, especially in developing countries, were the appropriate background conditions exist for the success of renewables. It is crucial, however, to provide the right societal and institutional embedding for renewables in the supply metric; by comparison the technical problems are relatively minor. They have to be finely tuned to fit into the local demand pattern. This site and niche specificity is still very poorly understood and needs a lot of working experience for success. Thus, although the future of renewable energy is promising but uncertain, there is another important potential source of primary energy - nuclear power. Opinions vary about its potential utility because it is associated with several unsolved problems.

# V. NUCLEAR ENERGY: THE UNSOLVED PROBLEM

## 1. The Peaceful Atom

60. In the years following World War II, the nuclear knowledge that under military control had led to the production of atomic weapons was redeployed for peaceful purposes by technologists working in the civilian research establishments of several countries. They harnessed the enormous heat energy liberated during atomic fission to produce electricity. The aim was to replace as far as possible the carbon based fuels: coal, oil, gas or wood normally used for thermal electricity generation. The prospects were very exciting: weight for weight, nuclear fuel has more than x1000,000 the heat value of high-grade coal. Even allowing for the very high costs of enriched (fuel-grade) uranium, electricity was still going to be cheaper from nuclear than from coal or oil (in terms of fuel prices and not counting power station costs). Even today, it is roughly x4 and x6 cheaper respectively. This would give much lower running costs, more than offsetting the higher construction costs for nuclear.

61. Several other benefits were obvious at the time. A nuclear reactor, unlike power stations run on fossil fuels, especially coal, did not produce oxidic and oxidizing gases, such as oxides of sulphur and nitrogen and ozone, and other potentially harmful substances: volatile organic compounds, dusts, smoke, etc.., all of which can either cause corrosion or serious human health and environmental problems. Furthermore, nuclear reactors, unlike fossil fuels, did not produce the gas carbon dioxide which even in the 1950s and 1960s was strongly suspected of causing global climate warming. Additionally, many felt at the time that the longer-term

futures of oil and gas were very uncertain, reserves being apparently limited either technologically or economically. Coal, although in plentiful supply for centuries ahead, was environmentally by far the worst fuel, producing all the unacceptable combustion products touched on above and in some regions was difficult and costly to mine and transport. Alternative energy sources such as the various forms (direct and indirect) of solar energy (para xx above), nuclear fission or geothermal were all seen as still being in the development stage and decades away in practice. The concepts of energy conservation and efficiency still had to wait for the 1970s before being worked out properly.

62. Of course, it was realized that no energy source would ever be risk free. There was the danger of spreading atomic weapons and nuclear terrorism, but work on the Non-Proliferation Treaty (NPT) suggested that these dangers could be avoided. Drafted in its final form in 1969, it included a promise by signatory governments possessing nuclear expertise to assist the non-nuclear signatories in developing nuclear power, but strictly for peaceful purposes only. Other problems, such as radiation risks, reactor safety and nuclear waste disposal were all acknowledged as very important but, with the right amount of effort, containable. It was in this atmosphere of post-war optimism that many hundreds of nuclear technologists embarked upon this task of turning "swords into ploughshares", driven by the humanitarian ideal that they could transform the destructive horror of the nuclear bomb into a benevolent power that would provide electricity in abundance and to shape a better life for all humanity.

63. And so that start was made, even in Japan where the government was able to retain the confidence of the public, who, despite the dreadful memory of Hiroshima and Nagasaki, began to accept the importance of turning atomic energy into peaceful uses, thus enabling a nuclear electricity programme to be launched successfully. Now, after almost four decades of immense technological effort to support nuclear development, this idea has been realized insofar as nuclear energy is widely available today. However, during this period of practical experience with building and running nuclear reactors, humanity has become much more clearly aware of the exact nature of all the benefits, costs and risks of nuclear energy.

## 2. The Growing Understanding of Nuclear Issues

64. As the benefits of "clean" and troublefree electricity began to flow in, some of the difficulties relating to the problems already indicated in para 3 began to emerge. These issues are outlined in the ensuing text as they appear to society at present. It must be emphasized that these perceptions will evolve and change with time, as more information becomes available and appropriate solutions to the problems are finally worked out.

### 2.1 Non Proliferation

65. Major issues raised by nuclear power but completely outside the control of nuclear technology are the problems of how to avoid the spread of nuclear weapons, the theft of nuclear materials and the threat of nuclear terrorism by criminal or quasi-governmental factions, and from military rebellions. These issues, once thought to have been reasonably safe-guarded by the arrangements made under the NPT and by IAEA are being reopened in the

light of recent experiences of international terrorism, political volatility in the Middle East and parts of Africa and increasing North - South polarization. The problem is further complicated by the debate on whether or not the possession of fuel reprocessing and breeder reactors will increase any tendencies to avoid or violate international agreements. The NPT remains the most serious attempt to date to reduce these nuclear weapons hazards. It mandated an institutional separation between military and civilian uses of nuclear energy. But for countries with full access to the complete nuclear fuel cycle, no technical separation really exists and not all states operate the necessary clear-cut administrative separation of civilian and military access, especially those who do not participate in NPT and do not open their nuclear programmes to IAEA inspection. Such situations still represent a danger to non-proliferation. They create political anxieties which could become a threat to world stability and peace.

2.2 Costs

66. The generation of electricity, however it is done, has become much more expensive in the last 15-20 years. This has caused special difficulties for nuclear power, again largely beyond the control of nuclear technologists. The earlier reactors in the U.S.A. cost US$ 135-150 per kilowatt to build, but by 1982, estimates for completion by the early 1990s were more than ten times higher. Currently, costs (in 1984 US dollars per kilowatt for commissioning in 1995) generally seem to range from ca. US$ 3000 in the U.S.A. to ca. US$ in Canada and U.K. to less than US$ 1000 in France, with ca. US$ 1500 prevailing in many countries worldwide. [42/, 43/] Costs of building coal and oil fired plants have also increased, but generally speaking, the cost advantage throughout the service life of a nuclear

installation on account of cheaper fuel has either been reduced or lost by increased construction costs. This has been a particular problem for the U.S.A. nuclear industry, largely brought about by the virtual doubling of the steel and concrete requirements needed to meet improved safety standards and the considerable extension of the licensing and construction periods.

67. These problems have been critically aggravated by the costs of borrowing money during the late 1970s and early 1980s. In the U.S.A., these factors would not necessarily have proved decisive had it not been for the fact that the electricity sector turned out to be overbuilt in the 1970s. Steady electricity growth of around 7 per cent a year for the period 1900 - 1970 fell to around 2 per cent by 1980, a time when there also occurred a big public debate about nuclear safety following the Three Mile Island reactor accident (Harrisburg, U.S.A.) in March 1979. These factors appear to be the main reasons for the cancellation of about 100 reactors by U.S.A. electricity utilities, with some banks even making cancellation of partly completed plants a pre-condition of further financing. The U.S.A. situation is an extreme case and the nuclear industry in countries with no fall-off in electricity demand growth and with shorter licensing and construction times have fared much better. But many countries worldwide are experiencing one or more of the causes of the U.S.A. station-cost problem, creating difficulties for their nuclear construction plans.

## 2.3 Health and Environment Risks

68. Very strict codes of safety practice are implemented in nuclear plants so that under officially approved operating conditions, the danger from radiation to reactor personnel and especially to the general public

is negligible. However, an accident occurring in a reactor may in certain rare cases (paragraphs 11-14) below be serious enough to cause an external release of radioactive substances. Most of these substances would be either unreactive noble gases which quickly dissipate in air, or would be non-gaseous materials which rapidly become redeposited close to the reactor, so that workers near the release may be contaminated. If this contamination is large enough, the workers may become very ill or die from radiation sickness. A small fraction of the release may in some instances be carried up into the atmosphere, becoming diluted and settling slowly back to earth as it is drifted by winds over hundreds or even thousands of kilometres. If the airborne radioactive substances are involved in rain or snow showers, they are precipitated very rapidly to the ground causing local concentrations. Radioactive elements deposited by these dry or wet routes may settle on water and get into fish, or on soil, where they may become firmly fixed, or they can enter soil and ground water to be absorbed by plants and consumed by livestock or game. In these ways, people are exposed either directly or indirectly (via air breathed, drinking water and food consumed) to radiation doses following a release of radioactive substances. Of the large number of radioactive elements which could be spread in the human environment in this way, only a small number are important in transmitting radiation doses to humans. The most crucial ones are iodine ($^{131}I$); caesium ($^{137}Cs$, $^{134}Cs$); strontium ($^{90}Sr$, $^{89}SR$). Others are important in the very long term.

69. Depending on the level of exposure, people are under a certain level of risk of becoming ill from anaemia or dying from leukaemia or cancers of the thyroid, bone or soft tissues. There is a further risk, also proportional to the dose received through time, of

alteration of the genetic material which may cause birth abnormalities or other hereditary defects. All these various effects usually become manifest during a period of ca. 50 years after exposure. Operating since 1928, the International Commission on Radiological Protection (ICRP) has issued recommendations on radiation dosage levels above which exposure in unacceptable. These have been developed for occupationally exposed workers and for the general public. The "Nuclear Safety Standards (NUSS) codes of IAEA were developed in 1975 to reduce safety differences among member states. Neither system is in any way binding on governments. If an accident occurs, individual governments have the responsibility of deciding at what level of radioactive contamination pasture land, drinking water, milk, meat, eggs, vegetables and fish, are to be banned for consumption by livestock or humans. Different countries - even different local government authorities within a country - have different criteria. Some have none at all, ICRP and NUSS notwithstanding. States with more rigorous standards may destroy large amounts of food or may ban food imports from a neighbour state with more permissive criteria. This causes great hardship to farmers who may not receive any compensation for their losses. It may also cause trade problems and political tension between states. Both of these difficulties occurred following the Chernobyl disaster when the need to develop at least regionally conformable contamination criteria and compensation arrangements was overwhelmingly demonstrated.

## 2.4 Nuclear Accident Risks

70. Nuclear safety returned to the newspaper headlines following the Three Mile Island (Harrisburg, U.S.A.) and the Chernobyl (U.S.S.R.) accidents. The best available estimates of a radioactive release following reactor malfunction were made in 1975 by the U.S.A. Nuclear

Regulatory Commission (USNRC).[44/] These were arrived at following highly complex statistical calculations estimating probabilistically the chances of component failures in western style light water reactors. This study recognized 9 Categories of radioactive release of graded severity for pressurized water reactors (PWRs) and 5 Categories for boiling water reactors (BWRs). Categories 1-7 for PWRs and Categories 1-4 for BWRs were releases associated with more or less severe melting of the reactor core. The most serious release (Category 1 in both cases) placed the risk at around once every 1,000,000 years of reactor operation. The first four Categories for PWRs and the first three for BWRs released significant amounts of the core's radionuclide inventory. They respectively represent about 20 per cent and 90 per cent of all core melt categories for each reactor type with respective probabilities of ca. 1 in 100,000 and ca. 1 in 50,000 reactor years of actually happening.

71. Although the type of reactor at Chernobyl was completely different from the types considered by the USNRC Study, judging by the fractions of the core inventory of the various radionuclides released at Chernobyl[45/] as set against the picture indicated by the USNRC Study, it would seem that Chernobyl may be equivalent to a release of somewhere between Categories 2 and 3 on the USNRC scale. From what is already known about the serious health and environment implications of Chernobyl, it therefore seems questionable to believe that only Category 1 releases in PWRs and BWRs can cause serious health and environment problems in the vicinity of the damaged reactor and important repercussions in neighbour states which are affected by any atmospheric emissions drifting across their borders.

72. Post-accident analysis of both Harrisburg and Chernobyl have shown that in both cases, human operator error was the main cause. Such problems are well nigh impossible to handle probabilistically. They occurred after ca. 2000 and ca. 4000 reactor years respectively. A recent analysis which allowed for their actual incidence has proposed that there is a 95 per cent probability of a major (core-damaging) accident within the next 20 years, i.e. within 10,000 reactor years, given the number of reactors expected to be operating up to the year 2000 [46/]. A further review of this analysis suggested that the available evidence indicated the probability of such an accident in the next 10 years is unlikely to be less than 25 per cent[47/]. Although the approaches of USNRC and the other two analyses (which included observed data) are different, both the latter suggest accident probabilities that are only x2 -x4 higher. But in all cases, the analyses indicate that although the risk of a radioactive release accident is small, it is by no means negligible for reactor operations at the present time.

73. The regional health and environment effects of such an accident have been outlined in paras 9-10. These are largely predictable from radioactive fall-out studies following early atomic weapons testing in the atmosphere and have been confirmed in practice following the Chernobyl accident. What could not be confidently predicted before Chernobyl were the local effects of such an accident and a much clearer picture is emerging as a result of the experiences there when a reactor exploded, following a series of inexcusable infringements of the official safety regulations, on 26 April 1986, causing the worst reactor accident ever experienced. There were more than 30 deaths and several hundreds injured in the immediate vicinity, either as a result of the explosions or during attempts to put out the graphite fire in the

reactor. About 135,000 people were evacuated from their homes within a radius of 15 kilometres around the reactor and it is not yet clear how many will eventually be able to return because of residual radioactivity. The school children of Kiev, a city of 24 million people 80 kilometres to the South of Chernobyl were sent away on holiday a few weeks after the accident and estimates of the regional cancer deaths during the next 50 years resulting from the radioactivity have been put between 5000 and 50,000.[48/, 49/] The damage has been estimated to cost US$ 3 - 5 billion (preliminary estimates)[50/] with about a further US$ 0.5 - 1 billion added by neighbour states from losses of foods for home consumption and export.

74. The reactor is now encased in concrete and enormous efforts have been made to prevent drinking water contamination. Radioactive topsoils have been bulldozed away and buried. What has become extremely clear is that the whole district had to be managed on something like a "war footing" and efforts resembling a large military operation were needed to contain the damage. Such accidents are comparable with major non-nuclear accidents such as Flixborough, Seveso and Bhopal, in terms of their local impacts at least. Many skilled observers argue that Chernobyl and also Harrisburg were "freak" accidents triggered by unbelievably incompetent operation behaviour. What is at least certain is that they demonstrated the crucial necessity of "foolproof" operator training, licensing and management as well as "mistake proof" control-panel layout and operationally "fail-safe" reactors, which in engineering terms at least, eliminate the risks of catastrophic accidents.

## 2.5 Radioactive Waste Disposal

75. Civil nuclear energy programmes worldwide have already generated many thousands of tonnes of spent fuel and high-level waste. Many governments have embarked on large-scale programmes to develop ways of isolating these from the biosphere for the many hundreds of thousands of years that they will remain hazardously radioactive. Many ways have been considered, but a common pattern is to render the wastes as far as possible insoluble in water by vitrification or similar methods, followed by deep geological disposal in leak- and corrosion-resistant containers placed in salt deposits, impermeable clays, granitic or similar hard rock where they can be kept out of reach of ground water and undisturbed by earth movements for very long periods of time. Other methods include sub-seabed disposal in the subduction zones or "trenches" between continental and oceanic tectonic plates. There is a very large technical literature on this subject which has also been occupying the professional attention of several international agencies, notably IAEA. All the exhaustive "desk studies" carried out so far have brought the state-of-the-art to the point of technical feasibility at least.[51/, 52/] However, experimental follow-through to calibrate and check these theoretical studies has been made difficult, at least in part due to substantial public opposition from many towns and districts to the designation of their land as a potential repository. This "not-in-my-backyard" syndrome will have to be overcome before "technical feasibility" can be translated even experimentally into actual "disposal" of the wastes with realistic cost estimates. A closely similar situation exists for the decommissioning and dismantling of nuclear power plants when they reach the end of their service lives. Dismantling techniques and costs are known from theoretical studies only.

76. Although it is frequently suggested that waste disposal should be achieved as a result of international co-operation, there are a number of difficulties with this idea. 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 international repositories either in the international commons or on national territory. Problems of agreeing on the location and supervision of such repositories seem so great as to make them unlikely to start up before a number of purely national repositories are brought into operation.

## 3. The Current International Situation

77. During the last 25 years, a growing awareness of the difficulties outlined in paras 5-16 above, have resulted in a wide range of reactions from technical experts, the public and governments, with the pro- and anti-nuclear extremes being the most vocal. Many experts still feel that so much can be learned from the problems experienced up to now that if the public climate allows them to solve the nuclear waste disposal and decommissioning issues experimentally and the cost of borrowing money remains reasonably below its 1980-82 peak, there is no reasons why nuclear energy should not emerge as a strong runner in the 1990s. At the other extreme, many experts take the view that there are so many unsolved problems and too many risks for society to continue with a nuclear future. Public reactions also vary. Although some countries have exhibited little public reaction, in others there appears to be a high level of anxiety which expresses itself in anti-nuclear results in public opinion polls or large anti-nuclear campaigns. Although several governments have no plans for atomic energy, the various difficulties above and

particularly the adverse public reactions have been of keep concern to several pro-nuclear democratic governments who have to get their nuclear policy voted in. Why does this wide spectrum of opinion exist? Whilst it is possible to map out all the individual risk components of the nuclear cycle and to obtain fairly objective estimates quantifying the probability of these risks actually occurring, the real problems arise when attaching value judgements to each risk probability. Because different governments have widely different attitudes and priorities and hence differing value systems, each will attach a different level of importance to the same quantified risk category. In this way, very different evaluation profiles emerge from much the same set of risk probability numbers. The same weighting problems occur between different groups of people or political parties in a pluralistic society. This is why different governments who have already gone through the process of nuclear evaluation have come up with very different conclusions and why in many pluralistic countries atomic energy has become a contentious and divisive political issue.

78. And so, whilst some states still remain nuclear-free, today nuclear reactors supply about 15 per cent of all the electricity generated, which is equivalent to around 15 per cent of global primary energy supply. Roughly one quarter of all countries worldwide have reactors. In 1986, there were 366 working and a further 140 planned [53/] with 10 governments possessing ca. 90 per cent of all installed capacity ( 5 GW (e)). Of these, there are 8 with a total capacity of 9 GW (e) which provided the following percentages of electric power in 1985: France 65; Sweden 42; FRG 31; Japan 23; U.K. 19; U.S.A. 16; Canada 13; U.S.S.R. 10. According to IAEA, in 1985 there were 55 research reactors worldwide, 33 of them in developing countries. Nevertheless, there

is little doubt that the difficulties referred to above have in one way or another contributed to a scaling back of future nuclear plans. In western Europe and North America, which today have almost 75 per cent of current world capacity, nuclear provides about one third of the energy that was forecast for it ten years ago. Apart from France, Japan, U.S.S.R. and several other countries in Eastern Europe who have decided to continue with their nuclear programmes, ordering, construction and licensing prospects for new reactors in many other countries look poor. In fact, between 1972 and 1986, earlier global projections of estimated capacity for the year 2000 have been revised downwards by nearly a factor of seven. Despite this, the growth of nuclear at around 15 per cent a year over the last 20 years is still impressive.

79. Following Chernobyl, there were significant changes in the nuclear stance of certain governments. Several, notably the U.S.S.R., China, France, Japan, Poland and the U.K. have maintained or reaffirmed their pro-nuclear policy. Others with a "no nuclear" or a "nuclear phase-out" policy (Australia, Austria, Denmark, Luxemburg, New Zealand, Sweden - and Ireland with an unofficial anti-nuclear position) have been joined by Greece and the Philippines. Meanwhile, Finland, Italy, the Netherlands, Switzerland and Yugoslavia are re-investigating nuclear safety and/or the anti-nuclear arguments, or have introduced legislation tying any further growth of nuclear energy and export/import of nuclear reactor technology to a satisfactory solution of the problem of disposal of radioactive wastes.

## 4. Conclusions and Recommendations

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

a) continue to remain with and develop non-nuclear sources of energy;

b) adopt and develop nuclear energy with the conviction that the associated problems and risks can and must be solved with a level of safety that is both nationally and, because of transboundary impacts, internationally acceptable;

c) regard nuclear power as important during a finite period of transition to safer and more desirable energy sources.

For those governments who intend to remain on the non-nuclear path, or those who see their nuclear programmes as a finite transitional phase, the vigorous promotion of energy efficient end-use practices in all energy sectors and a long-scale programme of research, development and demonstration for renewable energy sources must be given the highest priority. The recent development of clean (pollutant-free) coal technology should also be accorded high priority for careful examination with a view to widespread adoption.

81. Those governments who are politically dedicated to nuclear energy must give their strongest support to a series of measures designed to provide solid, lasting solutions to the problem of nuclear energy that still remain unsolved at the present time. Because the leakage or escape of radioactive materials does not stop at national boundaries, the non-nuclear or "qualified" nuclear governments in categories (a) and (c) above have a direct interest in urging and assisting their nuclear neighbour governments to seek such solutions as follows:

* It is essential that governments co-operate to develop internationally agreed codes of practice for the management of all aspects of nuclear energy via a comprehensive "systems" approach, covering technical, economic, social (including health and environment aspects) and political components of the overall problem.

82. In particular, international agreement must be reached on the following specific items:

* codes of practice for reactor operation, including minimum safety-standards and approved formats for the routine communication of important operational details such as fuel loading timetables. The aim should be towards international inspection of reactors;

* standards for operator training and internationally sanctioned licensing, with full exchanges of current experience between countries;

* development of site selection criteria and co-operation on the siting of nuclear installations (fuel-enrichment plants, reactors, reprocessing plants, radioactive waste storage repositories);

* a major internationally supported project to review existing safe reactor designs and to develop, build and run an inherently safe reactor with a view to providing a new generation of "fail-safe" power units;

* conformable minimum radiological protection standards;

* full governmental ratification of the conventions on "Early Notification of a Nuclear Accident" (including the development of an appropriate surveillance and

monitoring system); and on "Assistance in the Case of a Nuclear Accident or Radiological Emergency" as recently developed by IAEA;

* post-accident training, for containment, decontamination and long-term clean-up of affected sites, personnel and ecosystems;

* development of a code of practice on liability and agreed strategies on compensation, including methods of costing out current and future "committed" damage;

* development of agreements on the transboundary movement of all radioactive materials, including fuels, spent fuels and other wastes by land, sea or air; routine and accidental discharges from nuclear installations;

* exploratory discussions on the special problems posed in the future by the development of nuclear powered shipping;

* projects to design and build experimental waste repositories and for the decontamination and dismantling of time-expired nuclear reactors so that much needed international agreement can be reached on the safe disposal of radioactive waste materials;

* consolidating the Non Proliferation Treaty with vigorous efforts to increase its membership and the efficiency of the system of international guarantees so that non-proliferation of sensitive technology and materials can be handled in the stricted possible manner.

83. Until these problems are accepted as being solved to the general satisfaction of the international community, the period ahead, up to the year 2000, must be

regarded as "transitional from nuclear energy as currently practised" and a nuclear "interlude" to a radically different and safe nuclear future.

84. These conclusions represent a tremendous challenge to nuclear and non-nuclear governments alike. But the rapidity which which the two IAEA conventions on "Early Notification" and "Assistance" were drawn up is indicative of what can be achieved when, as noted by IAEA, there is "the political will to arrive at a consensus". Many international bodies concerned with radioactivity, human health and environment need to be involved, but the only organization capable of assuming the lead role is IAEA. This agency must be given the authority and resources to strengthen its capacity to handle the very great responsibility of nuclear safety and regulation issues and must be empowered to carry out an appropriate level of enforcement. This regulatory function should be very clearly separated in institutional terms from the agency's role in promoting nuclear energy.

85. The Commission believes that in the long run, generation of nuclear power is only justifiable if there are solid solutions to the unsolved problems to which it gives rise, and that nuclear energy should therefore be regarded as a transitional energy source until more environmentally safe alternatives are economically available. It recommends that the highest priority be accorded to research and development of such alternatives with particular emphasis on renewable energy sources, as well as on means of increasing the safety of nuclear energy.

# VI. WOOD FUELS: THE VANISHING RESOURCE

## 1. The Spreading Emergency

86. 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. Although wood ranks only fourth in the world's energy budget after coal, oil and natural gas (see Table 7-1), almost half the world's population relies on it, mainly for cooking. 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. 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 an absolute minimum of circa. 350 kilogrammes, to a "luxury consumption" of circa 2900 kilogrammes of air-dried wood, with the average being around 700 kilogrammes per person per year.[54/]

87. Although wood fuels are in adequate supply in many countries, as indicated earlier (para 21), they are bing widely over-harvested and are therefore becoming effectively non-renewable. The "fuelwood crisis", as it is called is particularly hard-hitting for the vast number of rural poor whose survival depends on access to local supplies of traditional fuels like fuelwood, cow dung and crop residues, and who lack land to grow wood or cash to buy it. At the same time unprecedented pressures are being placed on the same biomass base from the

agricultural and urban-industrial sectors. 55/, 56/, 57/, 58/ 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 oil or develop new sources of energy. Some forest loss is inevitable, of course, to make way for human settlements, agriculture and industry. But deforestation may cause soil degradation and erosion, siltation of reservoirs, reducing electricity production, flooding and loss in agricultural yields.[59] Thus, the continued rapid loss of forest cover can be environmentally, and hence economically, very serious for the regions concerned.

88. 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, fuelwood used in the rural areas comes from a mixture of sources, such as from scattered trees around villages, along roadsides, and boundary forests. 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 by cutting branches from trees. When fuelwood is in short supply, people normally respond by economizing in consumption; and when it is no longer available, rural people are forced to burn biomass wastes, such as cow dung, rice husks, cotton stalks and weeds. 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 biomass, etc..), and this may lead to soil deterioration. Eventually,

however, extreme shortage of every sort of biomass fuel leads inevitably to reducing the number of cooked meals, and shortening the cooking time for individual meals, which in the end means more malnourishment and degraded lifestyles.

89. The resolution of the wood fuels crisis in developing countries is an essential pre-condition for their future development. On the one hand, energy needs both in the rural and urban areas must be met, either with additional wood, or other biomass or alternative energy sources. 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 to proceed. Although wood will be superseded in many cases by cash economy fuels, such as kerosene, liquid propane gas or electricity, especially in town, it can also become a major primary energy source for conversion to liquid fuels, gases and electric power.

90. 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. There is, however, a new opportunity to tackle the problem afresh. 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.

91. 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 savings

would translate into money saved. 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 also use much less fuel should be made available much more widely in urban areas.

92. Although charcoal is a more convenient, cleaner fuel and much reduces eye irritation and respiratory trouble experienced from wood smoke, 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 using earth conversion pits where 100 kilogrammes of wood yield only 10-15 kilogrammes of charcoal. What is needed is their replacement with charcoal co-operatives or boards which could be involved in the planting of trees and marketing the product made in brick or metal kilns, in which 30 kilogrammes of charcoal per 100 kilogrammes of wood is readily obtained. 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. Efficiency measures, however, will only buy time for wood supply enhancement measures to be introduced.

93. Commercial forestry operations do not generally make sense for the provision of fuelwood in rural areas, but they can do 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 sometimes be planted successfully to provide wood fuels for the urban consumers. The additional environmental benefit of having a green zone around the city is not negligible either. 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. Some iron and steel industries in developing countries 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. Sometimes, especially in the initial stages, fiscal and tax incentives are necessary to get planting projects going. In a second stage these can be tied to success rates for tree growth, and can eventually be phased out. In urban areas, there are also relatively good prospects for increasing the supplies of alternative energy sources, such as electricity, liquid propane gas, kerosene and coal. 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.

94. 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 fuelwood available locally where the demand is to be met, and not in distant regions and forests where transport costs make it too expensive to obtain. The best way to do this is by employing various agro-forestry 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.

95. 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.[60/, 61/, 62/, 63/] Suitable solutions will have to be worked out for such local problems by the communities concerned. 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. The role of women in relation to fuelwood needs much more attention than hitherto. Since women are the main actors involved in the collection and use of fuelwood, development projects related to fuelwood must involve women much more.

## VII. ENERGY EFFICIENCY: MAINTAINING THE MOMENTUM

96. From the discussion so far, it would appear that as global population increases into the 21st century and as development proceeds, there will be a strongly increased demand for energy services. If the efficiency with which primary energy is converted into these services remains the same as at present, this translates into a strong

increase in demand for primary energy. Paragraph 7 above suggests that even to keep par with population growth, primary demand will have to increase over 1980 consumption by one third by 2025. If allowance is made for growth in per capita demand by developing countries (trebling and doubling in "Low-"and "Middle"-income economies respectively) global consumption will almost double. The discussion of the potential contribution which can be made by fossil fuels, renewable energy and nuclear energy suggests that none of these sources can be adequately deployed to meet the additional needs by 2025, although in the long run, renewable energy has the most promising allround potential. This line of argument has not allowed for changes in the efficiency with which primary energy can be used to deliver energy services. Investigation reveals that there is a wide range in the amounts of primary energy needed to deliver a unit of energy services depending on the intrinsic efficiency of the end-use equipment being used and on its state of maintenance and care in operation. Scenarios A, B and C in Tables 7-3 and 7-5 above, all depend for their low primary energy consumption on the fact that a very high level of end-use efficiency must be implemented. Bearing in mind the existing socio-economic, institutional and political inertial constraints to change, it is very unlikely that scenarios A and B can be fully realized by the early decades of the next century. Scenario C, however, has a better chance. Nevertheless, from the preceding discussion it is clearly desirable that energy efficiency should be the cutting edge of national energy policies for sustainable development. Measures to achieve it deserve the highest priority on national agendas. Although impressive gains in energy efficiency have been made since the first oil-price shock thirteen years ago, the recent plunging oil market has delayed or slowed down this progress in several countries. 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 from "best practice" technologies is one third to less than half that of typically available equipment. This is true of appliances for lighting, refrigeration and space cooling, needs which are growing rapidly in most developing countries and putting severe pressures on the available electricity supply systems. It is true of cooking fires and cooking equipment, with all their impacts on the sustainability of tree cover, the recycling of crop and animal residues now burnt for fuel, as well as on soil degradation and erosion. It is also true of agricultural cultivation and irrigation systems, of the automobile, and of many industrial processes and equipment.

97. 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. 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 fiftieth of the illumination of a 100-watt electric bulb and use just as much energy to do so. These examples illustrate the tragic paradox of poverty. It is not shortage of energy, but rather shortage of money which is the limiting factor for the poor. They are forced to live on a meagre "current account", and thus use "free-good" fuels and inefficient equipment, because they do not have the cash or savings to purchase energy efficient fuels and end-use devices. Consequently they finish up paying many times over for a

unit of delivered services. Although it is not possible to quote a figure for the overall investment requirements of an energy-efficient 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 made because of lowered energy supply needs.[7/] 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, street-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.[38/]

98. While there are countless examples of successful energy efficiency programmes in industrialized countries, these programmes still face a large number of difficulties in developing countries. Apart from technological, economic and structural constraints, many consumers, including large industries, do not really know exactly 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 many other methods have been used successfully to increase awareness and they urgently need to be extended widely. These tendencies are reinforced by energy pricing policies that may include subsidies and seldom reflect the real costs of producing or importing the

energy, let alone the external damage costs to health, property and the environment. Countries should evaluate the overall costs to government and society of the different energy options, both renewable and non-renewable, with all hidden and overt subsidies included to see how far the real energy costs can be passed on to the consumer. The true economic pricing of energy - with safeguards for the very poor - needs to be extended in all countries.

99. There are more subtle but no less important price and cost distortions. 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. Remodelling consumer pricing structures so that sharp tariff increases are made to users consuming electricity beyond a certain base-level which is costed at lower than normal rates has this effect. This two tier tariff system commonly used in California and elsewhere is also fairer to the utility needing to install additional supply. Many energy efficiency measures cost nothing to implement. But where investments are needed, they are frequently the main barrier to successful implementation, 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, special small loan- or hire purchase-arrangements 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, ranging from tax credits and loans with favourable repayment terms where

appropriate, to "invisible" measures such as loans repaid by topping up the new, reduced energy bills to the pre-conservation levels, or value added tax relief on the sale of energy efficient end-use devices, or similar types of subsidy measures.

100. Developing countries face particular constraints in this area. They frequently have foreign exchange difficulties which make it hard to purchase efficient, but costly energy conversion and end-use devices. Additionally, many effective measures for energy savings often turn out to be the "fine tuning" of already functioning systems.[64/] These do not always appear as attractive for funding to aid-agencies or local government officials as do new, large-scale energy supply hardware and other installations which are often perceived as more tangible and concrete symbols of progress. The manufacture, import or sale of equipment conforming to mandatory minimal energy consumption or efficiency standards is one of the most powerful and effective tools in promoting energy efficiency and producing predictable savings. Where the equipment concerned is traded internationally, these may require international co-operation. Countries, and where appropriate, regional organizations, should introduce and/ or extend increasingly strict efficiency standards for equipment and mandatory labelling of appliances.

101. 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 frequently a major source of local air pollution and regional acidification of the environment. 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 being exceeded. Indeed, unless strong action is taken, air pollution could become a major factor limiting industrial development in many Third World cities. With higher energy 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, mandatory standards providing for a steady increase in fuel economy may be necessary. Either way, the potential for substantial future gains in fuel economy is enormous; 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.[65/]

102. A key issue is how developing countries can secure similar improvements in the fuel economy of their vehicle fleets especially when their average fleet life is often double that of an industrialized country, leading to halved rates of renewal and improvement. Those countries that import their fleets, could lay down improved standards for new vehicles. However, in those countries where vehicles are assembled under licence with industrialized country manufacturers, the situation is different. The designs are frequently older 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. If the rate of fuel saving fails badly to keep pace with the fuel increases required by the rising demand for more transport, oil importing developing

countries should explore the potential in non-oil based transport fuels. Some actually have. The obvious candidate is ethanol and the experiences of Brazil, Kenya and Zimbabwe are very informative here.

103. 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 one of the main causes of pollution, especially in those countries that have not implemented strong environmental programmes over the past two decades. Most trends point to a very rapid growth of industry around 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 evolving fairly rapidly, undergoing a massive restructuring marked by a shift away from heavy industry towards higher technologies, the substitution of synthetics for natural inputs, and a growing shift towards less energy intensive production and in favour of "hi-tech" and service-industries. 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 by the availability of a skilled workforce, but also largely by higher energy prices. Nowadays, plants that are comparatively energy efficient and hence more economically competitive are common in every industrial sector.

104. During this period, the more energy intensive and polluting industrial processes have tended to accumulate in developing countries. Multinational corporations have often been criticized in the past for installing older or less clean technologies in developing countries, although it is usual and even necessary for industrialization to start-up with the heavy industries such as metal

smelting, cement and brick making which require a less skilled labour force but tend to be intrinsically more energy intensive and polluting. 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 industrial concerns to import plants on a turn-key or similar basis, should ensure that all licences provide for the best available energy- and environmentally- efficient technologies and processes. Moreover, such arrangements should require approval of plans for the safe management of all waste products. Development assistance, export credit and other international financing agencies involved should ensure that all these features are included in the financial plans of the industry. Developing countries often need to decide on the comparative advantage of the home production of industrial components. In suitable cases, the most energy intensive and polluting components might be imported, leaving the others to be made locally, thus achieving a far lower overall energy intensity and environmental penalty for the final product.

105. 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 services utility" with incentives to help existing industries to identify cost-effective opportunities for saving energy, could reduce energy demands by a further one third. Savings of this order will not only improve the competitiveness of a nation's industrial sector but also its balance of payments, reduce its debt requirements and increase the capacity of the environment in the cities of developing countries to accept more development.

106. Agriculture worldwide 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 developing countries through widespread increases in fertilizers, irrigation and mechanization would add 140 million tons of oil equivalent to their agricultural energy use. This is only some 5 per cent of present world energy consumption and almost certainly a small part of the energy that could be saved in other energy sectors in the developing world through appropriate efficiency measures. 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.

107. Agriculture in developing countries, on the other hand, suffers from low or inadequate 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, although it may be difficult to ensure that these gains are distributed equitably. Selective mechanization with small machines and improved use of animal draught 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. 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.

108. Buildings still offer enormous scope for improvement, perhaps the most widely understood ways of increasing the efficiency of energy consumption are in the home and workplace. Buildings in the tropics are now commonly designed to intercept the minimal amount of direct heating from sunlight by having very narrow east and west facing walls, but with long sides facing north and south and shaded from the angle of the overhead sun by recessed windows or wide sills. Such passive design maximizes shade and reduces air-conditioning costs drastically. Conversely, in cold climates, long, south-facing walls are designed to trap the warmth of the low sun. Plastic foam or other forms of cavity-wall and roof insulation together with double or triple glazing are commonly standard features of the carefully draught proofed buildings of many colder countries, where space heating is achieved by time-switched, thermostatically controlled warmth from electricity or fossil-fuels. An important environmental problem in such "airtight" house is the build-up of radiation from the radioactive gas radon, generated from the decay of radium occurring naturally in the building materials derived from some granitic rocks in parts of certain countries, especially Scandinavia and North America. When it is present, it

may confer on average, 50 - 60 per cent of the total annual radiation dosis received by the human body from all sources. In Sweden, various percentages (up to circa. 10) of the total human lung cancer burden have been ascribed to it and under these conditions, a certain level of ventilation is desirable to prevent radon accumulation and avoid the problem altogether.[66/]

109. Another very important method of heating buildings is by hot water, co-generated during electricity production and piped around whole districts to provide warmth and hot water. This extremely efficient use of fossil fuels demands the co-ordination of energy supply with local physical planning which few countries at present are institutionally equipped to handle. Where it has been highly successful, there has usually been local authority involvement in or control of regional energy-services boards, e.g. in Scandinavia and U.S.S.R. Given the development of these or similar institutional arrangements, co-generation could revolutionize energy efficiency in the heating and hot-water provision of buildings worldwide.

110. From the foregoing discussion it is obvious that energy savings, through the efficient use of fuels and power, should be top priority in any national energy policy. The whole battery of measures required to achieve this are already well known and many are referred to in the preceding text; they should be at the head of every national energy agenda. It is technically feasible to save at least one third and commonly a half of the energy currently being used in nearly all sectors of the economy. Not only does it make good sense economically particularly when foreign exchange is involved, it is also the most environmentally benign method of energy management.

111. When energy efficient end-use appliances are being used, the reduction in health and environment impacts from the fuels saved, and from the new power supply installations which do not need to be built as a result of a conservation strategy, are often large. A vigorous drive towards energy efficiency puts pressure on a whole range of investment programmes both large and small in all sectors of the energy economy to replace old, inefficient end-use appliances. This requires a fundamental change in the institutional arrangements for energy. Major investment in more energy supply by utilities has to be phased out and replaced by major investments in energy efficient hardware provision and in energy accounting and energy-services expertise.

112. At present, energy industries providing electricity, oil and gas are very strongly integrated around the complete control of production of the particular energy source and its distribution. Attempts are naturally made to reach back upstream to the primary energy source and convert it. Thus, electrical utilities strive to control hydropower and nuclear energy, gas utilities are interested in coal gasification, whilst oil concerns have considered its liquefaction. By contrast, their downstream management of energy end-use has received less attention up to now. But it would be highly profitable for them to embark on the production, sale or financing of energy-efficient end-use equipment. This now presents an important opportunity for any energy utility and a great challenge to their energy management skills.

113. In practice, this means a fundamental intellectual jump for utilities if they are to provide such services. Such an institutional change requires enthusiastic participation and even organized pressure on utilities by consumers in all the energy sectors in order to keep up

the momentum of change. Ideally of course, it would be far more efficient both in energy and institutional terms to develop agencies responsible for the local distribution and marketing of end-use appliances and also for all forms of energy bought wholesale from the large utilities and retailed to the consumer in the form of complete and efficiently integrated energy services. This could be achieved by private companies, local-authority linked energy boards, co-operatives or any other form of local institution appropriate to the political economy of the country concerned. Such a development is unlikely to occur without determined consumer pressure because of the monopolistic nature of many utilities.

114. The key to this consumer catalysis is a national information campaign to heighten awareness of the economic and environmental benefits of energy conservation. Governments can set up a series of district energy efficiency centres to demonstrate the benefits of efficient building insulation and end-use equipment. Such centres should demonstrate the whole range of energy efficient equipment with all pay-back times and installations services fully detailed. Such centres when set up (as in Jordan), have been extremely successful in educating and generating public action in all energy sectors.