Energy, Environment and International Development

Asit K. Biswas
Department of Environment, Ottawa

Margaret R. Biswas
Biswas and Associates, Ottawa

The present energy crisis is the symptom of a disease, but certainly not the disease itself. The paper traces the several events that happened during the early seventies which contributed to the development of this crisis, even though most of them have taken years, or even decades, in the making. The energy crisis dramatized the fragility of the world economy and the lack of world order.

Historically, as countries have advanced economically, their resource requirements have gone up as well. However, the share of the total energy pie of the developed nations had been gradually diminishing since the Second World War. Their energy consumption would probably come to an equilibrium within the next century but the developing countries would increasingly need more energy, if the anticipated economic growth takes place. Increased oil prices have had a more adverse effect on the developing countries than on the developed nations.

Agricultural yields in recent years have continually increased due to a substantial infusion of energy — in terms of mechanization and higher inputs of fertilizers, pesticides, a host of other chemicals and water. Analysis made of the different types of energy input to the corn production in the United States during 1945 to 1970 indicates that yields have increased over the years due to increasing inputs of energy, and currently, each level of additional energy input produces less and less of the product. Since food is a net product of an ecosystem, it is most important that the production processes should not destroy the very ecological basis on which food production rests.

The paper also discusses the alternatives for energy development, the role of technological developments to alleviate energy shortages, and conservation by more efficient use of energy. The authors conclude that effective policies in the area of energy and the environment can only be developed within a multidisciplinary context.

Introduction

In the sixteenth century, Akbar the Great, the celebrated Moghul Emperor of India, decided to establish a new capital for his vast empire. Accordingly, the best architects available were asked to design a magnificent palace at Fatehpur Sikri, near Agra, in the dry plains of Northern India. The cream of the Indian artisans worked for several years to complete the capital, and vast amounts of resources were spent on the realization of the Emperor's dream. As any traveller to Fatehpur Sikri will attest, it was an excellent testimonial to the Indian architecture. The completed palaces are still intact, untouched by the passage of centuries, which undoubtedly is a note-worthy achievement. The history of the new capital, however, was not so auspicious. Akbar used the new capital for 15 years, and then had to abandon it to return to his old capital rather ignominiously as all available water supply of the area was exhausted.

Fatehpur Sikri is an excellent monument to bad planning. The human history is full of such examples, but the "energy crisis" of 1973-74 will probably go down in history as one of the worst cases. Rising world demand for oil, increasing American, Japanese and European dependence on imported oil to sustain their industries and life-styles, and advance warning by the Arab countries to use oil as a political weapon, should have made the impending energy crisis more evident than was actually the case. It did not require sophisticated computer models to forecast the problem: anyone who could use an abacus could have predicted it!

Unfortunately, all the danger signals were not seriously considered. President Nixon, only a month before the last Arab-Israeli war, said: "Oil without a market . . . does not do a country much good." Most of the so-called energy specialists discounted the Arab threats due to their brief and ineffectual boycott of 1967. They did not realize that the world energy scenarios depend primarily upon four factors — geological reserves, consumption patterns, technological capability and political reality — and the last factor, politics, as it was shown recently, dominates the international oil situation to a great extent. Some have even argued that it is immoral of the Arabs to attempt to change political views by using oil as a weapon. Whatever may be the moral justifiability of such a step, it is certainly not the first attempt to use international trade as a means to change political attitudes. For example, United States monitors and vets the sale of equipment based upon current American technology and knowhow to the Communist countries (this even includes the foreign subsidiaries of the parent American companies), the British Labour Government refused the sale of weapons and aircrafts to Spain and South Africa; and several governments maintain the current embargo on trade with Rhodesia. There are certainly many other such precedents in ancillary areas. Thus, the Arabs certainly did not lack precedents for their course of action, however, unpalatable to Western nations it might have been.

The current public concern with energy crisis is primarily due to a few immediately visible dramatic events, practically all of which were precipitated by the actions of the Organization of Petroleum Exporting Countries (OPEC), either collectively or in groups. Firstly, the Arab boycott of some "unfriendly" Western countries made the average citizens realize to what extent their modern-day lifestyles have become dependent on energy prices and availability. The black-outs and brown-outs, certain long queues of automobiles to obtain gasoline in some areas, and the resulting publicity thereof, made the populace somewhat uncomfortable with regard to availability and reliability of energy supply. Speculations about the possibility of another world-wide depression like the thirties and forecasts of high unemployment rates by the forced closure of industries due to energy shortages created a discomforting anxiety in the public mind. In addition, the OPEC countries, finding themselves in a sellers market after a long interval, successfully managed to increase the price of oil dramatically through their cartel. The rapid escalation in oil prices, after decades of price stability or even decline in real terms, coupled with the fear of possible widespread shortages of an essential commodity, created the present energy crisis.

The majority of energy-related environmental problems have already been discussed in a previous report (Biswas, 1974) and in a series of papers (Biswas, 1974a; Biswas and Durie, 1973; Biswas and Hare, 1974; Biswas and Biswas, 1975). The objective of the present paper is to consider some new developments due to rapidly changing energy scenarios and also to discuss in detail some global parameters which were only briefly considered in the earlier publications.

Part of a Major Crisis

Even though most people have realised the reality and significance of the energy crisis, very few understand the real issues that lie at the heart of the crisis. *The present energy crisis is the symptom of a disease but certainly not the disease itself.* Thus, even if the global energy crisis is successfully solved within this decade (an event that is highly unlikely), all the problems would certainly not be over.

To begin with, several events happened during the early seventies, even though some of them have been years, or even decades, in the making. The most important one is the world population growth which has been constantly increasing as shown in Table 1. An interesting fact is that if one starts with only two dozen individuals a hundred thousand years ago, and assume an average increase of slightly less than 0.02 per cent per year, the present population could then be easily accounted for. The population increase, however, has not been at a constant rate throughout the history, for

TABLE 1
Estimates of Historical Population Growth

Date	Population (Millions)	Average annual increase (%) since preceding date[a]	Years required for population to double
7000-6000 B.C.	5-10		
1 A. D.	200-400		
1650	470-545		
1750	629-961	0.4	173
1800	813-1,125	0.4	173
1850	1,128-1,402	0.5	139
1900	1,550-1,762	0.5	139
1950	2,486	0.8	86
1960	2,982	1.8	38
1965	3,289	2.0	35

[a]Rates for periods prior to 1960-1965 are calculated on the basis of population at mid point of range.

Source: Data compiled from various UN publications.

there have been periods of decline due to "Malthusian checks," as well as periods of rapid increase. What is disturbing is the fact that the highest rates of growth have been continually sustained in the modern period, with marked acceleration evidenced only in the twentieth century. The rate at which the global population is increasing amounts to adding more than 3 new Canadas every year, a new Great Britain every 10 months, a whole United States every third year and an entire Soviet Union every fourth year (Biswas and Biswas, 1976).

To a great extent, we are to blame ourselves for the current population explosion. The concept of societal responsibility for the health and welfare of the general populace, very little considered a century ago, has now been more or less gradually accepted. As a result all governments, including the developing countries, where rapid population growths have created major problems, have accepted and adopted new policies to introduce measures for better sanitation and to control diseases and thus reduce mortality. New technological developments have produced cures for diseases, for which none were available only a few decades ago. For example, the life expectancy of an average Indian male had increased from 26.9 years in 1920 to 41.9 years in 1960, and is now well over 50. This means more people are alive today, and they are living for much longer periods. In addition, it has also increased the most fertile period of women and as a result they are producing more children.

Two other factors besides population, have also significantly contributed to our present collection of crises. Firstly, climate-wise, 1972 was a catastrophic year. Severe droughts or floods occurred in several parts of the world: Sahelian Zone of Africa, Southern Hemisphere, South-East Asia (including China) and the Soviet Union, which triggered a whole chain of perturbations in the availability and price of food grains. Secondly, the world economy came under severe stress in 1972. In addition to the problems of increasing population and rising per capita resource consumption, there was a decrease in mineral production due to slow-downs in several countries for different reasons. It was further compounded by the cyclic resumption of industrial activities in developed countries, increase of 6.3 per cent, compared to two years of relative stagnation, increase of 1.3 per cent in 1970 and 1971. All these contributed to inflationary pressures which resulted in a rapid increase in the price of raw materials. As a result, some prices doubled within a relatively short period, and in some cases increased by three to four times.

The energy crisis probably first dramatized the fragility of the world economy and the lack of the world order. But our present problems transcend this particular crisis, and one would be very short-sighted indeed if one were to concentrate all attention to the energy crisis per se, obfuscated by the fact that the price of oil has increased nearly four-fold within a very limited period of time. As the U.S. Secretary of State, Dr. Henry Kissinger (1974), has pointed out: "Each of the problems we face — of combating inflation and stimulating growth, of feeding the hungry and lifting the impoverished, of the scarcity of physical resources and the surplus of despair —is part of an international global problem." The present energy crisis should be visualised within this overall global framework. Hopefully, the present energy crisis would awaken mankind of the need to make a fundamental reexamination of the present status and way of life, for the good of both present and future generations.

Effects on Developed and Developing Countries

The unprecendented post-war expansion in world economic activity benefited all countries, but the benefits were very unevenly distributed due to their different stages of development. This and the fact that the developing countries had a far larger population growth than the developed countries, made the gap between the rich and the poor nations progressively wider. Admittedly, the developed countries have been providing aid, much needed investment capital and technological knowhow on an ever-increasing scale, but these have not proved to be very effective.

Traditionally and historically, as countries have advanced economically and technologically, their resource consumptions and requirements have gone up. Thus, the developed countries use more energy per capita than developing countries as shown in Table 2. For example, in 1969, the per capita energy consumption in the United States and Canada was 10,779 and 8,819 Kgms of coal equivalent respectively compared to 475 for Brazil, 470 for Algeria, 187 for India and only 29 for Ethiopia.

The future need for energy for societal development can broadly be divided for three categories of nations: developed, developing and the communist world. Ever since the Industrial Revolution, energy requirements of the developed countries have increased significantly so as to sustain their

TABLE 2

Per Capita Energy Consumption For Selected Countries, 1969

Country	Kilogrammes of coal equivalents
Developed Countries	
Australia	5,214
Canada	8,819
France	3,517
Great Britain	5,139
United States	10,773
Japan	2,828
Sweden	5,768
West Germany	4,850
Communist Countries	
Czechoslovakia	6,120
Hungary	2,896
USSR	4,200
Developing Countries	
Algeria	470
Brazil	475
Ceylon	133
Colombia	578
Ethiopia	29
India	187
Iran	366
Mexico	1,114
Philippines	268
Tunisia	248
Venezuela	2,096

Source: Data compiled from various UN publications

population growth and improve their standard of living. Thus, currently the United States uses more energy for the transportation sector alone than the entire energy used for all purposes by the combined population of India, China and the South-East Asia. In other words, 250 million Americans use more energy for transportation than 1300 million people for all purposes taken together.

Even though the developed nations are currently using a lion's share of the total world energy, their share of the total "energy pie" has been gradually diminishing, and this decrease started well before the Second World War. Thus, North America's share of global energy fell from as high as 50 per cent in the mid-twenties to 45 per cent in 1950 and to approximately one-third in 1968 (Darmstadler, 1972). In contrast, the Soviet Union's share of world energy consumption increased from less than 2 per cent in 1925, to 10 per cent just before the Second World War, to 15 per cent in 1968. This changing consumption pattern can be further seen from Table 3. The average annual growth for the developing countries during the 1950

TABLE 3
Energy, Consumption for major areas of the world, 1950 and 1968
(Weights in coal equivalent)

Major Areas	1950	1968	Average Annual Rate of Increase 1950-1968 (Percentage)
World			
Total (million tons)	2,518.8	6,016.1	5.0
Per capita (kg)	1,054	1,727	2.8
Developed Countries[a]			
Total (million tons)	1,866.8	3,774.5	4.0
Per capita (kg)	3,334	5,436	2.8
Communist Countries[b]			
Total (million tons)	512.5	1,744.7	7.1
Per capita (kg)	598	1,550	5.4
European Countries			
Total (million tons)	474.4	1,394.0	6.2
Per capita (kg)	1,659	3,850	4.8
Asian Countries			
Total (million tons)	38.1[c]	350.4	13.1
Per capita (kg)	66	458	11.4
Developing Countries[d]			
Total (million tons)	139.5	496.9	7.5
Per capita (kg)	128	299	4.8

[a]Includes North America, Western Europe, Japan, South Africa and Oceania.
[b]Includes Eastern European countries, the USSR, China, Mongolia, North Korea and North Viet-Nam.
[c]Estimate for China and North Korea only.
[d]Developing countries comprise countries in the Americas, Africa, and Asia, excluding the countries listed in footnotes a, b and c above.

Source: Biswas, Asit K., and Biswas, Margaret. 1974. *Energy and the Environment: Some Further Reconsiderations*. Ottawa: Department of Environment.

to 1968 period was 7.5 per cent; a figure that is higher than developed nations (5 per cent) or Communist countries (7.1 per cent). The table also shows that in spite of the population explosion in developing countries, their average per capita energy consumption increased at a much faster rate (4.8 per cent) compared to those of developed nations (2.8 per cent).

There are several factors which should be considered in any analysis of comparison of energy use between developed and developing countries. Firstly, the developing countries are primarily maintaining a minimum level of subsistence and currently use substantially less energy than the developed nations. For example, in 1969, the per capita energy use in Canada and the United States was 47 and 58 times that of India and 304 and 371 times that of Ethiopia respectively. Thus, even though the average annual rate of increase in energy consumption has been higher in developing countries for the past two decades, this increase is taking place from a very low base, and this means that the gap between the "haves" and the "have-nots" is still immense and would remain so for some considerable time. With unaltered trends, it would take several hundred years to close this gap. Also the low energy consumption of developing countries conceal further disparities between their comparatively prosperous urban centres and rural areas, where most of the population live at subsistence or below-subsistence levels. Transition of these developing countries to more industrial, literate, urban and agriculturally advanced societies would need a further infusion of energy.

The energy consumption in developed countries would probably come to an equilibrium level within the next century for several reasons. Firstly, the rapidly escalating energy prices would reduce demand and promote better conservation practices. Secondly, societies cannot continue to increase energy consumption *ad infinitum* because of realities of resources availability and economics. It is possible that development of new energy sources like fusion, which could be low-cost and "unlimited," could extend the physical limit of energy availability much further than currently anticipated. However, it still cannot be predicted for certain if fusion energy is technologically feasible, and even if it is feasible, its cost is likely to be much higher than currently predicted because of enormous technical and environmental problems which are yet to be surmounted. Even if the fusion energy is assumed to be ultimately possible, and proves to be "cheap" and "limitless," its rapid growth on a global basis could easily be constrained by the lack of ready availability of investment capital, which is a limited man-made resource. Thirdly, environmental considerations could make energy more expensive and could even curtail an excessive use of energy to safeguard human health or quality of life. In some areas, i.e., increase in carbon dioxide level of the atmosphere from energy-related activities, intense debates have already been generated amongst scientists about their overall effects on mankind and environment. Fourthly, it is highly likely that, after a certain threshold, quality of life or standard of living would be less dependent on increased energy use. Finally, population in many of the developed countries seems to be coming to an equilibrium, and this could contribute to eventual levelling of energy requirements in those areas.

Thus, even though the energy requirements of developed nations would probably tend to level-off gradually during the next several decades, the developing countries would increasingly need much more energy than they are using at present, if the hoped-for economic improvement takes place. This means that the developing countries would be increasingly using more and more of world's energy, and by the year 2000, it is expected that North America's share of global energy use would be reduced to about 25 per cent.

Much as though the present energy crisis and oil prices have hit the developed nations badly, the predicament of the developing countries is even worse. Current estimates indicate that *added* petroleum energy costs, both direct and indirect, to the developing countries would be of the order of $10 to $15 billion in 1974, compared to about $4 billion previously. Increased oil prices would result in additional expenditures of more than $60 billion for net importing countries (Jobert, 1974). Figure 1 shows the major oil exporters and importers and the nature of their overall trade. The sudden increase in the price of raw materials and agricultural products during the last 2 to 3 years has seriously aggravated the balance-of-payment problems for most nations of the world community. The situation is far worse for most developing countries whose balance-of-payments deficit have trebled in recent years. Inflation is outrunning aid measures at an ever increasing speed, and during the recent years more than totally used up the entire development aid provided by the developed nations. A better perspective of the situation can be obtained by comparing the total aid received by the developing nations in 1973, and then comparing it with only one additional price increase — that due to oil. The total aid to the developing world was around $8.5 billion in 1973, and their additional oil bill in 1974 was of the order of $10–$15 billion. Had every aid-giving country doubled their contribution in 1974, it would not have even paid their extra oil bill! Thus, the developing countries were in much worse shape in 1974 than they were in 1973. Had the developed countries trebled their aid programs, a fact that was totally unlikely, they might have been able to maintain *status quo*. Thus, energy crisis has hit developing countries harshly — harsh because price rises have been very swift and very great — and the economics of these nations are not resilient enough to absorb these type of hefty price increases without major perturbations in their existing social and economic systems. Since the financial resources of these countries are modest, the extra financial capital due to the energy crisis would have to be found at the cost of other basic major priority programs.

Thus, difficult though it has been for the United States, Western Europe and Japan to reconcile themselves to increased oil prices, it has dealt a far more savage blow to the economy of the developing countries where the majority of mankind lives. The economies of the developed countries would come to an equilibrium after some painful readjustments, but the developing countries would find it extremely hard to cope with the crisis by themselves.

Wood as a Source of Fuel

One major environmental concern of the energy consumption pattern of the developing countries is their marked dependence upon wood as a major source of fuel. Nearly 95 per cent of households in developing countries, where wood is readily available, use it as a primary source of energy (Openshaw, 1974). If we consider all the developing countries, including wood-poor and desert regions, the wood fuel usage rate is around 80 per cent. Nearly 85 per cent (2000 million tons air-dry weight) of the total wood consumption in developing countries can be attributed to its use as fuel. The corresponding figure for the world as a whole, for 1972, is around 65 per cent (2300 million tons), which is equivalent to the burning of 1300 million tons of coal.

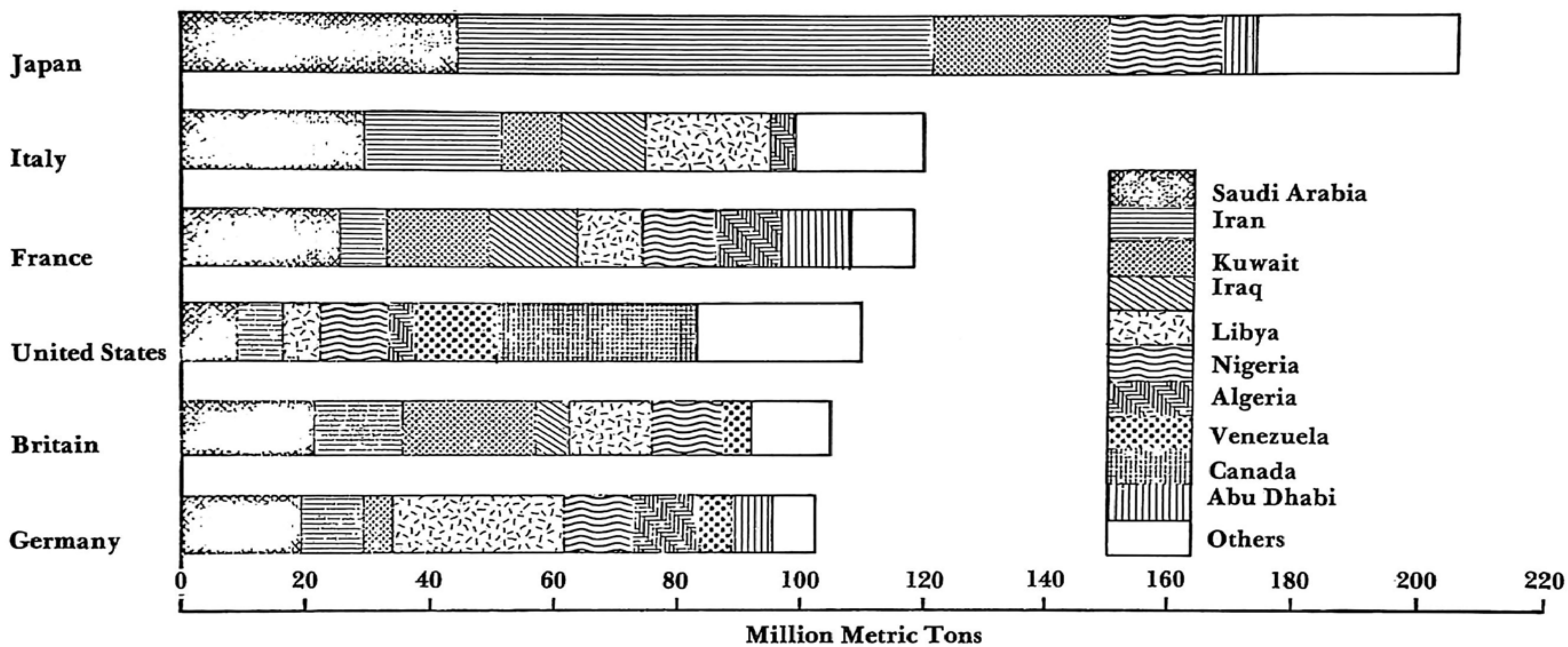

Figure 1. Major Oil Importers and the Exporting Countries, 1972

Source: Biswas, Asit K., and Biswas, Margaret R. 1974. *Energy and the Environment: Some Further Reconsiderations.* Ottawa: Department of Environment.

The per capita consumption of wood-fuel in developing countries is just over 1 ton per year. Table 4 shows the statistics for wood-fuel consumption in three developing countries: Tanzania, Gambia and Thailand. Because of the use of wood as fuel in the developing countries, their forest resources are being continually threatened. The forests are also under added pressure due to the need to provide additional agricultural land to grow more food for the ever-expanding population. The cut-and-burn agriculture poses a serious problem for the developing world.

The per capita use of wood as a source of energy in developing countries is decreasing slowly. All the current data indicate that as people become more affluent and industrialized, they switch to a different form of energy. Experiences in Canada and the United States have been somewhat similar. For example, the contribution of wood to primary energy consumption in Canada was nearly 12 per cent in 1945. Since then, its share of the market has steadily declined, both in absolute and percentage terms, so much so that its share of the total energy consumption has been reduced to only 2 per cent by 1969 (Biswas, 1974, 1974 a). The situation, however, is slightly different in developing countries at present. Even though their per capita consumption is decreasing slightly, the total demand for wood as fuel is increasing in absolute terms due to increase in population — at a rate slightly less than the population growth of the developing world, or about 2.5 per cent per year. Currently there is an excess of demand over supply, and the chances are the gap between the two is likely to widen in the future.

The environmental consequences of significant reduction of forest areas are serious, not only for the developing countries themselves but also for the world as a whole. Forests and woodlands are an important source of oxygen, and currently developing world's woodland account for nearly half of the global forest area. In addition, soil erosion becomes a serious problem due to the removal of the vegetative cover. (Biswas and Biswas, 1976a). Destruction of the forest cover is one of the major reasons for some of the recent Indian floods.[1] Similarly, continual cutting of the firewood in the Sahelian region of Africa has facilitated the rapid southward march of the Sahara desert. Otieno (1974) states that the rich forest resources of Africa are being exploited at such high rates that environmental distortions are already being felt in most African countries.

Deforestation is a typical environment-development problem of the developing world. Rapid escalation of "conventional" energy prices will probably accentuate this problem still further.

Energy for Food Production

No one can deny the success of modern agriculture, including the "green revolution" type of agriculture, in increasing all types of crop yields. This success has been made possible by increasing crop yields through technological innovations (hybrid grains; better fertilizers, pesticide and herbicides; improved farming techniques, etc.) and the presence of a beneficient weather (Alexander, 1974; McQuigg, 1974). The corn yield in the

TABLE 4
Woodfuel Consumption in some Developing Countries

Country	Wood Fuel Consumption Per Capita/year (tons)	Wood Fuel Consumption % of Total Timber Consumption	Population Using Woodfuel (%)	Charcoal Consumption Out of Total Woodfuel Consumption (%)	Urban Population (%)
Tanzania	1.8	96	99	4	7
Gambia	1.2	94	99	26	23
Thailand	1.1	76	97	45	15

Source: Adapted from Openshaw, K. 1974. Wood Fuels the Developing World. *New Scientist*. 61: 271-272.

United States per acre has increased from 34 bushels in 1945 to 38 in 1950, 41 in 1954, 54 in 1959, 68 in 1964 and 81 in 1970 (U.S. Department of Agriculture, 1970). Most crops would show such improvements in their yield pattern.

The success story of continual increase in agricultural yields in recent years is virtually known to each schoolboy, but what is not known is the fact that the modern agriculture has become increasingly energy-intensive during this period. Some major changes in the agricultural sector during the past four decades are briefly examined.

Increase in Farm Size

In the United States, the number of operating farms has been reduced from 6.3 million in 1940 to 2.8 million at present, with nearly 1 million disappearing since 1961. Consequently, average farm size has increased from 167 acres in 1940 to 297 in 1960 to close to 400 acres in 1970 (U.S. Department of Commerce, 1971). During the same period, the farm population has dwindled drastically from about 31.9 million (23.2 per cent of population) in 1940 to 9.4 million (4.8 per cent of population) in 1970 (Perelman, 1972). In other words, during the last few decades, the crop yields have improved significantly, and at the same time average farm size has increased but the number of farm workers has diminished. The situation is very similar in Canada, Great Britain or any other developed nation. This apparent dichotomy has been made possible by rapid industrialization, which, in turn, has made modern agriculture highly energy-intensive (Biswas and Biswas, 1975).

One may then legitimately ask how such as apparent dichotomy can take place. The answer, however, is fairly simple. This was made possible by vast infusion of energy. In an era of cheap energy prices, such massive and rapid industrialization of the agricultural production practices made economic sense. However, in a different era, when energy prices are high and the point of diminishing return has been reached in many instances, the present production practices have to be re-examined and perhaps reoriented.

Increase in Physical Inputs

Machines, however, are not the only form of energy input into the agricultural production process that have increased significantly in recent years. The use of fertilizers, pesticides, herbicides, propionic acid for grain preservation, and a host of other chemicals which all need further energy for their manufacturing processes have been increased. For example, 9,000 Kcal, 1,450 Kcal and 1,000 Kcal, of energy are necessary to manufacture one pound of nitrogen, phosphorus, and potassium fertilizers respectively. Further energy is necessary to apply these and other chemicals to the land and also to manufacture the machines that are used for their application. In addition, modern agriculture has been consuming more and more fertilizers, insecticides, and herbicides. Table 5 shows the increase in the num-

TABLE 5

Selected examples of energy inputs to agriculture in different countries of the world in 1966 and 1973.

	Tractors		Combines[a]		Fertilizers in thousand tons[b]: Nitrogen		Phosphate	
	1966	1973	1966	1973	1966-67	1973-74	1966-67	1973-74
Australia	300,859	342,400	64,744	63,300	108	176	979.7	1,170.6
Brazil	108,900	185,000			71.1	405	91.6	725
Canada	586,905	656,800	165,580	181,500	276.7	530	374	505
China (Mainland)	88,000	170,000			2,010	3,815	538	1,389.7
Egypt	14,500	18,500			243.8	330	43.4	75
Ethiopia	800	3,400	10	130	1.2	9.1	1.5	10.1
France	996,422	1,454,900	102,068	152,700	103	206.4	1,363.8	2,152.4
Germany, West	1,164,113	1,418,056	124,000	171,000	888.6	1,100.8	791.8	916.7
India	48,000	69,600			830.2	1,835	274.6	634
Japan	36,084	283,000			852.7	897.3	613.6	792.9
Kenya	5,729	6,700	910	1,200	11.8	20.4	16.6	20.7
Saudia Arabia	400	860	80	230	5.1	4	3.1	1.2
USSR	1,613,000	2,180,000	519,700	670,000	2,656	6,256	1,664	2,699
UK	475,000	465,000	64,000	64,600	759.8	980	439.1	434.6
United States	4,800,000	4,376,000	895,000	698,000	5,467.7	8,277	3,905.1	4,600
Zaire	850	1,100			1.3	3.2	0.4	1.6

[a]Combined harvester-thrashers in use
[b]Fertilizer year, 1st July-30th June

Source: Biswas, Asit K., and Biswas, Margaret R. 1975. *Man's Impacts on the Terrestrial Ecosystem: Food-Energy Interrelationships.* Key-note Address to the International Conference of Scientists on the Human Environment.

ber of tractors, combined harvesters, and trashers, and the amounts of nitrogenous and phosphatic fertilizers used, in some selected countries of the world from 1966 to 1973. The data used in this table have been compiled from various United Nations publications.

Modern agriculture has been consuming more and more fertilizers, insecticides and herbicides. The average nitrogen fertilizer requirements per acre of corn in the United States has steadily increased from 7 lbs in 1945 to about 112 lbs in 1970 — a 16-fold increase in 25 years. During the same period, the use of insecticides and herbicides has gone up from zero to 1 lb. The gradual increase in energy input for corn production during the years 1945 to 1970 is shown in Table 6.

TABLE 6
Average Energy Input Per Acre of Corn Production

Inputs	1945	1950	1954	1959	1964	1970
Labour (hours)	23	18	17	14	11	9
Machinery (10^3 kcal)	180	250	300	350	420	420
Gasoline (gal)	15	17	19	20	21	22
Nitrogen (lb)	7	15	27	41	58	112
Phosphorus (lb)	7	10	12	16	18	31
Potassium (lb)	5	10	18	30	29	60
Seeds for planting (bu)	0.17	0.20	0.25	0.30	0.33	0.33
Irrigation (10^3 kcal)	19	23	27	31	34	34
Insecticides (lb)	0	0.10	0.30	0.70	1.00	1.00
Herbicides (lb)	0	0.05	0.10	0.25	0.38	1.00
Drying (10^3 kcal)	10	30	60	100	120	120
Electricity (10^3 kcal)	32	54	100	140	203	310
Transportation	20	30	45	60	70	70
Corn yields (bu)	34	38	41	54	68	81

Source: Adapted from Pimentel, D. et al. 1973. Food Production and the Energy Crises. *Science* 182: 443-449.

From the above discussion, it is clear that food production has increased significantly over the years, but this has been made possible with ever-increasing inputs of energy. As the level of production intensity increases, each level of additional energy input produces less and less of the product.

The extent of energy-intensiveness of modern agriculture can be visualized by the following calculations. Let it be assumed that corn represents the typical energy input for crop production (its energy requirements is between the extremes of high-energy demand fruit production and low-energy demand small grain production) and that North American type of agriculture would be used (optimistic) to feed a world population of 4 billion (estimate for 1975 by UN). In 1970, corn required an energy input of 2.9 million Kcal per acre, equivalent to 80 gallons of gasoline (Pimentel et al, 1973). Under these assumptions, energy equivalent of 488 billion gallons of fuel would be needed to feed a population of 4 billion for one year on an average U.S. diet. At this rate of energy consumption, and if it is further assumed that only petroleum is used as the necessary energy input for food production, the total proven world petroleum reserves would only last for 29 years, if used exclusively for the agricultural sector. If the potential crude oil reserves is considered to be 2000 billion barrels, an estimate that seems to be mostly favoured (Warman, 1971), it would last approximately for 107 years, if used exclusively for food production under the same set of assumptions.

The urgency of increasing the world's food production should not be underestimated. It is vitally important, however, to ensure that the strategies adopted to increase food production on a short-term basis can be sustained and effectively integrated with long-term policies. There is a very real danger that, in order to increase food production in the short run on a crisis basis, strategies may be adopted which are self-defeating in the long run. In other words, there is a real possibility that the situation may become far more precarious in the mid- or late-1980s, when the demand for food would be much higher than it is today — due to both higher population and increased levels of affluence. This threat comes from the likelihood that food production will level off, or even start to decline, with our present acceptance of and reliance on short-term, *ad hoc,* and self-defeating ecologically unenlightened strategies. History is replete with telling examples from all corners of the world. As Dr. M. K. Tolba, Executive Director of the U.N. Environment Programme, pointed out in a very far-sighted speech at the World Food Conference at Rome (1974), man must realize the importance of maximizing agricultural production without destroying the ecological basis on which the entire food-production system rests, and this maximization must be done on a long-term, sustaining basis (Biswas and Biswas, 1975).

Protein and Hydrocarbon

One of the major problems facing the world at present is the protein shortage. Protein is the basic life substance of the cells, which constitutes the protoplasm, and next to water, is the most important ingredient of the human body. Living organisms, including man, need at least 12 per cent of their calorie intake in the form of protein. This simple fact, however, is often overlooked. For example, when agricultural efficiency is discussed, the yield per unit area is considered. Thus, we have been preoccupied with *quantity* of food and not with its *quality*. Result of this type of thinking is manifested in the fact that cells of present-day hybrid corns are being filled with carbohydrate at the expense of protein. Hence, protein concentrate is to be added to this type of corn to be fit for hog-feed whereas, prior to the agricultural revolution, it was not necessary. Expressed in a different way, "a piece of cheese or ham has to be added to the sandwich to become equivalent in terms of nutritive value to the same sandwich without any additions around the turn of the century." (Borgstrom 1969).

The "protein crisis" of the world is much worse than the "calorie crisis." More than enough calories for the entire world population could be provided by simply growing sugar beets in the northern part of the United

States and sugar cane in the south (Brogstrom, 1973). The protein shortage of the hungry world is much worse than calorie deficits. Thus, the war against world starvation can never be won unless calories and proteins are considered simultaneously.

One of the exciting possibilities open to mankind is the conversion of hydrocarbons to proteins. Proteins can be produced from hydrocarbons by the process of fermentation wherein microorganisms such as bacteria, yeasts and molds grow in the presence of feedstock. The idea is that the cells thus grown would provide an important source of protein. Based on current research results,[2] it can be predicted that large-scale production of proteins from hydrocarbons would become commercial toward the end of this decade or early 1980s.

Currently, several U.S. oil companies are building or planning to build small demonstration plants for production of proteins from hydrocarbons. The major effort so far has been on producing animal feed supplements which are currently somewhat more expensive than soymeal products. However, as the price of soybean increases, or for the countries that have to import soybean, the commercial viability of large-scale protein production is a distinct possibility. British Petroleum has already two plants selling protein products in the European market. Amoco Foods Co., a subsidiary of Standard Oil Co. (Indiana), has constructed a multi-million dollar plant which would for the first time produce proteins from hydrocarbons for human consumption on a commercial basis. The plant would produce more than 10 million pounds of tortula yeast per year. The yeast, a natural ingredient used for several years in a variety of foods, contains more than 50 per cent protein as well as other valuable vitamins and minerals. It would be grown on food-grade ethyl alcohol made from petroleum, and according to Standard Oil, would meet all the food regulations of the U.S. Government.

Petroleum resources can thus play an increasingly important role in alleviating the world malnutrition. And yet, this is one of the significant factors that has not yet been considered by any country in establishing a national energy policy. In fact, some have even short-sightedly argued that all hydrocarbon resources should be utilised as if they are "going out of style." The rationale behind this type of argument seems to be that technological developments in the energy field would make hydrocarbons obsolete in the next few decades, and hence the country should use them before they become obsolete. What is not realized is the simple fact that the same technological developments which they claim would make hydrocarbons obsolete as energy means, do also have the capacity to provide new uses for them, one of them being the manufacture of proteins.

Production of proteins from hydrocarbons is a major breakthrough for a protein-short world, especially if a year's supply of protein for every man, woman and child in Canada can be produced from only 1.5 per cent of the petroleum currently being used in the country.

Technological Innovations

There has been considerable controversy on the role of technological development on the future energy scene. On one extreme, it is suggested that since the total quantity of oil, coal, natural gas and other natural resources available in this world is finite, and the global requirements are going up on an exponential scale, man would run out of these resources within a frighteningly short period of time (Meadows et al, 1972). This school of thought has not considered the possible effects of technological developments which could substantially alter the picture. On the other extreme, it is suggested that all these doomsday projections are nothing but nonsense and "science-fiction" (Maddox, 1972; Beckerman, 1972). They conclude that "mankind will go on bumbling along in the same way as he has done before". There are certainly serious problems ahead, many of which are age-old problems like poverty, disease, prejudice, crime, inequality, population, etc., which man should be able to handle. Beckerman has suggested that a "Club of Athens" of the 5th Century B.C., using similar types of facts and techniques as the Club of Rome, could have predicted that the world was heading for disaster. By extrapolating the trend of timber shortages and pointing to the overpopulation of Athens, the "Club of Athens" could have concluded that they must renounce growth and give up hope of providing everyone with a timber house, a bronze statue of Poseidon in the back garden and a white-ground Lethykos on his mantelpiece!

The truth probably lies somewhere in between the two extreme viewpoints. For example, the present energy crisis is certainly not the first one faced. There was at least one before — around 1865 to 1867. Up until that period, the major energy source for artificial lighting in North America and Europe was whale and sperm oil. Since other alternative energy sources were not available, artificial lighting more or less depended exclusively on whaling industry. As pointed out earlier, one really did not need a sophisticated mathematical model to predict that there just was not enough whales in the world to satisfy the rapidly burgeoning demand for whale oil. Since the supply did not keep pace with demand, price of sperm oil rose from $0.43 per gallon in 1823 to $2.55 in 1866, and whale oil rose from $0.23 per gallon in 1832 to $1.45 in 1865 (Biswas and Biswas, 1974).

Besides the price increases, there is another similarity between the two energy crises. Like the present one which was due to the Middle East war, the history's first energy crisis was precipitated to a great extent by the American Civil War. The Civil War not only increased the demand for these types of oil, but also disrupted their production and distribution. Some of the whaling ships were conscripted and others were captured or destroyed by the Southern confederates. Consequently, the number of American whaling ships declined by more than 50 per cent and total tonnage by more than 60 per cent. This boosted the price of sperm oil to $2.55 a gallon in 1866.

The scarcity of these oils and the resulting price increases brought in a whole set of new forces into play. There was a growing incentive to develop new alternatives to these products, and this created new investment which accelerated the rate of search for alternatives. New technology was developed which made it economical to produce gas from coal in Europe. By 1867, new refining processes made it economical to refine kerosine from crude petroleum, which was first discovered in Pennsylvania in 1859. These two technological developments in Europe and North America solved the first energy crisis. They also made whale oil lamps antiques by 1896, and reduced the price of sperm oil to $0.40, cheaper than it had ever been in any earlier recorded period.

The above example is cited to indicate that many of the latter-day Cassandras have significantly underestimated the power of technological developments and economic marketforces that come into play in a resource-scarce society. This, however, does not mean that the other extreme school of thought, which categorizes our increasing resource consumptions as of no major significance is correct either.

This school suggests that as resources are used more and more, they become scarce, and thus create economically negative feed-backs, that is, increasing scarcity of any resource (including energy) would lead to an upward trend in its price which, in turn, would provide the necessary incentives to new exploration, further recycling and development of substitutes. In other words, resource scarcity and the resulting economic forces would provide the necessary stimulus to technological developments which would solve the problems in time.

The second major point of their argument is that even though the resources of the earth are finite, technological developments have so far made it possible and profitable to seek new reserves and develop them. The Russian academician Fedorov (1974) suggests that these developments have made it possible for the proven reserves to grow "all the time, both in total figures and in per capita terms." Beckerman (1972) states:

> . . . total natural occurrence of most metals in the top mile of Earth's crust has been estimated to be about a million times as great as present known reserves. Since the latter amount to about a hundred years' supplies this means we have enough to last about one hundred million years. Even though it may be impossible at present to mine to a depth of one mile at every point in the Earth's crust, by the time we reach the year A.D. 100,000,000 I am sure we will think up something.

In other words, have faith in technological developments: they will solve all problems of mankind!

There are several flaws in these types of arguments of which only the major ones would be briefly discussed herein. Firstly, it is a fact that technological developments have improved explorational and extraction practices in the past. For example, the average grade of copper mined in the United States has fallen from 1.6 per cent in 1936 to 1.22 in 1941, 0.98 in

1946, 0.97 in 1951, 0.84 in 1956, 0.82 in 1961, 0.79 in 1966 and 0.65 in 1971 (Biswas and Biswas, 1976). Also, as the price of copper has increased, there has been more and more substitution as one would expect. The problem of extrapolating this type of reasoning is that it may be possible to take care of 1, 2 or few select resource shortages in our stride, but our capability of taking care of shortages, natural or man-made, of several resources simultaneously is highly suspect. Currently, shortages tend to range from energy to toilet papers — all of which seem to be "necessary" to our present way of life.

Technological developments are not cheap: they need substantial capital investment. Thus, if the total costs of technological developments to devise alternatives for resource shortages as well as the costs of alleviating the problems of hunger, diseases, regional disparities, inequalities, housing, education, etc., both nationally and internationally, are added up, the richest countries of the world, or even group of such countries, would not have enough capital to pay for a significant percentage of the costs. As the productive capacity of the society is limited, the available investment capital is also limited. Since research and technological developments are direct functions of available capital, the extent of their effectiveness in devising new alternatives is also limited. Hence, society cannot and should not put all the eggs in the technological development basket, hoping that the future would be bright and beautiful, leaving man nothing to worry about.

The second problem is that nearly all the technological innovations which have contributed in the past to the development of lower and lower grades of resources have been made possible by increasing use of cheap and abundant energy. The rules of the game have now been completely changed. Energy is neither cheap nor abundant at present, and the era of cheap energy is long past. Some scientists suggest that breeder reactors will make "limitless" energy available again in the future, but even if breeder reactors become a reality and acceptable to society as a whole, energy will certainly not be cheap again. Thus, energy-intensive alternatives cannot be depended on *ad infinitum* to bail us out of our problems.

The third consideration, of course, is the environmental constraints. As more and more low-grade resources are used, more residuals are created which have to be disposed of in environmentally-acceptable fashions. This relationship can change if recycling processes are stepped up. But 100 per cent recycling is not possible or economically feasible, and hence after some time the point of diminishing return would be reached. There is, however, no doubt that we have quite far to go before such a point is reached.

Thus, looking at the whole scenario objectively, we neither share the views of the latter-day Cassandras who say that mankind would hardly survive the next hundred years, nor the views of the high priests of technology whose unbridled optimism would make one believe that marketforces would precipitate suitable technological developments at every stage, whenever it is needed. However, based on present analyses, we tend to be somewhat pessimistic.

Technological developments would provide new sources of energy, but the question of timing is very important. Research, development and marketing of new products take time and hence it is somewhat unlikely that there would be large-scale use of new sources of energy prior to the year 1990. Even in the case of nuclear energy, which has the most enviable record of enthusiastic support amongst all types of energy research by the governments of several countries, is considered, it has taken nearly 20 to 25 years to arrive at its present imperfect state. It still has not made a real impact on the present energy supply scene and nor has it yet solved many of the major environmental and ethical problems associated with its development and use.[3]

Technological developments have also been responsible in reducing resource demands. The efficiency of power output of the basic machines have steadily increased since about 1770. Thus, the amount of fuel required for the production of one kilowatt-hour of electricity declined from 6.85 pounds of coal equivalent in 1900 to about 0.95 in 1955 — well over a seven-fold decrease in nearly half a century. Although it is going to be increasingly more difficult to attain such major improvements in efficiency of energy production in the future, the general trend would certainly continue.

On a long-term basis, the best alternative energy source may well prove to be direct conversion of solar energy. The thermal power of solar radiation intercepted by the earth is 1.73×10^{17} watts (Biswas, 1974), which is nearly 5000 times all other combined steady fluxes of energy. In addition, it is a continuing source of energy: one that would not be depleted even over a geological period of time. Probably, the best areas to tap solar energy would be the deserts, where the solar radiation is concentrated, within 40° north and south of the equator. According to Hubbert (1973), the thermal power density of solar radiation in Southern Arizona varies from 300 calories per sq cm per day in winter to 650 calories per sq cm per day in summer. If the lower average figure of 300 calories per sq cm per day is assumed, with a 10 per cent efficiency for conversion to electrical energy, (a figure not unreasonable to be aimed at), then 1 sq km of collection area would yield 14.5 megawatts. Thus, the total area necessary for a 1,000 megawatt plant would be about 70 sq km, and the current U.S. electric power requirements would need a collection area of about 25,000 sq km or 9,000 sq mi, an area that is less than 10 per cent of the Arizona landmass.

The potential for solar energy is particularly promising for developing countries, which for the most part are in the tropics and sub-tropics. These countries have insufficient conventional energy sources, and hence they have to import energy at the current high world prices, which is detrimental to their overall economic development processes. For a developed and resource-rich country like Canada, the potential for solar energy is also significant. It would be of immediate interest to "isolated" communities all over Canada. In future, when the technology and economics of solar energy is well developed, it could be used as a conventional renewable source of energy, and thus release fossil fuels for other important alternative uses. (Biswas and Biswas, 1975). From an environmental viewpoint, even though a detailed environmental impact study has not yet been conducted, one can forecast with reasonable accuracy that it would certainly be more acceptable than nuclear energy to the society as a whole. One does not yet precisely know what new technological and environmental problems man might encounter in this area, but if past experiences are any guidance, one must expect some.

Some energy is certainly feasible technically. It has already been successfully harnessed for water heating and other purposes, and such equipments are now commercially available in many parts of the world. However, much research has yet to be conducted to make large-scale use of solar energy economically feasible and competitive with other existing forms of energy. Since technological innovations depend on the extent and nature of research and development carried out by both public and private sectors, a determined effort to develop solar energy must be made.[4] Thus, the role of all levels of governments is especially important because of the effects of uncertainties and externalities in these types of research and development expenditures.

The total research expenditure on solar energy development is not much. Whatever the present figure may be, it is certainly in thousands of dollars and not in millions. This compares to billions of dollars that have been spent or are being spent on development of nuclear energy. This, in the present era of energy crisis and environmental consciousness, is certainly unbalanced. A much higher level of research and development activities is necessary for effective development of large scale solar energy.

Conservation

Energy and environment are closely interrelated. In fact one can logically argue that the energy policies and environmental concerns, in a very real sense, are cuts of the same cloth. Every stage of exploration, extraction, upgrading, transportation and utilization of energy has an impact on the environment.[5] With ever-increasing production rates, the total discharge of waste materials from energy activities to the environment has gone up as well. Had all these activities been uniformly distributed over the entire country, the resulting environmental problems would not have been so bad. However, ever since the Industrial Revolution, which started the great migration from rural areas to urban centres, human activities are being increasingly concentrated in a few urban regions which means that the environment in a few select areas has to assimilate a variety as well as high magnitudes of residuals. The natural environment in those areas cannot assimilate the waste products as fast as they are produced, which precipitates the environmental problems.

Energy conservation practices may not be able to solve our energy crisis completely by itself, but their contributions to reduce our rapidly escalating energy requirements, and thus as a corollary concomitant environmental disruptions, should not be under-estimated. In addition, it is morally indefensible to use more energy when less energy could perform the same task without social and economic disruption. The overriding counterforce to energy and resources conservation is the basic human desire for convenience.

From a purely conservation viewpoint, the recent oil and natural gas price increases are probably the best thing that could have happened. The dramatic price increase of a generally under-valued resource not only increased public awareness to the problem but also was a good indication to an average citizen that energy, like other resources, should be used prudently. It may be considered axiomatic that when it hurts the pocket-book, people take conservation seriously instead of giving lip service to it. For example, current studies indicate that a 10 per cent increase in gasoline prices would reduce consumption by about 2 per cent in the short run and 8 per cent in the long run. A 10 per cent rise in electricity price would reduce consumption by 9 per cent, and a similar relationship exists for natural gas (Stobaugh, 1974). These are preliminary figures. They should not be taken too seriously but on the other hand, neither should they be ignored completely.

Some have argued that since the energy cost components of total production cost is low (only 3.6 per cent of producer's price in 1963), industry does not have the incentive to use energy efficiently. This has been challenged by Berg (1972), who presents compelling arguments to show that 25 per cent of the total energy used in the United States could be saved by more efficient use. This is not surprising since only a limited number of energy efficiency studies that have been completed so far (Berry and Fels, 1973) carried out a network analysis in terms of materials and energy of the entire automobile manufacturing process. They concluded that the real free energy consumed to manufacture one automobile is 37,275 Kwh. This could be theoretically reduced to only 1,035 Kwh by using the dominant technology presently available. Hannon (1973) suggests that savings of up to 39 per cent could be realized in the operation of certain equipment in the steel industry. Studies by Folk (1972) indicate that if the United States were to shift completely to returnable beverage containers, it would not only result in a national energy savings of about 0.5 per cent but also would increase employment by 130,000 jobs and reduce the consumer costs by $1.4 billion per year. Biswas and Jacobs (1972), and Hannon (1972) have pointed out the rich potentials of energy savings in recycling aluminum, steel, plastic, paper and cardboard.

One of the major reasons why industry has become energy-intensive is because of their practice of trading labor for energy. Automation is probably the major culprit which has increased energy consumption to sustain and improve man's affluence. Admittedly, energy is necessary in the production of commodities, and production is necessary because of consumption. Thus, assuming that all production is necessary (which is debatable), industrial processes have gradually become more energy-intensive and less labour-intensive. For example, during the period 1951 to

1969, the wholesale price index of electrical machinery increased by 50 per cent, but the ratio of production workers' wages to the cost of electricity increased by 225 per cent (Hannon, 1973). Since the only efficiency yardstick of industry is profit, it is not surprising that the industrial decision-makers opted for cheaper machines to replace increasingly expensive workers. This, in turn, gradually increased the energy-intensiveness of the production processes.

The present standard of living can be maintained with somewhere between 30 to 45 per cent less energy by changing production processes, materials, time, modes of transportation and other minor life-style changes. This saving no doubt is very important and worthwhile. However, what is more important is to remember that conservation alone will not solve our energy crisis. If our energy requirements continue to grow at 4 to 5 per cent a year indefinitely, 30 to 45 per cent saving would only buy us a few years — 10 at most. What is essential is that the society as a whole would ultimately have to consider altering our long-range growth pattern, which seems to be an impossible horse to try to keep on riding.

The Future

Some of the developed nations are now slowly moving into a new phase, the post-industrial society (Bell, 1973). Looking back, one can say that much of the present industrial civilization has developed during the past 250 years, and one of its main symptoms has been exponential growth in the consumption of various resources, mostly within the range of 4 to 8 per cent a year. For example, the world electrical power generating capacity is increasing at 8 per cent per year, with a doubling time of 8.7 years. During 1950 to 1969, world energy consumption increased by an average annual rate of 4.6 per cent, liquid fuels by 7 per cent, natural gas by 7.8 per cent, and hydro and nuclear energy (combined) by 6.4 per cent. The total number of automobiles in the world and the number of miles flown by scheduled civilian aircrafts is doubling every 10 years. The world population, as mentioned earlier, would now double in 35 years.

What are the implications of these types of growth rates? In some cases, man may withstand another doubling, and in others, maybe several doublings. Where this point of no return is, one really does not know. Nor does one know how to estimate it with reasonable accuracy because of the extreme uncertainties associated with the forecasting of the future, especially in the areas of technological innovations and changing societal norms and values. What is known, however, is a fundamental principle of ecology: there is no such thing as a free lunch. One has to pay for it sooner or later, and the real problem is that it is not known when one may be called upon to pay for the free lunch, probably with compound interest.

The simple truth is human society cannot have prosperity without responsibility. So far mankind has clamoured for prosperity, but has generally tended to shy away from the resulting eco-environmental responsibilities. Society as a whole has yet to fully recognize that the "good life" is as much based on quality as on quantity. Growth may not be bad: in fact some forms of growth are positively beneficial. The problem is to decide what forms of growth would improve our life-style and what forms would be detrimental. A conscious effort should then be made to maximize the advantages and minimize the disadvantages. We have enough faith in the humanity to say that it can be done, but we are pragmatist enough to say it would need a new mode of thinking and development of new patterns of attitudes and perceptions. The transition would be painful for many people.

Unfortunately, there are no quick and easy solutions. Contrary to certain doomsday prophets, one should not blame technological developments for all the present problems. In fact, faced with a faltering global economy of physical scarcity, science and technology could be man's most precious resource, and must be used judiciously to solve the problems, some of which they might have even helped to create.

In the area of planning, it seems that man really has not learned much from past mistakes. For example, current developments indicate gradual transformation toward an "electrical society" around the year 2000, whence it seems, a significant portion of electricity would be generated by nuclear reactors. Assuming society does go that route[6] to an electrical age, its consequences on resource industries, say, steel or copper, have not yet been cursorily analyzed, nor has it been analyzed what would the total cumulative effect be on the ecology and environment. If all developed countries, especially North America, Western Europe and Japan, simultaneously move toward the electrical society, would the "energy crisis" be substituted with another resource crisis? Man could very well face another "crisis" in an essential ingredient for such a pattern of development, because of natural reasons or because adequate production planning was not done in advance. Thus, we seem to be continually engaged in incremental *ad hoc* planning rather than total comprehensive planning (Biswas, 1975, 1976).

Effective policies in the area of energy and environment can only be developed within a broader context of social policy: these cannot be developed solely on the basis of available scientific and technical information. So far, no country has really faced up to the basic task of making political decisions about their future. We have not really asked ourselves what type of society we want for a specific country, say Canada, by the year 2000 or 2020. As Caldwell (1973) suggests: "If a society cannot, or will not, discover what it is doing and if it does not evaluate its trends and probable futures against some criteria of well-being, it is difficult to see how it can evaluate second- and third-order decisions regarding energy and environment; thus, a foundation for rational decision-making will not be present." *Ad hoc* improvisations and incremental decision-making may create more problems than they may solve, and policies based on fickle public emotion and short-term political expediency would generally prove to be liabilities rather than assets on a long-term basis. Neither should a national energy-environment policy be formulated solely on the basis of existing or projected uses of energy or primarily in relation to the interests of energy industries — both public and private.

The final decision on energy-environment policy would inevitably be political, and within a democratic framework this is what it should be. However, it is imperative that the final public choice be exercised intelligently, based upon proper representation of facts and options. This is going to be a most difficult and challenging task. When the problems of unreliable data are considered, accelerated changes in social, economic and technological parameters, and the near-impossibility of forecasting national and global developments, the magnitude and complexity of such a task should not be underestimated. The process may be difficult and challenging, but it also presents a golden opportunity: an opportunity where through a combination of fortuitous circumstances and design, mankind is in a position to decide and shape their future society, and must make the best of this rare and unique opportunity, since opportunities, once past, cannot be usually retrieved.

FOOTNOTES

1. The consequences of deforestation have been known to man for well over 2300 years. For example, Plato has succinctly discussed the problems arising from denudation of land (Biswas, 1972). It seems that often times, we really do not learn much from past mistakes. Even if the information is available for centuries, as in this case, we somehow do not use it.
2. Much of the advanced research in this area has been conducted by British Petroleum in England.
3. For a detailed discussion of problems associated with nuclear energy, see the chapter 'Energy' by Asit K. Biswas (1974), *In* Human Ecology, edited by F. Sargeant. Amsterdam: North Holland Publishing Co.
4. This is in contrast with the accidental results of individual and uncoordinated inventive efforts. Society just cannot depend on such "accidental" innovations any more.
5. For a detailed analysis of environmental impacts of energy development, see Biswas (1974) and Biswas and Hare (1974).
6. This should not be construed as the authors' endorsement for nuclear power, which still has some fundamental problems to be solved.

REFERENCES

Alexander, T. 1974. Ominous Changes in the World's Weather. *Fortune.*

Bell, D. 1973. *The Post-Industrial Society.* New York: Basic Books.

Berry, R. S., and Fels, M. F. 1973. The Energy Cost of Automobiles. *Science and Public Affairs.* 29: 11-60.

Beckerman, W. 1972. Economists, Scientists and Environmental Catastrophe. *Oxford Economic Papers.*

Berg, C. 1972. Energy Conservation Through Effective Utilization. Washington: National Bureau of Standards.

Biswas, Asit K. 1972. *History of Hydrology, 2nd Edition.* Amsterdam: North-Holland Publishing Co.

Biswas, Asit K., and Jacobs, A. H. 1972. *Solid Wastes Management: Problems and Perspectives.* Ottawa, Canada: Department of Environment.

Biswas, Asit K., and Durie, R. W. 1973. Environmental Implications of Future Energy Alternatives. Paper Presented at the National Congress of the Canadian Gas Association, Calgary, Canada.

Biswas, Asit K. 1974. *Energy*. In *Human Ecology* Edited by F. Sargent. Amsterdam: North-Holland Publishing Co.

——— 1974. *Energy and the Environment, Report No. 1*. Ottawa: Department of Environment.

Biswas, Asit K., and Biswas, Margaret R. 1974. *Energy and The Environment: Some Further Reconsiderations*. Ottawa: Department of Environment.

Biswas, Asit K., and Hare, F. K. 1974. *Energy and the Environment*. In Proceedings of the Ninth World Energy Conference, Vol. 2: Paper 2, Michigan.

Biswas, Asit K. 1975. Mathematical Modelling and Environmental Decision-Making. *Ecological Modelling*. 1:31-48.

Biswas, Asit K., and Biswas, Margaret R. 1975. Energy, Environment and World Development. *Canadian Geographical Journal* 91: 4-13.

——— 1975. Man's Impacts on the Terrestrial Ecosystem: Food-Energy Interrelationships. Key-note Address to the International Conference of Scientists on the Human Environment.

——— 1975. World Food Conference: A Perspective. *Agriculture and Environment*. 2: 15-39.

——— 1976. Environmental Considerations in Increasing World Food Production. *Agriculture and Environment*. Forthcoming.

——— 1976. *Raw Materials and the Environment*. Milan: Encyclopedia Della Sienza E Della Tecnica, Forthcoming.

——— 1976. State of the Environment and Its Implications to Resource Policy Development. *BioScience* 26: 19-25.

Biswas, Asit K. 1976. *Systems Approach to Water Management*. New York: McGraw-Hill Publishing Co.

Blaxter, K. L. 1973. *The Limits to Agricultural Improvement*. Newcastle-upon-Tyne: Newcastle Agricultural Society.

Borgstrom, G. 1969. *Too Many*. New York: Collier Books.

——— 1973. *World Food Resources*. New York: Intext Educational Publishers.

Caldwell, L. K. 1973. Energy and the Environment: The Bases for Public Policy. *The Annals of the American Academy of Science:* 410: 127-138.

Darmstadter, J. 1972. Patterns of Energy Use in the United States. In *Energy, Economic Growth and the Environment*, Ed. S. H. Schurr. Baltimore: Johns Hopkins.

Fedorov, E. 1974. Nature and Society. *Development Forum:* 2: 1-2.

Hannon, B. M. 1972. System Energy and Recycling: A Study of the Container Industry. *American Society of Mechanical Engineering*.

——— 1973. An Energy Standard of Value. *Annals of the American Academy of Science*. 410: 139-153.

Hubbert, M. K. 1973. Survey of World Energy Resources. Paper Presented to the 75th Meeting of the Canadian Institute of Mining, Vancouver, B.C.

Jobert, M. 1974. Statement Made at the Sixth Special Session of United Nations General Assembly on Raw Materials and Development: Document A/PV 2209. New York: United Nations.

Kissinger, H. 1974. Statement Made at the Sixth Special Session of the United Nations General Assembly on Raw Materials and Development: Document A/PV 2214. New York: United Nations.

Maddox, J. 1972. *The Doomsday Syndrome.* New York: McGraw-Hill.

McQuigg, J. D. 1974. *Climatic Variability and the World Food Situation.* Missouri: Environmental Data Service.

Meadows, D. H., et al. 1972. *The Limits to Growth.* New York: Universe Books.

Openshaw, K. 1974. Wood Fuels the Developing World. *New Scientist* 61: 271-272.

Otieno, N. C. 1974. *Africa and the Environmental Challenge.* Kenya: Seminar on Environment and Development.

Perelman, M. J. 1972. Farming With Petroleum. *Environment.* 14: 8-13.

Pimentel, D., Hurd, L. E., Bellotti, A. C., Forster, M. J., Oka, I. N., Sholes, O. E., and Whitman, R. J. 1973. Food Production and the Energy Crisis. *Science* 182: 443-449.

Stobaugh, R. B. 1974. Gas Rationing is no Panacea. *Wall Street Journal* January 4.

Tolba, M. K. 1975. Address to the World Food Conference. Rome: World Food Conference Secretariat.

U.S. Department of Agriculture. 1970. Agricultural Statistics. Washington, D.C.: U.S. Government Printing Office.

U.S. Department of Commerce. 1971. Statistical Abstracts of the United States. Washington, D.C.

Warman, H. R. 1971. Future Problems in Petroleum Exploration. *Petroleum Review* 25: 96-101.