The Fundamental Questions Program and its conceptual basis

Fundamental Questions Paper No. 1

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A. Organisation of the program

The Fundamental Questions Program (FQP) is based on appreciation of the fact that the biosphere, as a system capable of supporting human-kind, will not tolerate indefinitely the present pattern of resource use, energy use and waste production characteristic of our modern society. The program is designed to promote research and systematic discussion on the implications of this fact for human society in general, and for Australian society in particular [1].

The program can be regarded as consisting of three parts (see Figure 1):

I. An integrative biohistorical assessment of the human situation on earth, and especially in Australia.

II. Consideration of the implications of this assessment for the future of Australian society.

III. Reintegration, synthesis and practical policies.

Part I. Integrative biohistorical assessment of the human situation

This part of the program is the responsibility of the Integrating Group of the Fundamental Questions Program at ANU. It introduces the integrative conceptual framework of the program and summarises ecological and biosocial trends in the human situation in historical perspective, first at the global level, but mainly concentrating on the Australian scene. Its emphasis is ecological and biosocial actualities, as distinct from cultural arrangements, which are mainly the concern of Parts II and III of the program. Thus, Part I deals with changes in the biophysical world and in human experience, and discusses the relationships between these changes and societal activities, such as farming, manufacturing, mining and transportation.

Publications arising from this Part of the program will include a background volume, provisionally entitled Australians and the biosphere: a biohistorical appraisal and some fundamental questions. Other papers will be produced, analysing and describing aspects of the situation in biohistorical perspective.

Part I of the program raises important questions about the future of human society relating, for example, to the economic system, social organisation, educational programs and value systems.

Part II. Consideration of the societal implications of the ecological and biosocial assessment.

This part of the program consists of responses of social scientists and other interested individuals and groups to questions about the future of society arising out of the biohistorical assessment discussed in Part I. Participants in Part II of the program, most of whom are likely to be specialists in particular academic disciplines, develop their ideas on possible societal scenarios for the future that would be ecologically sustainable and humanly desirable.

In some cases convenors invite and coordinate contributions from a number of individuals within their own general field of interest (e.g. education, economics), and workshops are being organised to bring together people interested in a particular theme for discussion and debate. Initially, the following themes are
PART I
INTEGRATING GROUP

papers on the conceptual basis of the program

Background Volume
- an ecological and biosocial analysis of the human situation globally and in Australia
- conceptual and historical background
- biophysical environment
- human population
- technometabolism
- some fundamental questions about the future of society

PART II
RESPONDING AUTHORS

Papers and Monographs
- consideration of the implications of the ecological and biosocial analysis of the human situation for the future of world society in general, and Australian society in particular, focussing on such themes as:
  - economic arrangements
  - societal organisation
  - the value system
  - education
  - human health & well-being
  - societal responses to uncertainties

PART III
INTEGRATING GROUP

Papers and Monograph
- reintegration, synthesis, and consideration of the implications for societal policies and action

Figure 1. Structure of the Fundamental Questions Program

receiving special attention in Part II of the program:

- ecological sustainability and the economic arrangements of society;
- ecological sustainability and social organisation;
- the built environment and ecological sustainability;
- education for, and in, an ecologically sustainable society;
- human health and well-being in an ecologically sustainable society;
- societal values in an ecologically sustainable society;
- societal responses to ecological uncertainties;

- energy options for an ecologically sustainable society.

Part II of the program results in the publication of a series of Fundamental Questions Papers, as well as some monographs, each focusing on a particular societal theme. Some of the monographs will be the outcome of the workshops arranged by convenors.

Part III. Reintegration, synthesis and practical policies.

This part of the program is the responsibility of a convenor and a small team of individuals who are experienced in integrative and transdisciplinary scholarship. It will: (1) consider the responses of the contributors to Part II of the program in relation to the ecological and biosocial assessment of the situation developed in Part I; (2) consider the
relationships between the inputs in the different themes of Part II of the program (e.g. education, value systems, economic systems, the built environment); (3) analyse the inputs into Part II of the program in terms of agreement, disagreement, consistencies and inconsistencies; and (4) consider the implications of the recommendations arising in Part II of the program for societal policies at the practical level.

Fundamental Questions Seminars and Informal Discussions

A series of seminars and informal discussions focuses on the implications for the future of human society of the need for a new societal system which satisfies the health requirements both of the biosphere and of the human population.

Publications

The following publications are envisaged:

1. The background volume, provisionally entitled *Australians and the biosphere: a biohistorical assessment and some fundamental questions* (about 250 pages).

2. A series of *Fundamental Questions Papers*, published by the Centre for Resource and Environmental Studies, ANU.

3. A number of monographs, each focusing on a particular societal theme.

It is intended that these publications be both academically rigorous and readily comprehensible to the interested general reader.

Together, the background volume, the Fundamental Questions Papers and the monographs will fill a serious gap in the socio-environmental literature, and it is hoped that they will make a significant contribution to social debate in Australia on these critical issues and ultimately to policy formulation.

B. The conceptual basis of the program: a synopsis

Introduction

The Fundamental Questions Program takes the conceptual framework of biohistory as its starting point, and this framework is used as a basis for the ecological and biosocial assessment of the human situation in Part I of the program [2]. Biohistory may be defined as an approach to the study of human situations which reflects the broad sequence of happenings in the history of the biosphere, from the beginning of life to the present day (Figure 2) [3]. Its starting point is the study of the history of life on earth, the basic principles of evolution, ecology and physiology, and the sensitivities of living organisms and ecosystems. Next it considers the evolutionary background, biology and innate sensitivities of humans, and the emergence in evolution, and the biological significance of the human aptitude for culture.

It then focuses on the interplay between the processes and products of culture and biological systems, including humans themselves as biological organisms and the ecosystems of which humans are a part.

The word 'culture' in this context is taken to mean the various abstract aspects of human societal systems, including beliefs, knowledge, assumptions, values and technology (i.e. technical know-how). Also considered as an aspect of culture are the various cultural arrangements that arise in society through the aptitude for culture, such as the social hierarchies, institutions, social organisation, the economic system and legislation (Figure 3).

Especially important among the consequences of human culture, from the standpoint both of the ecosystems of the biosphere and of human experience, are various human artefacts, which include for example, all tools, ornaments, machines, works of art, buildings and roads. These artefacts are part of the biophysical environment, and in our conceptual model are regarded as an aspect of the biosphere (Figure 3).

This simple model can also be expressed as a pyramid (Figure 4), reflecting the interdependencies of the three elements. At the base of the pyramid are the underlying biophysical processes of the biosphere which gave rise to humans.
Figure 3. Conceptual model

The biohistorical approach provides a logical conceptual framework for the systematic integrative study of human situations. This framework recognises three important clusters of variables: those pertaining to the biosphere, those pertaining to humans as biological organisms, and those pertaining to culture. Each of the three clusters of variables is itself, of course, made up of many interacting and interdependent parts, and more complex models can be constructed to take account of these different components [4].

An important aspect of biohistory is the study of adaptive processes, biological and cultural, that come into play when societal activities have impacts on biological systems which are disadvantageous, or which are perceived to be disadvantageous, for humankind. It pays attention especially to the processes of cultural adaptation that may be brought into action in response to culturally induced threats to human survival and well-being. Such cultural adaptive responses have been very important in human history; and whether or not humankind survives the next century will depend on the extent to which they are successful in the near future [5].

Biohistory is concerned not only with unravelling and describing significant interrelationships in human ecosystems between cultural and biophysical variables, but also with
the identification of fundamental principles that help us to understand the nature of the constraints imposed on human society by virtue of its dependence on biological systems and processes. Some of these principles derive directly from the biophysical and social sciences, and these include principles relating to thermodynamics, biogeochemical cycles, soil ecology, natural selection, physiology, health and disease, alienation, anomie and corporate behaviour. Others derive from biohistory itself and specifically concern the interplay between biophysical and cultural processes. These include principles relating to the impacts of cultural processes on the health of humans and of ecosystems; the biological consequences of the human aptitude for culture expressed in unnatural environment; somatic and extrasomatic energy flows; biometabolism and technometabolism; the four ecological phases of human existence (see below); technoaddiction; the different forms of biological and cultural adaptation to adverse conditions available to human kind.

One important outcome of the biohistorical analysis of the history of humankind should be mentioned here. In terms both of the ecological relationships between human populations and the rest of the biosphere and of the biological and social conditions of life of humans themselves, human society can be seen as having experienced four distinct ecological phases.

The four ecological phases are as follows:

1. The hunter-gatherer phase, by far the longest of the four phases, lasting for hundreds of thousands of years.

2. The early farming phase, which began in some parts of the world 11,000 - 12,000 years ago.

3. The early urban phase, which began in south-western Asia around 6000-9000 years ago.

4. The high-energy phase. This phase began in Western Europe and North America 150-200 years ago. For ecological reasons (see below), it will be by far the shortest of the four phases.

The most intensive examples of high-energy societies are those of Western Europe, the USA, the USSR, Japan, Australia and parts of southern Africa. However, the impact of these societies and the value systems on which they are based are now felt throughout the world.

From the standpoint of the theme of this paper, the important fact is that the fourth, high-energy phase has a number of outstanding characteristics which are, in the long run, not ecologically sustainable [6].

Ecological and biosocial developments at the global level

The biosphere and human society

The emergence through evolution of the human aptitude for culture was a development of profound significance not only for the human species itself, but also for the rest of life on earth. From an ecological point of view, one of its most important consequences was the fact that it gave rise to a new dimension in the metabolism of human populations.

Even in the time of our australopithecine ancestors, the use of wooden and stone tools involved certain material inputs into the social system and outputs in the form both of intended products, such as tools and weapons, and of waste material, in the form of chips and flakes. Much more significant ecologically, however, was the introduction half a million or more years ago of the deliberate and regular use of fire. Apart from its implications for the material inputs and outputs of society, it meant that for the first time humans were making deliberate use of extrasomatic energy – energy that is distinct from the somatic energy taken into the human body in chemical form as food. This particular use of extrasomatic energy had far-reaching effects on the biology of human populations and the natural environment. It has been estimated that, on average, the amount of energy used by hunter-gatherers in the form of fire was roughly equivalent, on a per capita basis, to the amount of somatic energy used each day by the average individual. Thus, after the introduction of the regular use of fire, the overall amount of energy used by humans (somatic and extrasomatic) amounted to about 2 human energy equivalents (HEE) per day [7].

This additional culture-induced dimension of resource and energy use and waste production by humankind is referred to as technometabolism, [8] as distinct from bio-metabo-
Figure 5. Energy use by the human species and by other living organisms in the biosphere

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while containing the great mass of the total human population, contribute only a small fraction of its technometabolism. In fact, it is generally accepted that the biosphere, as a system capable of supporting humanity, would not be able to survive the hypothetical situation in which the intensity and nature of technometabolism in all countries was equal to that of the present day high-energy societies [10]. Indeed, it is clear that it would not be able to tolerate indefinitely even the present global pattern of technometabolism.

Another significant and revealing measure of societal activity is the per capita technometabolism of human populations. As mentioned above, the introduction of the use of fire in the primeval era already increased the per capita total metabolism to about 2 HEE per day [11]. At present the per capita use of energy in the advanced industrial economies ranges from about 40 to 110 HEE [12]. This increase in extrasomatic energy use is associated with changes in the material inputs and outputs of technometabolism. For example, in the affluent regions each human being uses, on average, about half a tonne of iron every year (about 35 tonnes in a lifetime), and each is responsible for the discharge into the atmosphere of 20-40 tonnes of carbon dioxide a year.

Because of the complexity of biophysical systems of the earth's surface it is impossible, at present state of our knowledge, to be certain which aspect of the biosphere is most under threat, and from what specific cause; nor can we predict precisely how much longer the biosphere could continue to carry this intensifying ecological load before undergoing irreversible changes that would lead to collapse of the system as a habitat for the human species. These uncertainties are a highly significant and inescapable aspect of current reality. Nevertheless, it is important that we do not allow them to mask the certainties, which can be summarised as follows:

1. There are limits to the resilience, absorptive capacity (for waste products and toxic substances) and adaptability of biological systems – a principle which applies as much to the biosphere as a whole as it does to local ecosystems and to individual organisms.

2. The present pattern of increasing intensity of technometabolism in high-energy societies is not sustainable ecologically in the long term: if it is not brought under control through deliberate societal action, it will come to an end either as a result of resource depletion or, more seriously, as a consequence of irreversible damage to the biosphere caused by technological waste products.

3. Ominous changes in the biosphere (the outcomes of which are at present uncertain) are already manifest at regional and global levels. These include the greenhouse effect, the depletion of the ozone layer, the effects of acid rain in northern and southern Europe and northern America, extensive desertification in arid regions and widespread changes in the oceans.

With respect to the future, three possibilities exist. First, as a consequence of the ecological overload imposed on it by human society, the biosphere as a system capable of supporting humanity and civilisation may collapse, bringing the human species to an end. Second, a major ecological catastrophe may occur, but leaving some human survivors, who might then begin a new civilisation, possibly based on wiser patterns of use of resources and energy.

The third possibility is that the dominant culture of the high-energy societies comes to embrace an appreciation of the monstrous ecological absurdity of the current situation, and sets about designing new societies that are capable of existing in harmony with the natural environment, and of satisfying the health needs both of the biosphere and of the human population. That is, it is possible that humans might yet, through their aptitude for culture, overcome the current culturally induced threats to their survival, and move into an ecologically sustainable and humanly desirable fifth phase of existence.

Human experience in biohistorical perspective

Cultural developments since the domestic transition, and especially since the urban transition, have had major impacts on human organisms and populations as biological systems. For example, societal developments associated with urbanisation resulted in human beings experiencing en-
environments and behaviour patterns that were very different from those of their ancestors in hunter-gatherer habitats. Moreover, the advent of occupational specialisation gave rise to greatly increased variability in the quality of human experience even within single populations. These changes in human life conditions led, in turn, to new patterns of health and disease, and to a long series of ‘diseases of civilisation’ including, for example, cholera, typhoid, smallpox, plague, influenza, the common cold, scurvy, beri-beri, pellagra, obesity, diabetes, cardiovascular disease, cancer and the various pathological consequences of drug abuse.

Over the past 100 to 150 years, cultural adaptive processes have been brought into play, especially in the affluent populations. These have greatly reduced the incidence of severe contagious disease and malnutrition. Indeed, one serious disease, smallpox, has been eliminated from the face of the earth [13]. As a consequence of these various adaptive measures, the life expectancy at birth in Western countries is almost certainly higher than at any time in human history (around 76 years male/female average). This contrasts with many Third World countries, where malnutrition, contagious disease and infection with metazoal parasites are still important causes of ill health, although decreasing in incidence in most areas. The life expectancy at birth in India is about 49 years, in Nepal about 52 years, and in Ethiopia about 42 years. [14]

It is apparent that there is a general correlation at present between the intensity of technometabolism in human populations and life expectancy at birth. For example, in the USA technometabolism is running at a rate of about 90 HEE and life expectancy is 76 years, in China the rate of technometabolism is about 5 HEE, and life expectancy 69 years, and in Kenya the technometabolism runs at about 1.0 HEE and life expectancy is 54 years. One of the fundamental questions that we need to ask is whether this correlation is inevitable. Would it be possible for societies to be organised in such a way that human beings could lead healthy and enjoyable lives without consuming resources and using energy at the present per capita rates of the developed countries – rates which are, for example, 20-30 times greater than that of Shakespearian Britain? In this context it is noteworthy that there are a few countries, for example Spain and Cuba, where in the mid 1980s the life expectancy was as high as anywhere in the world, but where the per capita technometabolism was, in energy terms, about one-fifth of that of North America [15].

Ecological phase five

Before turning to consider Australia in biohistorical perspective, a statement must be made about one of the central premises of the Fundamental Questions Program that arises from the ecological and biosocial assessment of the human situation on the global level. In essence, if civilisation is to continue to exist, the present trends in technometabolism (involving continually increasing consumption of resources and use of energy by human beings) must eventually be replaced by a new pattern – a pattern which is characterised by a restored ecological balance between human populations and the ecosystems of the earth, so that bioproductivity is maintained and the biogeochemical cycles remain intact. We refer to this hypothetical phase in human history as ecological phase five.

For the long-term survival and well-being of humankind on earth, it is self-evident that the prevailing conditions must satisfy the health needs both of the biosphere and of human beings. From this starting point, and on the basis of our understanding of the sensitivities of ecosystems and of human organisms, we can recognise certain essential characteristics of an ecological phase five society – a society which is ecologically sustainable and humanly desirable for an indefinite period. We refer to them as ecological imperatives.

Three of these ecological imperatives may be stated as follows:

1. The size of the human population on earth must be relatively stable (or decreasing) [16].

2. The overall technometabolism of human society must be of a kind and of an intensity that can be indefinitely tolerated by the biosphere without interfering with its capacity to support humanity. This will necessarily involve drastically lower levels of use of fossil fuels as sources of energy than is the case at present [17]. It also means that society must not release into the environment dangerous quantities of chemical compounds, such as CFCs and PCBs, or radioactive substances, that have

-
the capacity to interfere, directly or indirectly, with the processes of life.

3. The organisation of society and the economic system must be such that human health, enjoyment of life and high rates of employment are not dependent on high or increasing levels of consumption of the products of resource- and energy-intensive industry, or on activities that decrease the productivity and integrity of ecosystems [18].

The Fundamental Questions Program also assumes that much greater equity than exists at present, in terms of both the satisfaction of human health needs and the distribution of natural resources, should be an essential aim of society at both regional and global levels. This will involve not only decreasing the per capita consumption of resources and energy in the high-energy societies but also increasing it in many developing countries.

These ecological imperatives obviously have important implications for the organisation of society, the economic system, the dominant value system, the educational system and other aspects of societal conditions, including human health and well-being.

Two points need to be stressed. First, the ecological imperatives do not preclude a progressive improvement of the human condition, in terms of equity, health and the quality of life. Indeed, we suggest that such changes would not only be consistent with such improvement, but could favour it. Second, it is appreciated that various palliative technological measures, such as increasing the energy-efficiency of certain industrial processes and of domestic appliances, have the potential to reduce the rate of intensification of technometabolism. Indeed, this has occurred to some extent in recent years during which, as a consequence of fortuitous economic pressures, the rate of increase in release of carbon dioxide in some developed countries slowed from about four percent per annum to one percent per annum (while allowing continued ‘economic growth’ at about four percent per annum) [19]. However, there are definite limits to improvements in the efficiency of energy-use, and there is no escaping the ecological axiom that no ecosystem, or collection of ecosystems, can support indefinitely a continually increasing consumption of resources and discharge of wastes by a population of any species. Homo sapiens is no exception to this law of nature.

The Australian situation

In Australia the transformation from ecological phase 1 to phase 4 has spanned only 200 years. Until the end of the 18th century, a hunter-gatherer society had persisted on the continent for at least 40 000 years. Its main ecological impact had been the result of fire, used not only for providing warmth and for cooking but also, as an aspect of land management, for burning areas of bush.

Since the time of the European invasion, major changes have occurred in the biophysical environment, affecting the patterns and levels of bioproduction, the distribution of flora and fauna (native and introduced), the depth and chemical quality of soil, the distribution and quality of water and, in some areas, the quality of air. These changes have been associated mainly with such societal activities as farming, forestry, manufacturing, building, transportation, mining and tourism. Moreover, the human population of Australia has grown to around 16 million, the great majority of whom are of Caucasoid stock. At the time of the initial European settlement, the Aboriginal population was probably about 750 000: today it is around 230 000. About 3 per cent of the present population of Australia is of Mongoloid origin.

At present Australia is, in most of its ecological and biosocial characteristics, a typical phase 4, high-energy society. Technometabolism is intensifying, and in terms of human energy equivalents, the per capita technometabolism has increased from about 25 HEE in 1950 to nearly 60 HEE at the present time (Figure 6) [20]. This change has been associated with an increasing per capita material standard of living. It is less clear, however, what this dramatic increase in resource and energy use has really meant for people in terms of their enjoyment of life and patterns of health and disease. The intensification of technometabolism has certainly not been associated with the elimination of poverty, nor with an increasingly equitable distribution of material wealth [21].

Let us consider briefly energy use in Australia as it relates to the greenhouse effect. On a per capita basis Australians are among the
major contributors to the increasing concentration of carbon dioxide in the atmosphere, each of us on average being responsible for the release of about 23 tonnes of carbon dioxide per year.

At the global level, it is estimated that a drop in total fossil fuel use of at least 60 per cent (but more likely 80 per cent) will be necessary to bring a halt to the increase in carbon dioxide concentration in the atmosphere. Bearing in mind that some increase in extrasomatic energy use in Third World population is inevitable and desirable, it is abundantly clear that if progressive and unpredictable climatic change is to be avoided, drastic reduction in fossil fuel use in the developed countries is absolutely essential.

On the basis of these considerations, and as a starting point for discussion, the Fundamental Questions Program includes the proposal that as a first step in the rationalisation of resource and energy use for an ecologically sustainable future, we should aim in Australia for a reduction in fossil fuel consumption to one-fifth of the present level, and for a drop in total energy use to one-third of the present per capital rate [22]. This would necessarily involve a great increase in use of extrasomatic energy from renewable sources. The intensity of technometabolism, in energy terms, would be about 20 HEE, which is about the same as that of Australia in 1940 and Spain and Israel in 1984. It is 10-20 times greater than the rate in some Third World countries today. In our view, with all the advances in technology and in the understanding of human health needs of the 20th century, it should be within our capabilities to organise our society so that people can live healthy, enjoyable and rewarding lives at this relatively modest rate of resource and energy use. Ultimately, we suggest, a rate of energy use of about 20 HEE would be a reasonable objective for all human populations, providing the extrasomatic sources are mainly of the renewable and non-polluting kind.

The Fundamental Questions Program

Australian society, as we have seen, is firmly in the high-energy class, and as such it is part of the ecologically unsustainable global high-energy complex. Consequently, significant changes in societal conditions in Australia are inevitable in the relatively short-term future. The Fundamental Questions Program is based on the view that this is an urgent matter, and that it is important that we give a great deal of thought to the implications of the current ecological realities for the future of our society. There are two reasons for this. First, it is clearly desirable that the societal changes come about in as orderly manner as possible, and that they are of a kind that is beneficial both to the human population and to the biosphere. Second, for several reasons we are in a position in Australia to play a leading role at the global level in the process of social change towards an ecologically sustainable and humanly desirable future for humankind [23].
In deliberating about the future of Australian society in this context, we must bear in mind three sets of considerations:

1. Australia will be part of a world society undergoing major changes in patterns of resource and energy use and, inevitably, in societal and economic organisation – changes which will lead, hopefully, to new, ecologically sustainable arrangements.

2. Apart from global issues (relating, for example, to the use of fossil fuels), Australian society must take care of and nurture its own ecosystems, protecting their integrity, diversity and bioproducitivity.

3. Australian society must (a) be such that the health and well-being needs of the human population are satisfied, (b) be such that the basic behavioural characteristics of humans result in specific behaviours which are in the best interests of society as a whole and of the biosphere, and (c) be more equitable than it is at present, in terms of the quality and enjoyment of life, the allocation of material resources and the satisfaction of health needs.

Clearly, the biohistorical assessment of the human situation on earth day raises some urgent questions about the future of our society. The fact that the problems are extremely complex and bear on many different interrelated aspects of the social system cannot be accepted as an excuse for postponing serious consideration on these issues. The aim of the Fundamental Questions Program is to promote systematic interdisciplinary discussion and debate on these questions, and to communicate the outcome as widely as possible.

Notes

1. This program is headed by Stephen Boyd at the Centre for Resource and Environmental Studies (CRES), ANU.

2. These notes summarise the conceptual basis of the Fundamental Questions Program. A more detailed account will be provided in the background volume to the program, provisionally entitled Australians and the biosphere: a biohistorical assessment and some fundamental questions, and in other publications arising out of Part I of the FQP.

3. For more detailed discussion on the conceptual framework of biohistory, see Boyd 1987, Boyd et al. 1990.

4. We have found it is useful to prepare check lists of the components (and processes) of special significance within the three broad areas of interest. These check lists are no more than methodological aids to ensure that, in the integrative analysis of a given situation or option, all the relevant aspects are taken into account. The check lists themselves tell us nothing of the nature or significance of the dynamic interrelationships between the different parts of the system. See, for example, Boyd 1979.

5. For discussion on the processes of cultural adaptation, see Boyd 1987.

6. An ecologically sustainable human situation is one in which the bioproductivity (production of organic matter through photosynthesis) of the ecosystems of the biosphere is indefinitely maintained and in which prevailing conditions satisfy the universal health needs of the human population.

7. 1 HEE is taken to be 10 MJ per day, or about 115 watts.

8. Biometabolism is the input of materials (e.g. food, water, oxygen) and output of wastes (e.g. carbon dioxide, nitrogenous compounds, water) and throughput of energy into and out of human organisms; technometabolism is the inputs of resources and outputs of manufactured products and wastes, and throughput of energy, resulting from technological, as distinct from biological, processes.

9. The per capita rate of use of metal was, however, very low compared with the present day.
10. See, for example, World Commission on Environment and Development 1987, page 14.


12. See, for example, figures in United Nations 1986.


16. The actual size of this sustainable stable population will depend on its pattern of resource and energy use. The biosphere would not be able to support the present world population at a per capita intensity of technometabolism equal to that of the present-day high-energy societies. See, for example, Whittaker and Likens, 1975.

17. For the purpose of this Program, we suggest a target of one-fifth the present per capita intensity of technometabolism of North America. The reasons for this choice are discussed in Boyden et al 1990.

18. The word 'employment' is used here in a broad sense to include all direct or indirect (e.g. wage-earning) subsistence activities that are associated with a sense of personal involvement and purpose.


22. This energy scenario is discussed in more detail in Boyden et al 1990.


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