WORLD DESIGN SCIENCE DECADE 1965-1975

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Phase II (1967) Document 6

THE ECOLOGICAL CONTEXT: ENERGY AND MATERIALS

World Resources Inventory
Southern Illinois University
Carbondale, Illinois, U.S.A.

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THE ECOLOGICAL CONTEXT: ENERGY AND MATERIALS

by: John McHale

World Resources Inventory
Southern Illinois University
Carbondale, Illinois, USA

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Carl G. Nelson - senior research assistant and graphic coordinator.

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Other volumes in this series are:

Phase I	(1963) Document 1:	Inventory of World Resources Human Trends and Needs by R. Buckminster Fuller and John McHale
Phase I	(1964) Document 2:	The Design Initiative by R. Buckminster Fuller
Phase I	(1965) Document 3:	Comprehensive Thinking by R. Buckminster Fuller
Phase I	(1965) Document 4:	The Ten Year Program by John McHale
Phase II	(1967) Document 5:	Comprehensive Design Strategy by R. Buckminster Fuller

N.B. The present volume (Document 6) extends the outline of Phase II given in Document 4, "The Ten Year Program," above.

World Resources Inventory
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Carbondale, Illinois
U. S. A.

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PREFACE

In the second half of the twentieth century, there is a perceptible shift in human consciousness and conceptuality which begins to alter man's overall relations, both to his fellow men and to his planetary habitat. Aspects of this change in conceptuality extend inwardly, from unravelling of the micro life-code at the molecular level, to the successful maintenance of men beyond the earth's atmosphere and under it's oceans, to the outward monitoring of other worlds and galaxies.

A new awareness of the origins, parameters and possible limits of human life and intelligence is engendered in these explorations. In our relation to time, we now begin to probe and plan forward into the future, almost in due ratio to the extent that we successively locate the beginnings of life itself even more remotely in the past.

At the daily level of experience, we may note this increased awareness in more popular acceptance of a 'one world' view. Even where this lacks any positive action, and is most often qualified in 'their world' or 'our world' terms, it still marks a shift toward recognition of the planetary interdependence of the human community and the sustaining system of natural forces within which it exists. Such awareness is due, in no small measure to the swift and myriad diffusion of images and messages in the world communications networks. The repercussions of local events of any large scale consequence for the whole community are rapidly felt and reacted to around the world.

Where tribal man became disoriented when separated from his immediate group and surroundings, and early city/local state, man could barely conceive of any larger territory; we are now in a period when many men think casually in terms of the whole earth. The planet as 'life space' comes as naturally to the grasp as did the previous successive conceptual extensions of childhood area, hometown, region or country.

Accompanying these various expansions of the levels of conceptual awareness is a significant recourse to ecology[1], or ecologically oriented thinking, as a defining framework for their containment and inter-relation. Beginning in botany with the study of the interactions of plants with other organisms, and with their environs, this transdisciplinary approach now begins to encompass the study of large scale regional ecosystems and global interactions and distributions. The role of man, both as symbiotic component and disruptive agency has been particularly focussed upon in recent years.

> Human ecology involves finding out what resources are available in our environment and how to make the best use of them. We have to think, first of all, of all the materials resources -- minerals, water-power, soil, forest, agricultural production -- but we must also think of the non-material or enjoyment resources of the habitat, such as natural beauty or enjoyment, interest and adventure, wild scenery and wild life . . .if man is responsible for the future of this planet, he must pay more attention to ecology -- the science of relations between organisms and their environment.[2]

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[1]Coined by Haeckel in 1873 -- the Greek roots Oikonons, 'house'; and Logos, knowledge.

[2]"Towards a Fulfillment Society", Sir Julian Huxley FRS., New Scientist (Eng.), 27 June, 1963.

The above quotation might almost serve as a definition of our present program -- as it also implies, in making the best use of resources, that we consider the re-design of such uses in more naturally efficient ways. What we have earlier referred to as 'literacy regarding world problems' is essentially contained within such an approach.

The various major problems evidenced in the present disparities between developed and lesser developed regions of the world -- food, shelter, health, life expectancy and education -- may be more clearly defined in terms of ecological imbalances. In adopting such a viewpoint, we can more sharply outline them in operational terms. The urgency of their solution thereby broadens from its present evaluative level, of appeals to the humanitarian concern of the more fortunate few -- to the common self preservation of all.

Within the closely knit interdependence of our now, global, community the continued disparities between have and have not nations may be viewed as a grave threat to the overall maintenance of the human community. The explosive rises in population, the pressures on food lands and other resources, the scale of wastage, disorganization and pestilence now accompanying our 'local wars are also linked in due measure to the revolution in human expectations -- a further, even if negative, aspect of the increase in awareness referred to above. As physical events, these press ever more critically upon the total resources and social energies of the developed regions. As world problems, they go increasingly beyond the capacity of any locally organized effort to mitigate or solve them, in anything but the shortest range.

In these terms, there are no 'local' problems anymore -- such as may be left to the exigencies and dangerous predilections of local economic or political 'convenience'. We have now reached the point in human affairs at which the ecological requirements for sustaining the world community take precedence over, and are superogative to, the more transient value systems and vested interests of any local society!

> The world, then, which the expanding network of electronic communication is fast reducing to a complex but single eco-system, confronts the technological civilization with a profound and growing imbalance . . . The first step towards a human future is the acceptance of responsibility for meeting the emergency in our total environment by creating those generalized human conditions which will at least prevent the system from degenerating further. In the immediate term, the only way we know how to do this is by devoting the necessary physical resources to feeding the hungry; in the mediate term, we must do it by inventing the necessary means to graft our technological knowledge on all branches of the human tree.[3]

As we examine not only the local aspects of such problems within the lesser developed areas, but also their global effects on the more fortunate, it is clear that they form part of a larger context of ecological mismanagement. Wasteful resource-usage, soil exhaustion and spoliation, air, water and earth pollution, etc., are world phenomena. They have

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[3]<u>Technology and Man's Future</u> -- Hasan Ozbekhan, Systems Development Corp., (U.S.), Sp-2494; May 1966.

all been contingent factors on human occupancy of the earth during historical time. Until recently, however, their effects were more localized and their scale relatively small. Now they may affect a whole region or continent in a few years, or in a few days, in the case of radioactive fallout. Most of the problems of the lesser developed regions are all present in greater or lesser degree in the so-called developed regions. All are, in varying measure, contingent upon the 'piecemeal' nature of our present modes of knowledge integration, the gaps between such knowledge, its diffusion and effective application, and the lack of a consistent body of agreement on the physical stewardship of the planet.

In this phase of our program, the focus on the use of key energy and material resources may not be dealt with only in technological or economic and social planning terms. They require setting within the broadest ecological context. It has seemed pertinent, therefore, in this source document to include some introductory materials which may serve to provide some orientation to the overall ecological framework within which the present uses and the necessary re-design of our energy and materials resources may be considered. The future of generalized architecture and environmental planning lies most obviously in this approach.

John McHale
Carbondale, Illinois, USA
June 1967

AN OVERVIEW

Life on earth has been possible only during the past billions of years through the relatively stable inter-relationships of the variables of climate, the composition of the atmosphere, the oceans, and the life-sustaining qualities of the land surface, the natural reservoirs and cycles.

Within the thinly spread bio-film of air, earth and water space around the planet, all living organisms exist then in various systems of delicately balanced symbiotic relations. The close tolerances of many of these relationships have only become known to us, generally through their disruption, in recent times.

> For at least 2,000,000 years, men have been reproducing and multiplying on a little automated space ship called earth, in an automated universe in which the entire process is so successfully predesigned that men did not even know that they were so naive as to think they had invented their own success as they lived egocentrically on a seemingly static earth.[1]

Apart from the comparatively local disturbances of natural cycles occasioned through hunting, herding and primitive agricultural practices, man, until quite recently, did not have the developed capacities to interfere seriously with the major life sustaining processes of the planet. He could live and find food only under conditions restricted by his technological development. The earth surface available to him, with breathable air, water and arable land, was less than one-eighth of the earth area, the remainder -- of the seas,-mountain peaks, glacial and desert areas -- was mainly inaccessible to human habitation or large scale use. Though the evidence of ancient disruption of natural balance is still with us in the form of man-made deserts, e.g., de-forested lands, etc., these were essentially local in their scope and consequences. It is only in the most recent and brief historical period that man has developed sufficient power to be actually, and even more potentially, dangerous to the overall ecosystem -- hence, to the maintenance of the human community within that system.

His acquisition of specifically technological means of gaining control over local aspects of the environ through fire, implements, weapons, etc., is accompanied by the swift increase and geographical spread of human populations. From approximately 20 millions in 3000 B.C., this increased to 500 millions by the 17th Century; in the short interval since then, there has been a five-fold multiplication -- to 2,500 million people. This latter and explosive increase occurs most significantly in relation to the introduction of inanimate energies in machine production; to mechanized agriculture and the use of chemical fertilizers, improved sanitation, general health measures and higher life expectancy.

As each earlier invention had increased the amount of energy and survival advantage available to man, so it had adjusted the ecological balance to favor his increase, with corresponding adjustments in all other living populations within the system. The latest growth change in human population since the onset of the industrial revolutions is, within all previous contexts, an extremely 'abnormal' one -- "It represents, in fact, one of the greatest biological upheavals known in geological, as well as in human history."[2] In the

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[1] "Prospects for Humanity", R. B. Fuller, Saturday Review, Aug. 29, 1964.

[2] Energy Resources, National Academy of Sciences, (U.S.), N.R.C., Pub. no., 1000-D, 1962.

longer range, of course, this expansion may be viewed as the 'natural' evolutionary development of an unique species.

The first fifty years of this new phase, of adaptation and 'species extension through intensive industrialization, seemed to confirm the notion that man could indeed conquer nature -- could free himself from the biological laws governing other species' development. As the series of such technological revolutions has multiplied in frequency and power amplification, this has been somewhat tempered by the equivalent increase of knowledge about the overall effects on the planetary habitat. Both the extended possibilities of human control of the environ and its present and potential limitations have become the focal point of our mid-Twentieth Century dialogues.

Though it has been obvious, for some time, that we cannot simply extrapolate human development in terms of 'natural laws', and that Malthusian and other limits may not strictly apply, there are still many central questions remaining. Since man, as a species, side-stepped the normal biological sequence of evolutionary adaptation through his capacity to externalize his intellectual and physical means, in symbolic and technological systems, he is, in this sense, more directly in control of his own future evolvement. The extent of that control, over the environ and over his own 'uncontrolled' activities within the environ, rests on his capacity to apply himself consciously to an adaptive process which has been largely unconscious.

Through his intelligence, man has enlarged his 'ecological niche' to include the whole planet. His activities are no longer constrained to horizontal deployments around its surface but go increasingly into and beyond the atmosphere, beneath the oceans, and include the transformation of vast amounts of the material resources of the planet to his purposes.

> The mechanical revolution . . . brought into use strata of the earth previously beyond the reach of man. The subsurface was made to yield its wealth both of fossil fuels, the sources of inanimate energy itself, and of the metals required for the application and control of this new energy. Moreover, man pushed his frontiers upward as well. The air became a source of nitrogen; sunshine itself could be more fully used; radioactivity was discovered; and the energy of moving water came to be exploited in different ways and, hence, more fully. Generalizing, one might say that man pushed the exploitation of land vertically, both downward and upward. Land thus ceased to be identical with surface, with a thin layer of soil or surface minerals. It was no longer two dimensional; it spread out into the third dimension, to say nothing of the fourth dimension of the physicist.[3]

The scale of these activities and the expansion, and proliferation, of man-made systems now approach magnitudes in which they directly affect larger and larger areas, sectors and relationships of the overall ecosystem.

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[3] Introduction to World Resources, Erich W. Zimmermann, ed. Henry L. Hunker, (Harper & Row, New York, 1964).

Negative and Positive Aspects

Where such extended controls of man have increased survival advantage for greater numbers of men, and thus forwarded the human enterprise, we may count the overall balance till now as favourable. Our next priority -- toward enormously extending such survival advantage to the greatest number of men -- requires an even more rapid and extensive growth in scientific and technological undertakings on a world scale. This will require taking cognizance, not only of the great positives of our recent acquisition of sufficient material power to carry out such a task -- but also, an immense stocktaking of the negatives which are inherent in the present lack of conscious integration and planning of our major technological systems.

Such systems now comprise not only local industrialization in the sense of mass production factory facilities, but all the globally interrelated systems complexes of transportation, communication, production and distribution facilities. There is no longer a division possible between factory and farm or, in this sense, town and country; all are closely interlocked in a close symbiotic relation -- a man-made ecology which we now see, almost for the first time, as an integrally functioning 'organic' sector within the overall ecosystem.

Agriculture, until recently, viewed as an independent sector of human activity from industry, is now more clearly viewed as a frontier area of scientific and technological attention. It is one, particularly, in which traditional modes are no longer adequate to the complexity and size of immediate requirements.

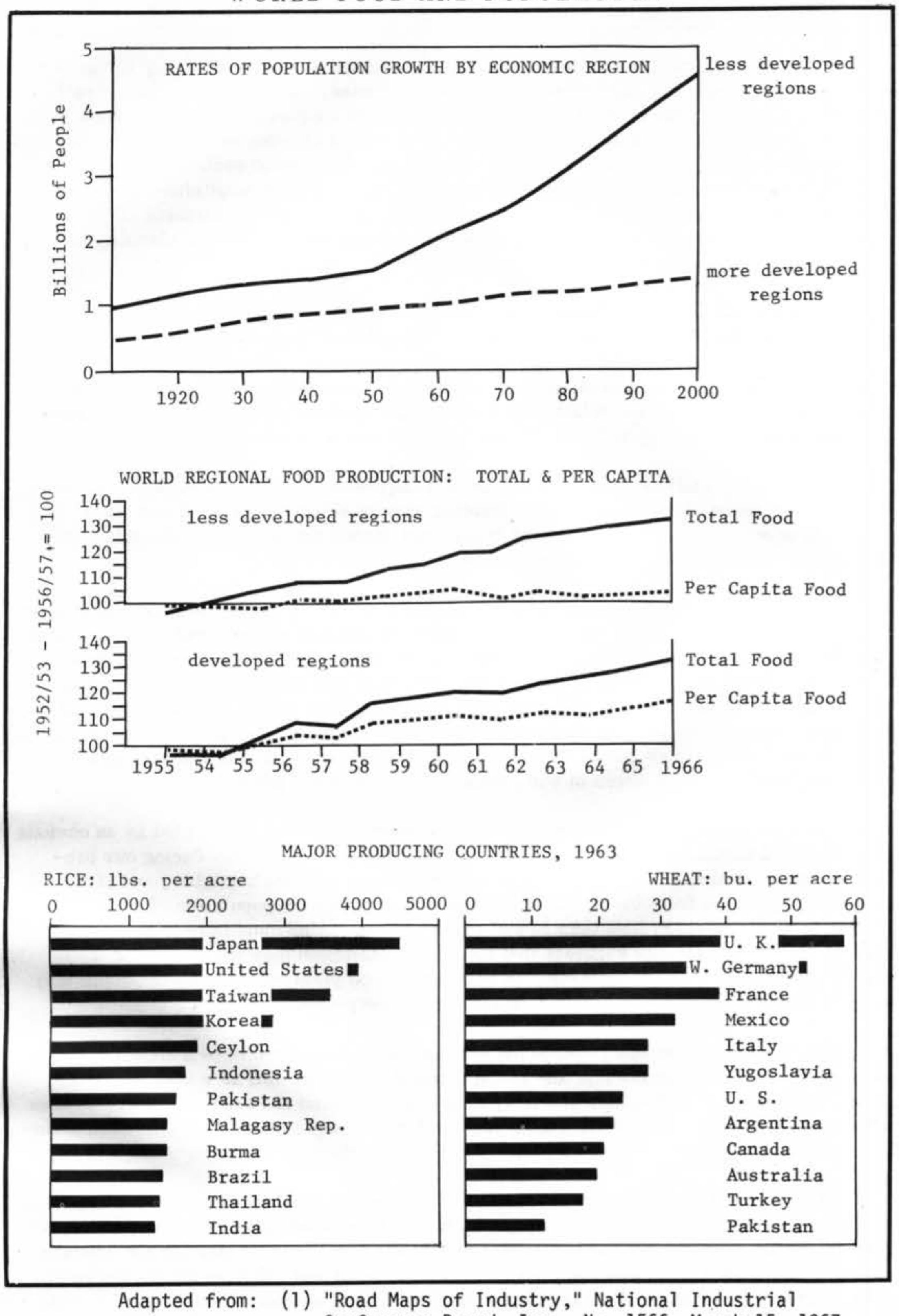
Though the growth of population has been accompanied by more intensive cultivation and higher food yields per acre, the amount of presently useable soil per capita is declining, and, in many areas, becomes impoverished through ill use. As the historical pattern of deforestation, which produced many of the great desert areas, continues, there is added to this the increasing amount of arable land claimed for building dams, roads, industrial installations, mining, etc., -- all of the necessary uses of an increasing technological system. In the United States alone, urbanization and transportation have been calculated to draw more than a million acres of soil, each year, from cultivation.

The decreasing amount of land per capita, however, though often cited as an obvious limiting factor of human expansion, is a relative measure -- crucial only during our presently critical transition period. The actual amount of land surface available, and still unused, may be gauged from the fact, for example, that the entire population of the United States occupies much less than 10% of the land area. Also, and importantly, man's increasing ecological mobility suggests that fixed land habitation may only be one of a number of alternative forward patterns. In relation to food yield -- many more people may be fed <u>off</u> the land than on it, in terms of agricultural occupation.

The depletion of animal populations has also been considerable -- a recent estimate suggests that 107 kinds of mammals and 100 species of birds, as well as a vastly greater number of plant species and lesser animals, have been rendered extinct in the past nineteen hundred years. Of these losses, 70% have occurred in the past century and have been mainly due to human agencies -- less through hunting than destruction of habitat.

Other uses of the earth, incident on our developed technological capacities, have also increased enormously in the past hundred years. As against approximately 50 tons of raw materials per person consumed in 1880, we now use over 300 tons per person annually. When this is translated into amounts of iron, coal, oil, wood and other products 'harvested' from the earth, processed, and redistributed elsewhere, the operation becomes of considerable ecological magnitude. For example, of all the coal mined by 1960, only 20% was before

WORLD FOOD AND POPULATION



Adapted from: (1) "Road Maps of Industry," National Industrial Conference Board, Inc., No. 1566, March 15, 1967.
(2) "Population and Food Supply," Conrad Taenber, <u>The Annals of the American Academy of Political & Social Science</u>, January 1967. p. 77.

1900, and the remaining 80% since that time. The energies used in the extraction, processing, transportation and use cycles of all the industrial materials are obtained mainly from burning the fossil fuels -- each ton of which used releases large amounts of carbon dioxide and other gases into the atmosphere. From 1860 to 1960, this has been calculated to have increased the atmosphere carbon dioxide concentration by 14%; during the eight years from 1954 to 1962, the average rate of increase was 5%. Sulphur oxides, a more immediately harmful aerial pollutant in highly industrialized countries, is expected to show a 75% increase over present critical levels by 1980. A single fossil fuel, power generating plant may emit several hundred tons of sulphur dioxide per day and, under certain weather conditions, locally overburden the air of a whole city. Then this effect is increased by larger multiple fuel uses in dense urban concentrations, the results may be lethally apparent -- four thousand persons died, directly or indirectly from one week of such intense pollution in London in 1952, and one thousand in 1956. The annual emission into the atmosphere of such pollutants, other than carbon dioxide, is estimated at 125 million tons for the United States alone. In addition to aerial pollution, it has also been calculated that certain elements, e.g., argon, neon, krypton, etc., essential to life maintenance are now being 'mined' out of the atmosphere by industrial operations at a faster rate than they are being produced by natural processes.

When we speak of increasing the per capita availability of industrial energies and extracting higher performance per pound from our metallic resources, these are key factors in the re-design of our use systems. Even if present generating and production power technologies were converted 50 per cent to nonfossil fuels, it has been estimated that pollutant by-products from the reaminder would still double present levels every twenty years.

The dependence of one sixth of the world's food supply on 'artificial' nitrogen from the chemical industry is another factor in the overall ecosystem system function. There is a tendency to separate agriculture from industry in everyday thinking, but the image of the farmer as conserver, and industry as the spoiler, of nature is no longer true -- if it ever was. To make each million tons of such nitrogenous fertilizer annually, we use, in direct and related industries, a million tons of steel and five million tons of coal. Some 50 million tons of such support nitrogen are estimated to be required annually by 2000 A.D. The amounts of other agricultural chemicals which will require equally massive support technologies, to further maintain and increase crop yields, is only now becoming apparent.

The irony, in terms of our present ecological mismanagement, is that in making the chemical fertilizers and other nutrients to render the land more productive, we indirectly destroy the crops through the byproducts of similar industrial processes. Each calorie of food produced in highly mechanized agriculture requires roughly another calorie of fuel to power tractors, harvesters, processing and transportation. Such fuels are usually the fossil fuels used in internal combustion engines and contribute further sources of aerial pollutants to industrial smoke.

> Vegetation damage has been caused in at least half the states in the nation (U.S.) by photo-chemical smog, ozone, sulphur dioxide, fluorides, or ethylene . . . Livestock damage is usually subtle and chronic . . . The extent of loss of future forest yield that can be attributed to polluted air is not fully known.[4]

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[4] Waste Management and Control, National Academy of Sciences (U.S.), N.R.C., Pub. no. 1400, 1966, p. 127.

Water, a key resource in daily life, agriculture and industry is also in critical balance in many world regions. Approximately 95 per cent of fresh waters are presently used at a greater rate than their precipitation replacement in ground surface waters. Though much water use is of a multi-purpose 'cycling' nature, and therefore differs from the more single use/discard pattern of other resources, the bulk increases in each use now begins to strain the storage, replenishment and natural recycling capacities of many areas. Population growth and urban concentration have been considerable factors of increase -- in the United States, consumption has risen from 40 billion gallons per day in 1900 to over 300 billion gallons in the 1960's. The average Western per capita use is 150 gallons each day. Industry increasingly requires vast quantities of process water, from:

7-25 gallons to produce 1 gallon of gasoline
25,000 gallons to produce 1 ton of steel
50,000 gallons to produce ' ton of paper
250,000 gallons to produce 1 ton of acetate
600,000 gallons to produce 1 ton of synthetic rubber.

Agriculture still accounts directly for 50 per cent of all usage, requiring 400-500 pounds of water for each pound of dry plant produce. The water to specific crop-ratio varies considerably -- but, in general, the lesser developed, agriculturally-based regions consume as much water per capita as the technologically advanced.

When air, water and earth uses are compounded with mounting waste and sewage disposal, the emphasis on the required re-design of all such human systems becomes acute. The natural systems of air/water/soil purification are now so overburdened, through increase and misuse in many areas of the world, that concern is now expressed about their overall malfunction for greater areas. These are no longer 'local' problems as each subsector of the overall ecosystem eventually effects other sectors if misused on a large enough scale.

Waste disposal, even in the most advanced countries is still archaic. Those methods used in our larger urban concentrations are little improved from the traditional systems evolved for much smaller and less waste-productive communities of the pre-industrial period. The average city of half million people now disposes of 50 million gallons of sewage daily and produces solid wastes of about 8 pounds per person each day.

> Pollutants are the residues of things we make use of once and throw away . . .As the earth becomes more crowded there is no longer an 'away' . . .our whole economy is based on taking natural resources, converting them into things that are consumer products, selling them to consumers and then forgetting about them. But there are no consumers -- only users. The user employs the product, sometimes changes it in form, but he does not consume he just discards it . . .One person's trash basket is another person's living space.[5]

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[5] Ibid.

The use of water courses, of rivers, streams and lakes, has also been grossly affected, not only in the 'discard/residue' process of sewage disposal from cities and the increasing discharges of industrial wastes, but from intensified agricultural practices. Large amounts of soil additives in the form of fertilizers and chemical nutrients are washed off the lands through rainfall, irrigation and drainage into the natural water courses where they disturb the aquatic life balances. The undue growth of algae and plant growths decreases the oxygen supply for fish and other organisms thus attenuating the self-renewal of the water system. Again, such problems are not localized. In the case of pesticide 'run offs' and other toxic agents, introduced into upper river reaches, their concentrated effects may only be felt thousands of miles away, e.g., the massive fish kills, of around 12 million, in the Mississippi and Gulf of Mexico in recent years.

Inadvertent poisoning of organic life through the unplanned and uncoordinated introduction of various toxins into the environ is not restricted to plants and animals. The effects on man are, in many cases, greater -- but receive less direct attention. Some 500 new chemical compounds, each year, go into widespread usage in the highly industrialized countries with little planned attention to their long term deleterious effects. Without going into the more publicized aspects of radioactive fallout, a simpler case may be adduced of 'lead fallout' -- from tetra ethyl lead in auto fuel additives. After almost fifty years of rapidly increasing use, such lead contamination is now being monitored at levels approaching toxicity in waters, crops and the human system.

Returning to the more positive aspects of man's ecological activities, it is necessary to redress, in part, the semantic bias on 'pollutants, garbage and poisons'. This usually tends to suggest vast quantities of alien substances being injected into an otherwise perfectly functioning system. Rather -- pollutants are as we perceive and designate them: poisons are natural substances 'out of place', or in excess of tolerable levels. The gases and dust of forest fires, volcanic ashes, pollens, marsh effluents, etc., are all 'natural' pollutants of the natural environments. Our concern here is to more fully appraise the role of man-made systems which are also <u>natural systems</u> in the overall integral functioning of the ecosystem.

The problem aspects which we have stressed are only problems through lack of 'design' and more thoroughly anticipatory planning. The naturally occurring forces operative in the environ can be more selectively and systematically used to absorb pollutants, reduce sewage/garbage and reprocess discards and residue on a much vaster scale.

Our lack of adequate knowledge and equal lack of foresight and control are the main factors which overburden the natural regulatory systems and lead to their malfunction and breakdown. Some large scale sectors, such as the global atmosphere, have enormous absorptive and regenerative capacities -- others, such as a local soil area, forest, lake or watershed are more precariously balanced and may <u>not</u> be renewable or recoverable in anything but very long range terms.

Some of the mandatory requirements for the merely adequate maintenance of the ecosystem are already clear. We need to re-design our major social, industrial and agricultural undertakings toward their more efficient and systematic functioning -- as ecologically operating systems, rather than 'piecemeal' aggregates of unrelated processes. This would apply not only to environmental controls -- such as houses, cities and other facilities -- but to all of our environmental control facilities which now comprise within themselves a vast 'socio-agri-industrial ecology'. We need to refashion this system so that it can serve many more people at better standards and at higher performance levels than ever before:

a) to 'recycle' the metals and materials in the system -- so that there is a swifter turnover with the least lag in scrapping and processing cycles. In high grade technological process, each use cycle tends, through overall development, to achieve more, not less, performance per invested unit of materials.

b) to employ increasingly our 'income' energies of solar, water, wind, tidal and nuclear power, rather than the hazardous and depletive fossil fuels. The latter represent major 'capital' investments which once used are not replaceable. They are too precious to 'burn up' in our currently prodigal fashion, but they may be more efficiently -- and more fractionally -- employed in indirect conversion to plastics, foodstuffs, etc.

c) to refashion our food cycle that we may more swiftly augment the present starvation diets of more than half the developing world. We need, however, to go also beyond emergency satisfaction of immediate needs toward the more extensive ecological re-design of our whole agri-industrial system; employing the most efficient 'natural' means of food conversion through the plant/animal chains and the possibilities inherent in microbiological, biosynthetic and other processes.

d) to set up eco-monitoring and control centers which will act as 'early warning' systems in relation to our large scale scientific and technological undertakings -- analysing and evaluating their immediate and largest range effects on the overall ecological matrix and their positive and negative implications for the quality of the human environ.

These are but a few of our urgent tasks!

In essence, we have to re-design the presently chaotic elements of our developed and 'externalized' human metabolic system into a series of 'closed' ecological loops phased in with, and taking gainful symbiotic advantage of, the overall ecosystem. The wastes of one type of production cycle become the raw materials of another, thus energy converted and dissipated for one purpose may serve many more. The noxious 'garbage' of several processes may be valuable 'nutrients' materials in another sector. Each component subsystem now requires critical evaluation and re-design in terms of such higher performance and more economical function. The directly quantitative gains implied in this re-design are also qualitative in terms of more 'useful' function, in the reduction of pollution hazards, in less 'destruction' of the natural environ -- and in the increased social and physical advantages available to all men.

Our thinking must obviously go beyond immediate preoccupation with locally vested interest in the prior solution of this or that isolated problem! The only design context for all of our major problems is the global context. The range of our design thinking is that which may extrapolate human ecological requirements, beyond subsistence survival, to the maximal advantage of all. It must also accept the challenge of designing not only for 'tomorrow' but for a century of tomorrows.

This may often entail 'non-design' as well as re-design. The scale of our present technological capacities are such that we cannot act without more accurate gauges of their immediate and largest range effects. Where it may be pleaded, for example, by special interest groups that we have enough coal, oil and gas reserves for 500 years, any expanded use at the present rate and level of technology is obviously precluded by their adverse side effects on the ecosystem. In such cases, a resource, an invention or process -- so evaluated as to be dangerous to the maintenance of the life systems -- should be left in 'storage' -- until a more evolved society may use it less prodigally and less dangerously!

Such an orientation leads to further considerations involving our global, rather than local committments. As stated, no large scale human problem may now be solved outside of this context. Air, water and soil pollution are not local -- the air is not restrained within municipal or national boundaries, nor are the waters.

Where massive imbalances occur -- whether bio-physical in terms of earthquakes and other natural catastrophes or socio-physical in terms of hunger, disease and the catastrophe of war -- we need to recall that the resources of the planet can no more belong, by geographical chance, to any individual, corporation, country or national group than the air we breathe. National ownership of a key watershed, mineral deposit or scientific discovery is as farcical, and dangerous, a proposition as our supposedly national sovereignty of an 'air space'.

The evolutionary transition towards world man now faces an analogous situation to that of emerging national or empire man in the preceeding two centuries. Then, the local ideological issues revolved around national control of public health, of child welfare, education, pure food and water legislation, etc. The same arguments now prevail, at the world level, regarding the rights and privileges of individual nations -- as if they were isolated, self-contained and wholly autonomous physical and social entities. Though such a fiction may be a comforting 'prop' for local individual and social identity in a rapidly changing world, it is dangerously removed from reality.

The scale of our global systems of production/distribution, communication/transportation, etc., has now gone beyond the capacities of any single national or even regional group to wholly sustain and operate. They require, and are dependent upon, the resource range of the entire planet for the metals and materials of which they are built -- and in which no nation is now self-sufficient. Each system is intricately and complexly interlocked with all others -- production with transport, with communications, etc. The whole is increasingly dependent on the global interchange, not only of physical resources and finished products, but of the 'knowledge pool' -- of research, development, technical and managerial expertise and the highly trained personnel who sustain and expand this.

Ours is possibly one of the most critical periods in human experience up till this time. Poised in the transition between one kind of world to another, we are literally on the hinge of a great transformation in the whole human condition. The next fifty years may be the most crucial in all of man's history. We have few guides to follow and almost no historical precedents. "Many of the old moralities have suddenly become immoralities of the most devastating character."[6] All of our previously local actions are now writ large on a planetary scale. The knowledge with which we might make the correct decisions is barely adequate -- yet our gross ecological errors may reverberate for many generations.

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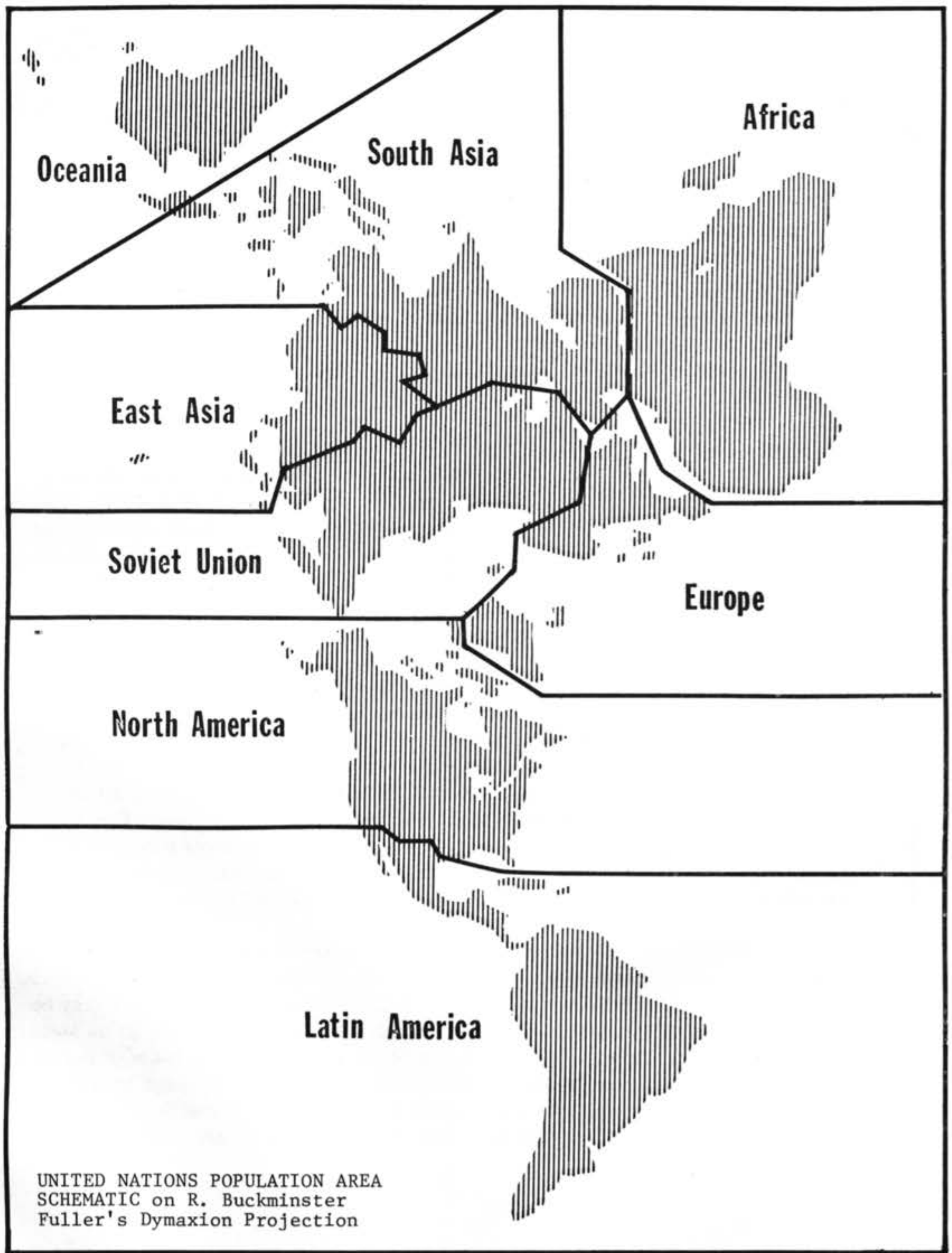
[6] "Truth and Consequences in a New Era," R. C. Cook, Population Bulletin, Vol. XXII, No. 4, Nov. 1966, (U.S.).

WORLD POPULATION AREAS



The schematic world map above and the list opposite show the country and regional groupings used in the U.N. population projections discussed in the Population Bulletin cited below.

COUNTRIES IN WORLD POPULATION AREAS

Oceania

AUSTRALIA & N. ZEALAND

MELANESIA
- New Guinea
- Papua

POLYNESIA & MICRONESIA
- Fiji Islands
- Western Samoa

East Asia

MAINLAND REGION
- China (Mainland)
- Hong Kong
- Mongolia

JAPAN

OTHER EAST ASIA
- (Korea (N. & S.)
- China (Taiwan)
- Ryukyu Islands

Soviet Union

North America

- Canada
- United States

Latin America

TROPICAL S. AMERICA
- Brazil
- Colombia
- Peru
- Venezuela
- Ecuador
- Bolivia
- British Guiana

MIDDLE AMERICA
- Mexico
- Guatemala
- El Salvador
- Honduras
- Nicaragua
- Costa Rica
- Panama

TEMPERATE S. AMERICA
- Argentina
- Chile
- Uruguay
- Paraguay

CARIBBEAN
- Cuba
- Haiti
- Dominican Republic
- Puerto Rico
- Jamaica
- Trinidad and Tobago

South Asia

MIDDLE SOUTH ASIA
- India
- Pakistan
- Iran
- Afghanistan
- Ceylon
- Nepal
- Bhutan
- Sikkim
- Maldive Islands

SOUTH EAST ASIA
- Indonesia
- Viet-Nam (N. & S.)
- Philippines
- Thailand
- Burma
- Malaysia
- Singapore
- Cambodia
- Laos

SOUTH WEST ASIA
- Turkey
- Iraq
- Saudi Arabia
- Syria
- Yemen
- Israel
- Jordan
- Lebanon
- Cyprus
- Kuwait

Africa

WESTERN AFRICA
- Nigeria
- Ghana
- Upper Volta
- Mali
- Ivory Coast
- Senegal
- Guinea
- Niger
- Sierra Leone
- Dahomey
- Togo
- Liberia
- Mauritania
- Gambia

EASTERN AFRICA
- Ethiopia
- Tanzania
- Kenya
- Uganda
- Mozembique
- Madagascar
- Southern Rhodesia
- Nyasaland
- Zambia
- Rwanda
- Burundi
- Somalia
- Mauritius

MIDDLE AFRICA
- Congo (Leopoldville)
- Angola
- Cameroon
- Chad
- Central African Rep.
- Congo (Brazzaville)
- Gabon

NORTHERN AFRICA
- Egypt (U.A.R.)
- Sudan
- Morocco
- Algeria
- Tunisia
- Libya

SOUTHERN AFRICA
- South Africa

Europe

WESTERN EUROPE
- Germany (West)
- France
- Netherlands
- Belgium
- Austria
- Switzerland
- Luxembourg

SOUTHERN EUROPE
- Italy
- Spain
- Yugoslavia
- Portugal
- Greece
- Albania
- Malta

EASTERN EUROPE
- Poland
- Romania
- Germany (East)
- Czechoslovakia
- Hungary
- Bulgaria

NORTHERN EUROPE
- United Kingdom
- Sweden
- Denmark
- Finland
- Norway
- Iceland
- Ireland

Source: "World Population Projections 1965-2000," Population Bulletin, Population Reference Bureau, Inc., October 1965. pp. 94-95.

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MAN AND THE BIOSPHERE

The volume of air, water and soil surrounding the earth within which the physio-chemical conditions are supportive of life has been variously termed the bio, or ecosphere, the bio-film or envelope. Extending vertically upwards into the air to a height of approximately 6.25 miles, downwards to the greatest known depths of the oceans, 35,800 feet, and to a few thousand feet below the earth's surface.

This 'life space' is a unitary system of processes contained within the three layers of the atmosphere, the hydrosphere and the lithosphere; characterised by various parameters of temperature, pressure, humidity; electrical potentials; interface exchanges of liquid-solid, solid-gas, gas-liquid, etc. All of these are, in turn, conditioned by the energy radiations providing motive power for the system. The latter energy derives from one major source, solar radiation, but there may be added to this the kinetic and potential energy of the earth from the gravitational system, and the geothermal energies from the interior of the earth mass.

Other major 'systems' constants governing optimal sizes, physical configuration, life cycle and metabolic rate of living forms would be:

a) Gravity -- the physical and structural effects relating to this; pressures of gases, material strengths and stabilities. The ways in which such relationships are stable in various 'phase states' -- liquid, gaseous, solid -- between temperature ranges, permit a variety of physiological systems and organic forms within the different earth and water environs.

b) Temperature -- the medium frequency of heat and radiation excitation on the earth's surface allows low temperature energy and materials exchange.

The atmospheric filtering of radiation, the gravitational, pressure and temperature constants above, provide a median environment for organic life, of a sufficiently steady state for long evolutionary change, and of sufficient range to allow great species variety.

The systems or 'process' variables related to the above would be:

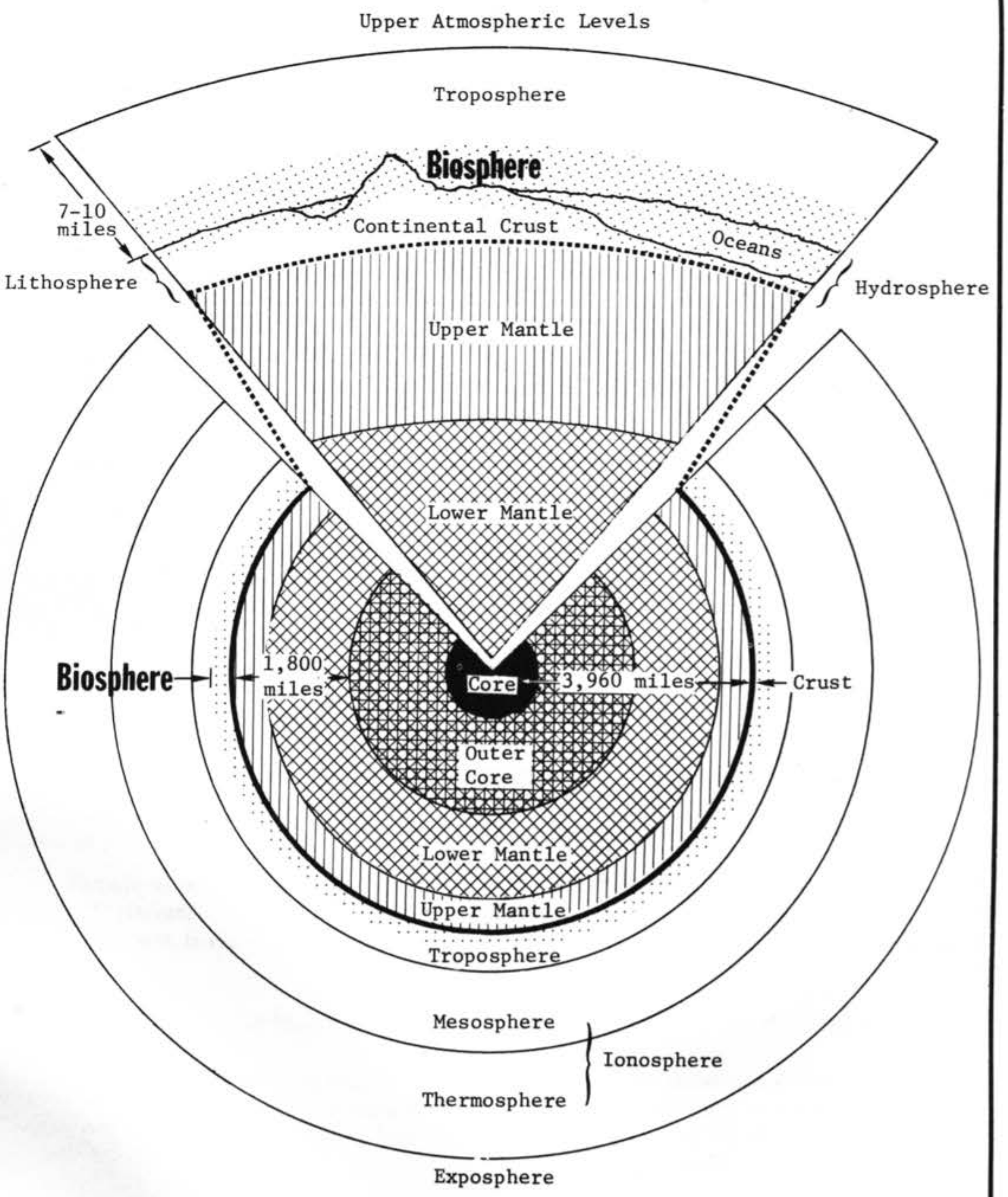
a) those frequencies of exposure to solar radiation governed by rotation of the planetary mass, giving climatic variation together with the distribution of water and land -- the geographic factors.

b) in turn, these may be related to the distribution of energy and material resources of various kinds in the various sectors of the biosphere.

Other variables in the system could be multiplied by the cross-relation of the above, and by further introduction of altitude, continental mass relations, soil, vegetation distributions, marine environ conditions, etc.

The extent to which living organisms are also viably affected by the vast electro-

THE EARTH'S BIOSPHERE



The biosphere is that thin film of air, earth and water around the globe within which most living organisms are found. Within this 'life space' are all the energy patterns and processes of interaction which sustain our major activities. Though extending vertically about seven miles into the air and for thousands of feet below the earth and oceans its most densely populated region is just above and below sea level.

magnetic systems surrounding, and external to, the earth, is little known at present.

The planetary surface is relatively 'meager' -- approximately 197 million square miles, of which 57 million square miles is land and 140 million square miles is water. In human terms, we live on a small island at the bottom of an ocean of air, surrounded by an ocean of water. Within this life zone, most living forms are held close to the surface of the earth, but the organic evolutionary process has been specifically characterised by the enlargement of occupancy of the vertical and horizontal ranges of the biosphere. Our own most singular and recent mark of life space extension has been to broach it's limits -- by orbiting both animals, plants and men, outside of the earth's atmosphere.

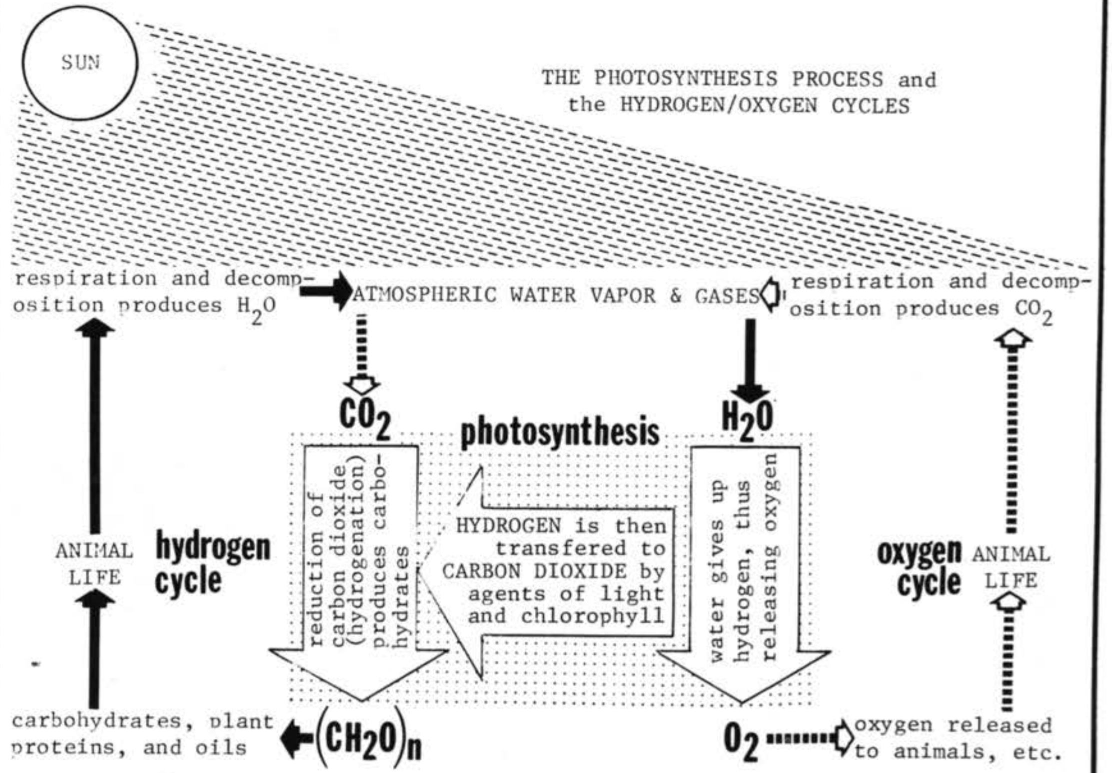
Despite the close dimensions of the life zone, and the relatively narrow physio-chemical tolerances endurable by living organisms, there are a countless variety of habitats within which forms of life pursue their cycles of individual growth and decay.

Man, of middle 'size' in range, and one of the least specialized of complex living forms, has almost evolved beyond the stage where he is constrained within any specific habitat or 'ecological niche' parameters. These may be distinctly characterized for most other organisms -- by differences in medium, of earth, air and water; in physio-chemical factors of salinity, acidity, etc.; temperature, pressure and light availability. At the gross end of the scale, we may distinguish such ecological habitats as climatic zones, ranging through the tropical, subtropical, temperate, subarctic and arctic, etc. At the micro end, however, we have bacterial spores at the limits of the bio-atmosphere, organisms under several atmospheric pressures in the ocean depths, and those whose 'niche' is on, or within, the tissues of another life form.

The fundamental relation between all organisms and their environ (as including other organisms) is the maintenance of life through various types of energy exchanges. The basic life materials are the chemical elements, e.g., the human organism is 99 per cent composed of hydrogen, oxygen, carbon, nitrogen, calcium and phosphorus with various other trace elements in fractional amounts; its mass is 60 per cent water. Such materials are, of course, energy -- at varying levels of relatively temporal organization. We could, therefore, refer to all materials as energy whose 'mass' and structural characteristics have given stable configurations in the particular material state.

Energy and materials are in constant and complexly regenerative flows between, and within, organisms and the environ. One such major flow in the biosphere is, for example, the process of <u>photosynthesis</u>, through which plant life utilizes solar energy through its enzyme systems to convert, or 'build', carbon dioxide and water into the more complex carbohydrates. These, in turn, provide food energy for other organisms which, in the reverse of the photosynthesis process, 'break down' such complex materials -- on the one hand, into growth/maintenance elements, e.g., the internal metabolism of digestion, conversion, storage, etc., and, on the other, into further external exchanges, e.g., in respiration, in the mobility necessary to obtain more food energies, etc. Photosynthesis is the first step in the overall energy flow, within the biosphere, which sustains all the complexly interdependent systems of living organisms. In the simple food chain, used as an example -- which might go from plant to herbivorous animal to man. As no energy conversion is 100 per cent efficient, so much is 'lost' at each link in the chain. Theoretically the end point occurs when all the energy has been dissipated and the organism's decay converts the initially 'built up' elements back into their original state. However, even at this simple level of consideration, the growth/decay cycles are such that the process is in part regenerative, e.g., decay is in itself a further microbial reduction which produces nutrients for the plant, so 'closing' the cycle. Also, when we consider the role of man in the process, this again alters it significantly.

PHOTOSYNTHESIS



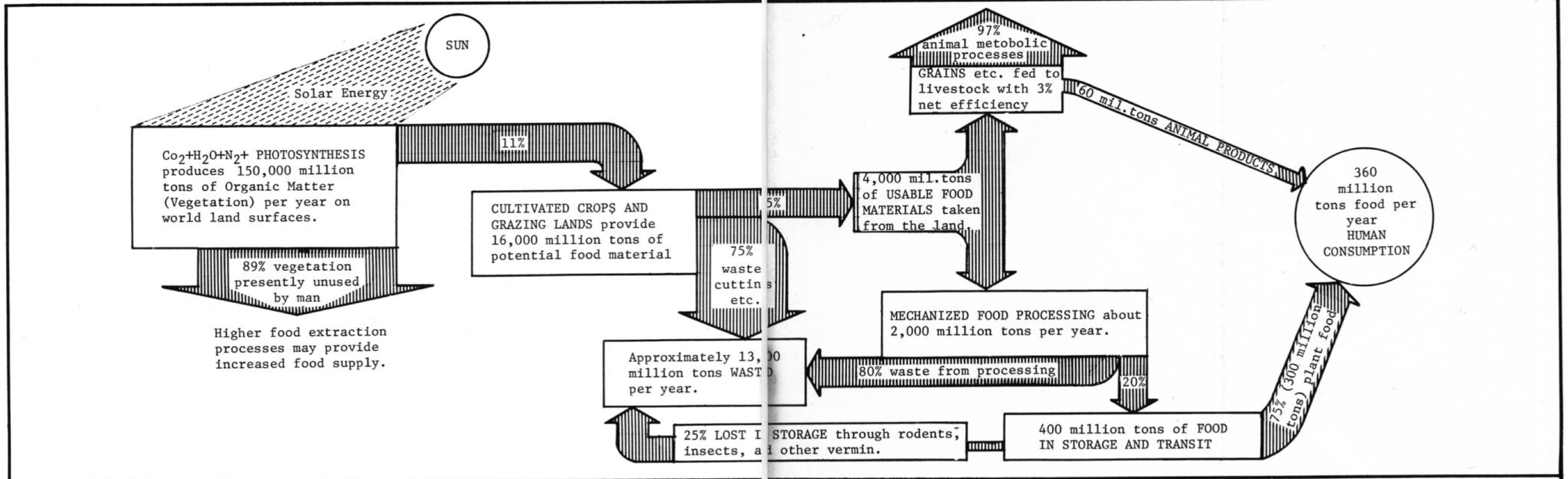
$$\begin{pmatrix}\text{carbon}\\\text{dioxide}\end{pmatrix} + (\text{water}) + \overset{\textbf{light energy}}{\begin{pmatrix}\text{in presence of}\\\text{enzyme systems}\\\text{associated with}\\\text{chlorophyll}\end{pmatrix}} = (\text{glucose}) + (\text{oxygen})$$

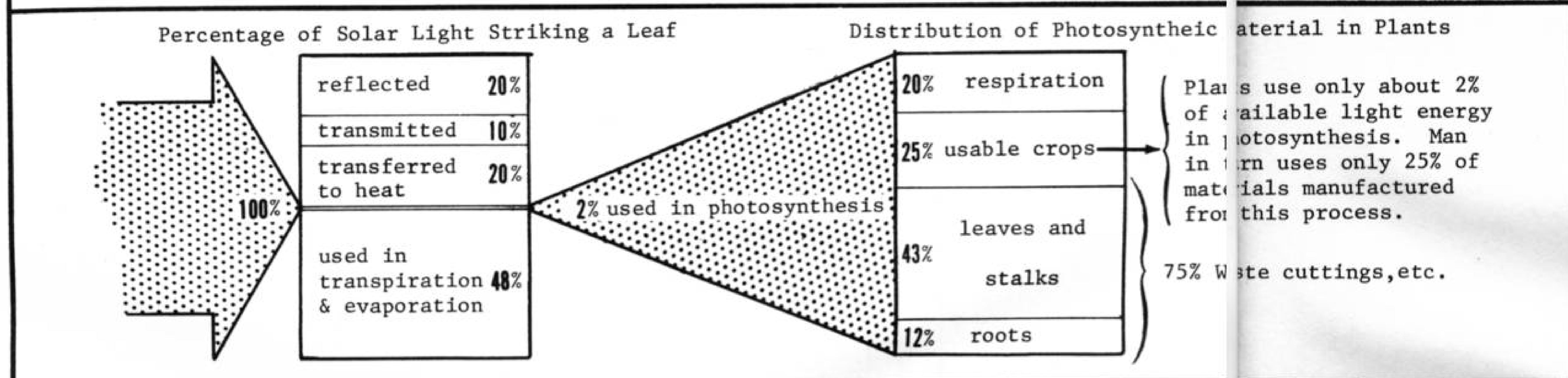
"Chemically the photosynthetic process involves the storage of a part of the sunlight energy as potential or "bound" energy of food...is much more complicated than indicated in the above word formula....The photosynthetic process of food manufacture is...the synthesis of amino acids, proteins, and other vital materials ...this occurs simultaneously with the synthesis of carbohydrates (glucose), some of the basic steps involved being the same. The reverse of photosynthesis, or respiration, results in the oxidation of foods with the release of energy....A part of the synthesized food is used, by the producers themselves. The excess as well as the producer protoplasm is then utilized by the consumers and decomposers, or part of it is stored or transported into other systems." --E. P. Odum.

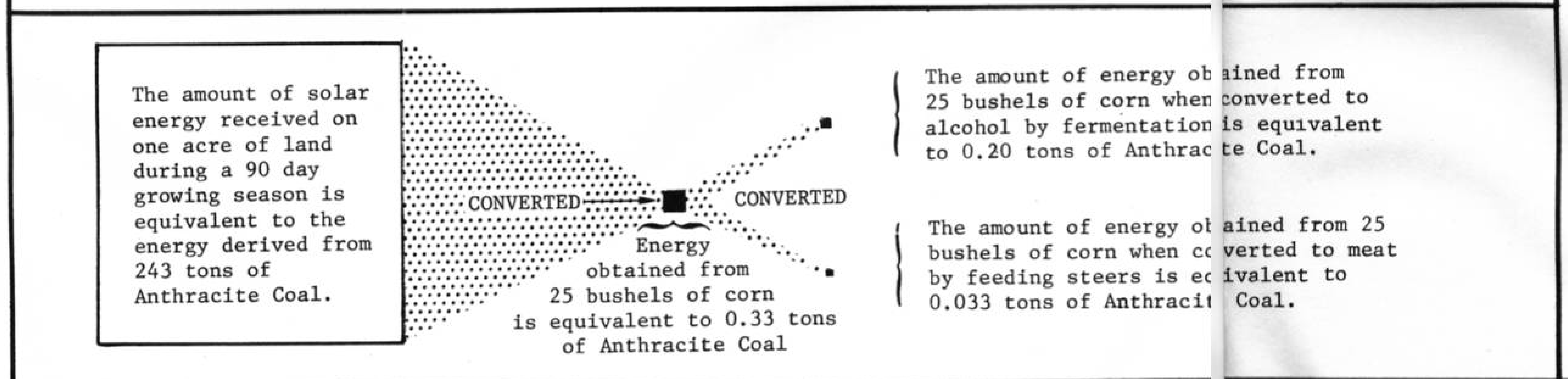
"...thirty-five percent yield in energy conversion by plants is very respectable -- considering that we do not know of any reaction produced by visible light outside the plant cell which would convert as much as 10 percent of absorbed light into chemical energy. If some economical means could be found to capture and convert even 10 percent of light energy, the discovery conceivably could produce a greater revolution in our power economy than can be expected at present from the much-publicized discovery of atomic energy." --E. I. Rabinowitch.

Sources: (1) Fundamentals of Ecology, E. P. Odum, (New York: Holt, Reinhart, Winston), 1959. p. 18.
(2) "Photosynthesis," E. I. Rabinowitch, Scientific American, Vol. 179, 1948. pp. 30-31.

PHOTOSYNTHETIC ENERGY CONVERSION







"....The natural chemical storage of solar energy by photosynthesis in agriculture is inefficient. Ordinarily, only about one-fifth of one percent of the annual supply of solar radiation falling on agricultural land is utilized in plant growth. But in devices, with the direct use of the solar radiation, higher efficiencies are possible -- perhaps 40 percent for the distillation of water, 25 percent for solar refrigeration, and 10 percent for conversion into electricity with silicon photovoltaic cells. We can use the sun effectively for cooking, for heating water and heating houses, for cooling and refrigeration, for distilling water, and for producing mechanical and electrical power with heat engines, thermoelectric converters, and photovoltaic cells.

"...Solar energy cannot now compete economically with cheap fuel and electricity as we have it in industrialized countries. But there are 2 billion people in the world who do not now have any electricity; and most of these people live in the sun belt near the equator. In many of these areas there are few deposits of fossil fuel and no opportunities for hydroelectric power. Solar radiation is often the most important, potentially available, natural ressource." -- F. Daniels.

Sources: (1) "Food for the World," Howard W. Mattson, International Science and Technology, December 1965. p.34. (2) "Phot synthesis," H. A. Spoehr, (Chemical Catalog Com. nc.), 1926. pp. 31-40. (3) "Direct Use of the Sun's Energy," Farrington Daniels, American Scientist, Vol. 55, January 1967. p. 16.

The overall energy flux into and out of the biosphere and its larger containing earth system, by radiation received from the sun and that radiated outwardly from the earth, is roughly in balance. This allows us to consider the biosphere, theoretically, as a locally 'closed' system -- within which no energy may be lost or gained overall. The energy flow within the biosphere, as a closed local system, should ultimately be reduced through its various exchange losses to an evenly dissipated end state -- of entropy or minimal energy flux. This state of minimal order, of the final running down of the system, may be characterised, partially, by the process of organic decay. In this stage, the arrest of material growth and the slowing down of external and internal energy flows is finally resolved in the disintegration of the complex organic structure into its elementary constituents.

Entropy is also used, in terms of information, as a measure of uncertainty, or disorder, of knowledge. To the extent that it increases order and predictability in the system, and reverses the tendency towards 'running down', information is anti-entropic. As the agency or principle of complex ordering in the environ, its role has not yet been fully or clearly defined in relation to energy and material organization. It is significant, however, that whilst the amount of available energy and material elements in the ecosystem remains relatively constant, the amount of order increases. The bio-evolutionary direction is towards increased complexity of order -- information increases and accumulates.

> The information extracted from the environment by one organism does not in equal measure reduce the amount of information available to any other organism, nor does what is learned by one diminish the amount that can be learned by another. A genetic population in expanding its numbers increases, if anything, its per capita information supply, even if per capita supplies of materials and energy be reduced . . . Evolution viewed as a "learning process" entails the incorporation of more information into population systems: 'In the long view there has been an increase in the complexity of genetic instructions (Medawar, 1961)'. . . Social organisms in sharing information increase the amount by increasing the distribution rather than inversely.[1]

Man's function in the ecosystem may then be viewed as:

> a) Entropic -- in using energies to reduce complex material resources to simpler structures, i.e., where he acts as an 'unconscious' biological agency as in food processing, reducing and extinguishing other organic populations, disordering towards malfunction of 'natural' systems, in air, water, earth, pollution, etc.

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[1]"Social Organization and the Ecosystem", O.T. Duncan, Chapter 2, p. 44, Handbook of Modern Sociology, edited by R. L. Faris, (pub. Rand McNally & Co., U.S., 1964).

b) Anti-entropic -- where he uses energies more consciously to modify and transform his environ toward higher levels of complexity. Through the application of organized information/knowledge in his 'artificial' systems, he increasingly re-processes, re-orders and re-distributes energy and materials in more, rather than less, complex forms.

The balance between his entropic (disordering) propensities, and his anti-entropic (ordering) propensities is, in this sense, a central point of our present discussions.[2] We can only surmise, in terms of our brief historical record, that this balance is already tipped, through evolutionary development, towards the anti-entropic as more favourable to the survival of the species.

The concept may also be extended beyond life on earth, toward the imminent engagement of man with extra-terrestrial systems. Some of these, such as the moon, are of a different and apparently less complex order and lower energy level. What may be the 'evolutionary' effect of introducing anti-entropic bias into such entropically oriented systems? The question enlarges philosophically to the consideration of all life forms, including the non-human, as an anti-entropic process or principle.

Our more immediately pressing consideration is, however, human life and society within the present confines of the biosphere.

The basic biological functions which we share with other organisms only furnish some of the parameters of our overall ecosystem requirements. Our further needs are complicated by the high degree of social development of the human species. Social patterns are more determinant of biological events than we generally concede.

We may schematize our ecosystem relations by labelling certain areas of the environ system and the 'human systems' through which we relate to these. This should be treated as an extremely limited conceptual convenience. Such schematic models, in which division or 'boxes' are set out in linearly connected fashion, can, <u>in no way</u>, approximate the dynamic complexity of our simplest relationships in which every aspect of every activity is interconnected.

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[2]The hinge of this proposition rests, of course, with a specifically anthropocentric view of 'order'!

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ENVIRON SYSTEM(S)

Atmospheric ---- Terrestrial ---- Marine

Atmospheric

Though the shell of 'atmospheres' surrounding the earth extends thousands of miles above the surface, the sector most immediately concerned in the human biosphere is the tropospheric layer. This constitutes about 70 per cent of the air mass confined in a narrow layer about 6 miles in depth. Within this layer move the global and local wind systems which 'ventilate' the ecosystem, carrying water vapor and other gaseous and solid exchanges around the earth's surface, and playing a major role in the climatic system. This shifting air mass is a vast cycling reservoir which modifies, redistributes and reorganizes the various energies and materials which are taken up into its systematic flows. The passage of an 'air parcel' around the earth in mid latitudes requires about one month -- a complete interchange of all circulating air masses between latitudes and hemispheres is calculated to take about two years.

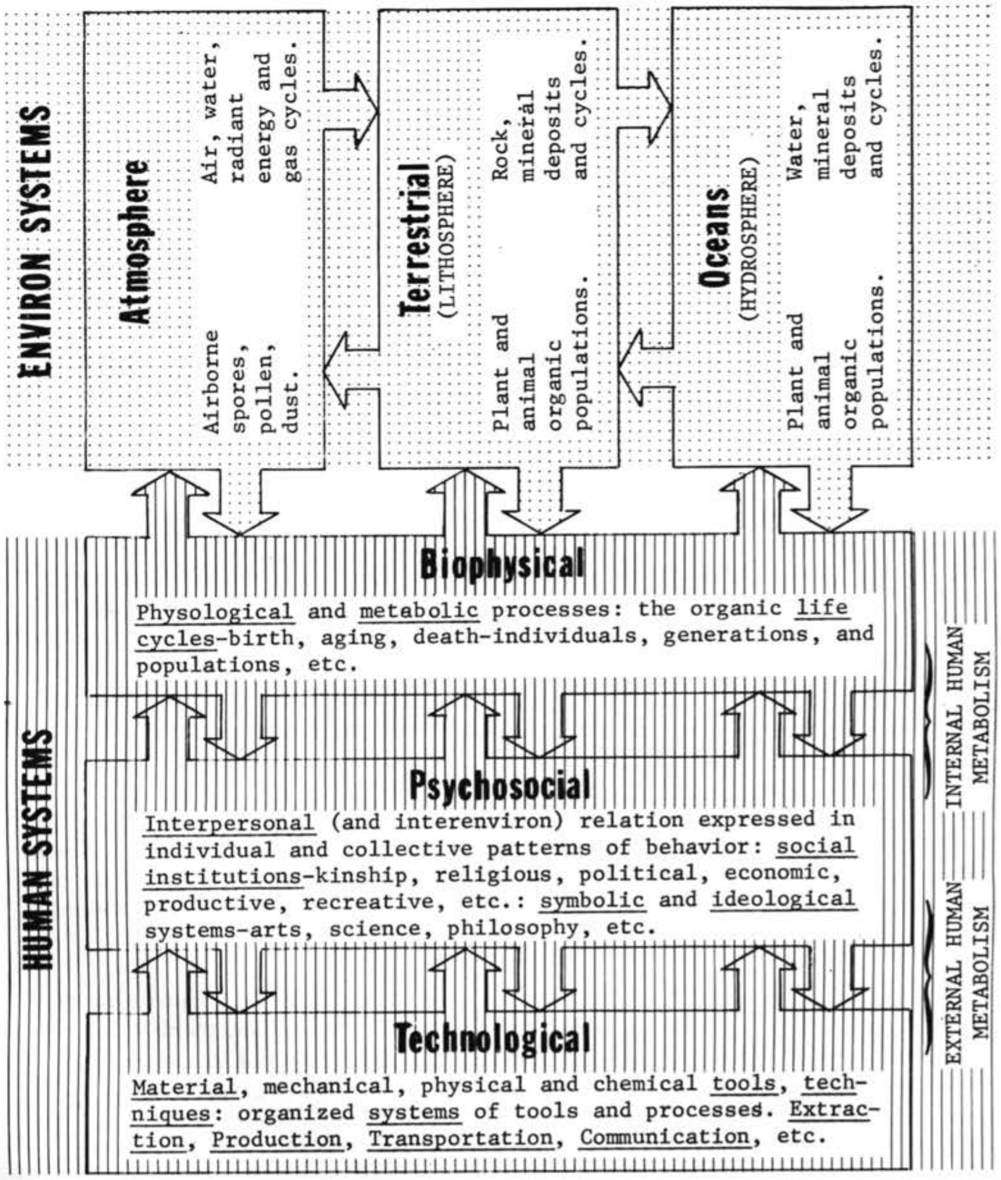
The composition of the atmosphere close to the earth's surface is mainly nitrogen, oxygen and argon in approximately 75, 23 and 1 per cent by volume. Other constituents amounting to less than a tenth of 1 per cent are hydrogen, neon, helium, krypton, xenon, radon, tritium, etc. We are generally not aware of the extent to which the atmospheric environ is freely 'mined' of its elements in our various agricultural and industrial technologies. They are, of course, 'replaced' by other parts of the organic and inorganic cycle. But we have, as yet, no accurate monitoring of the vastly enlarged scale at which this or that key constituent may be in the process of extraction in excess of renewal by the ecosystem.

All available waters in the biosphere come from condensation of water vapor circulated in the atmospheric system -- as rain, snow, hail, dew, etc. The distribution of this evaporation/precipitation/exchange cycle is global and links the terrestrial, atmospheric and marine environs in a massive interchange, not only of water, but of various other material elements injected into the different sectors of the cycle.

In addition to gases and water vapor, the atmospheric air masses carry around the earth quantities of dust, bacterial spores, decomposition and combustion particles and soil removed by wind erosion and evaporation. Where we referred to the pollution of the atmosphere and water as a global, not local, problem -- we may note here that dust particle masses and other materials noted above may be carried almost 3000 miles by a wind of only 10 miles per hour before they are deposited on the earth surface. Dust and sand storms are a common enough phenomenon -- during the United States' dust bowl storms of 1934, it was calculated that about 700 million tons of topsoil materials were eventually blown out to sea.

The 'greenhouse' effect of the atmospheric layers is so-called from the way in which these layers admit the major portion of incoming short wave solar radiation, but trap the outgoing long wave radiation moving upward from the earth surface -- thus retarding the dissipation of energies from the biosphere and stabilizing the temperature at the earth's surface. Particular attention has been given, in recent years, to the way in which the increase of atmospheric carbon dioxide, due to the use of fossil fuels, may further accentuate this heat trapping 'greenhouse' effect. Suggestions have been made that this direct, but originally unwitting interference with one of the largest of the ecosystem's maintenance patterns could, eventually, raise average temperatures to a sufficient degree

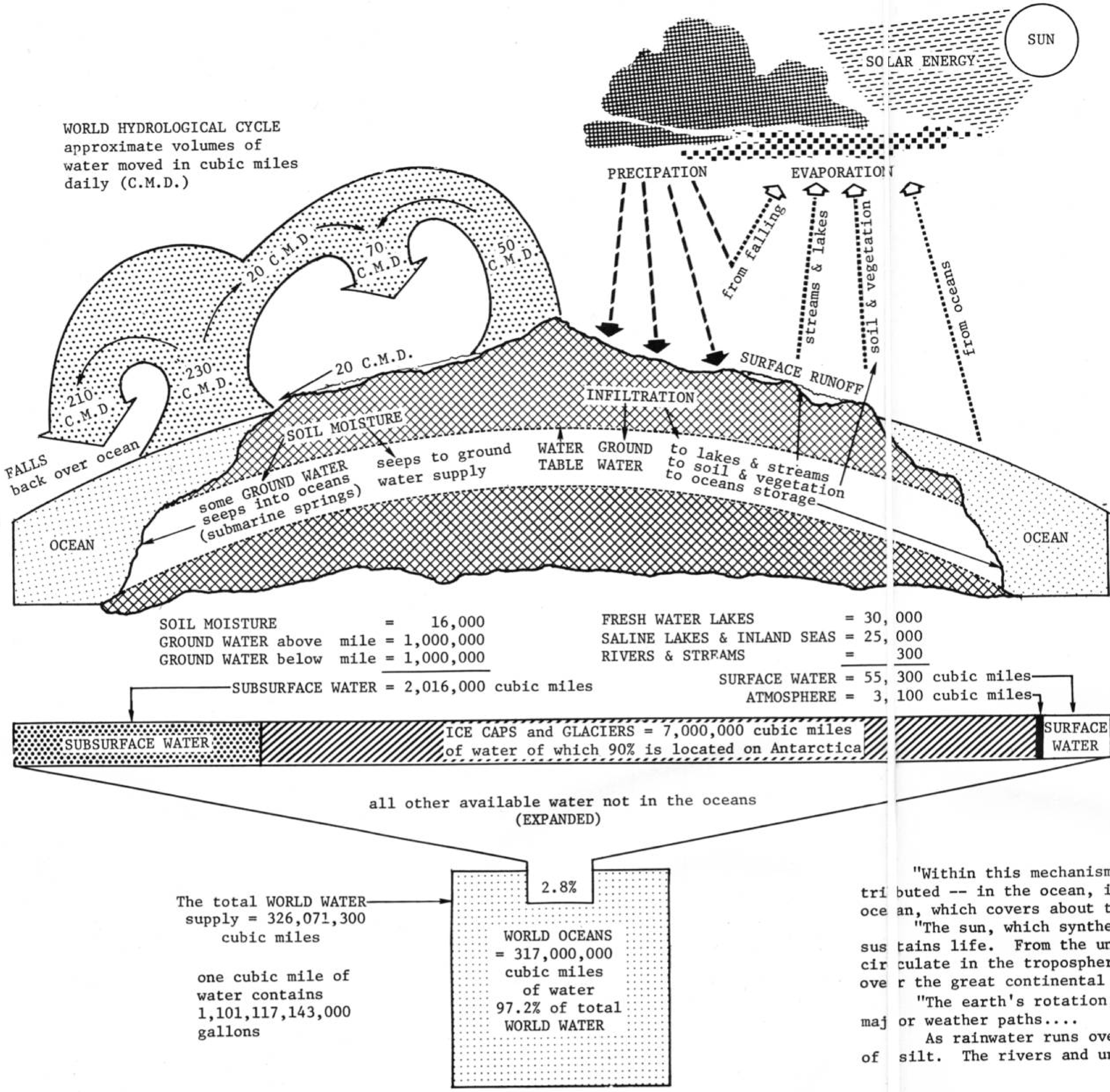
THE GLOBAL ECOSYSTEM

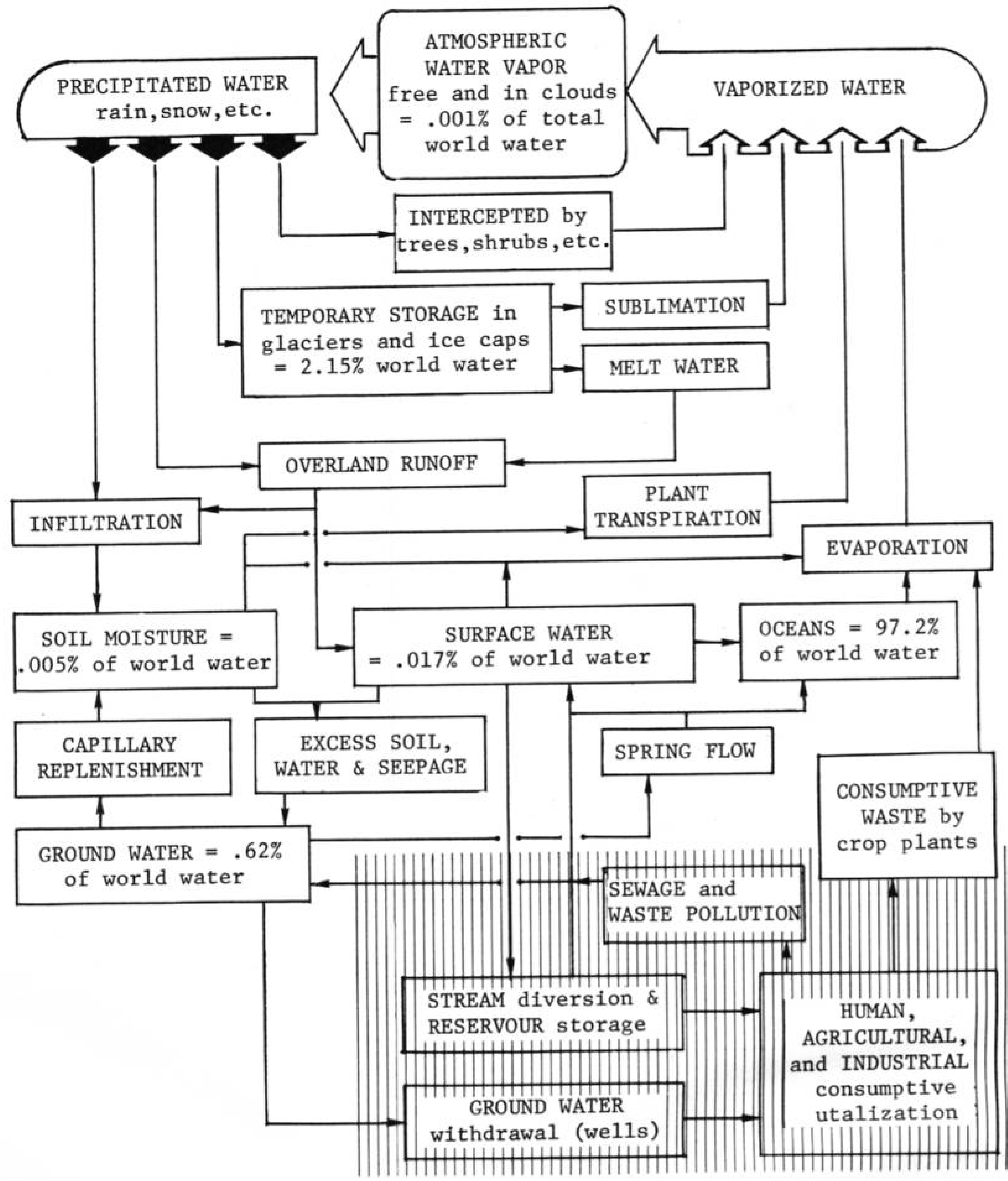


We need to extend the physical and biological concepts of ecology to include the social behaviors of man--as critical factors in the maintenance of his dynamic ecological balance. Nature is not only modified by human action as manifested in science and technology--through physical transformations of the earth to economic purpose--but also by those factors, less amenable to direct perception and measure, which are political-ethical systems, education, needs for social contiguity and communication, art, religion, etc. Such 'socio-cultural' factors have played and will increasingly continue to play a considerable role in man's forward evolutionary trending and its effects on the overall ecology of the earth.

Source: Document 4, The Ten Year Program, John McHale, (Illinois: World Resources Inventory), 1965. p. 23

WORLD HYDROLOGIC CYCLE





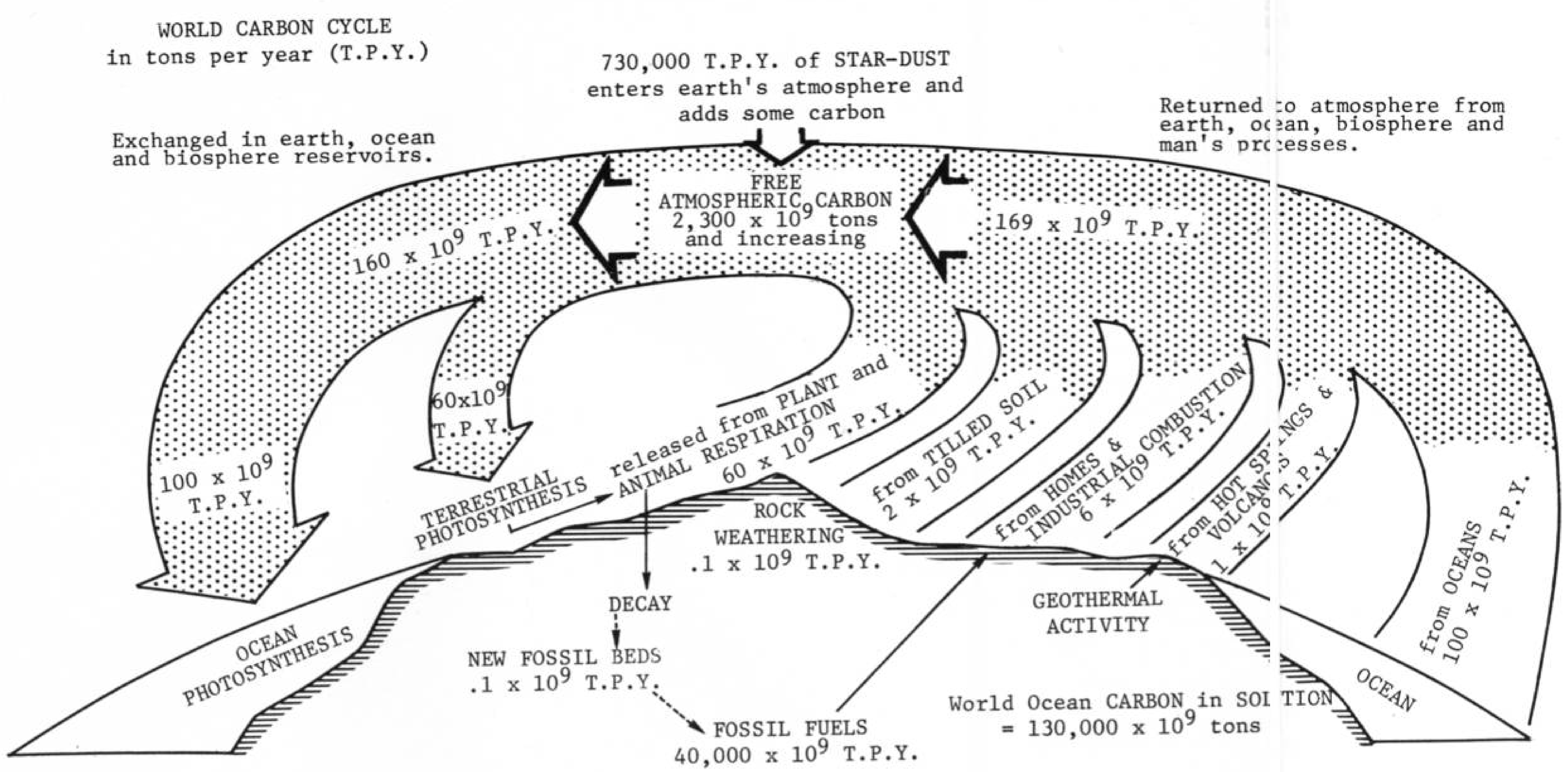
"Within this mechanism the amount of water remains essentially constant. But the way water is distributed -- in the ocean, in the atmosphere, on and under the land -- varies from minute to minute. The ocean, which covers about three-fourths of the globe, is the principal reservoir of water....

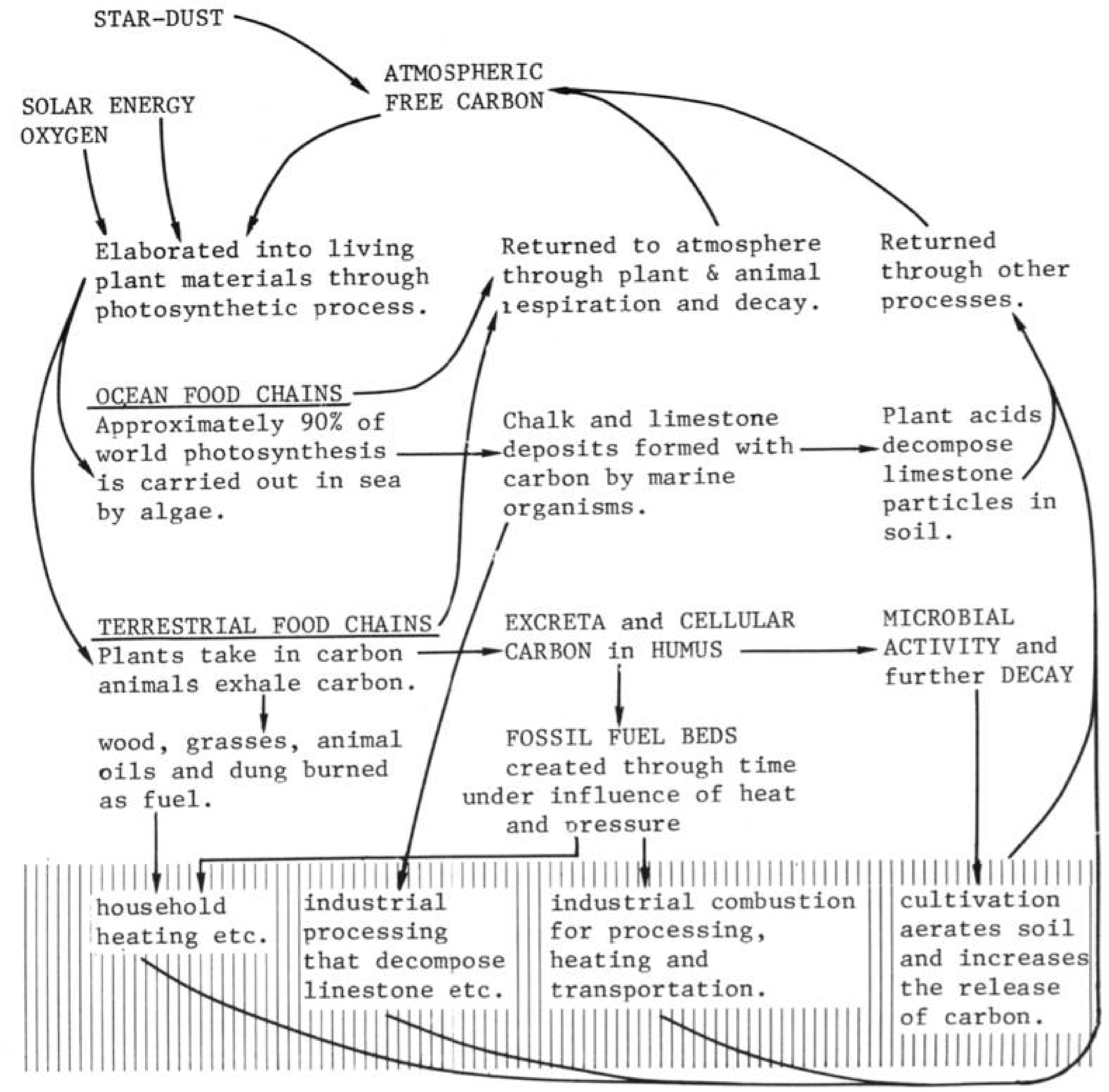
"The sun, which synthesizes man's food and keeps him from freezing, also brings him the water that sustains life. From the undrinkable ocean brine, solar energy distills pure water vapor. As the winds circulate in the troposphere -- the turbulent lower layer of the atmosphere -- they carry these vapors far over the great continental land masses....

"The earth's rotation, solar heating, and the prevailing winds and ocean currents determine these major weather paths....

As rainwater runs over and through the ground, it carries with it dissolved minerals and particles of silt. The rivers and underground water courses carry this into the ocean." --"Water-A Special Report".

Data: (1) "World Water Cycle," TIME Magazine, October 1, 1965 (2) "Water," LIFE Science Library, LIFE. p. 38. Source: (1) "Water -- A Special Report," POWER, June 1966. pp. S8, S10.





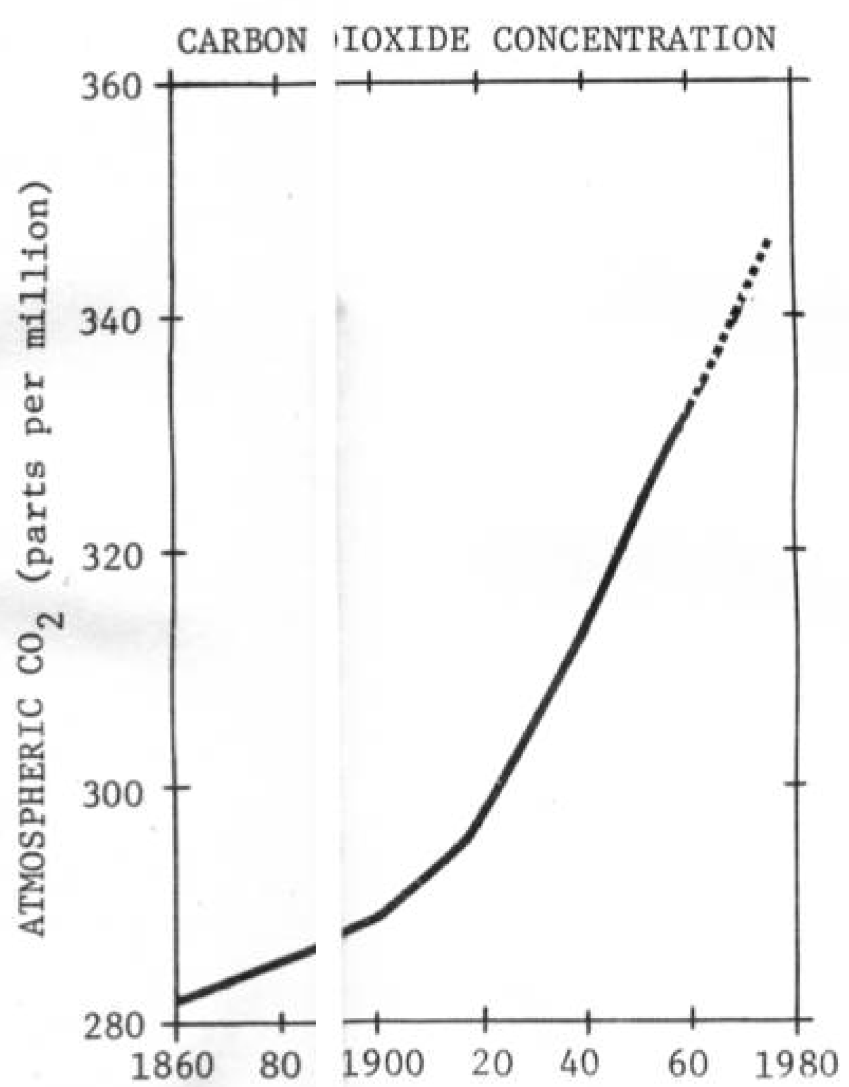
"...The atmosphere and the oceans continuously exchange carbon dioxide with rocks and with living organisms. They gain carbon dioxide from the volcanic activity that releases gases from the earth's interior and from the respiration and decay of organisms; they lose carbon dioxide to the weathering of rock and the photosynthesis of plants. As these processes change pace, the content of carbon dioxide in the atmosphere also changes, shifting the radiation balance and raising or lowering the earth's temperature....

....The geological record indicates that the huge capacity of the biosphere to store and turn over carbon dioxide has also had its effect upon climatic change. We know that plants borrow 60 billion tons of carbon dioxide yearly for photosynthesis. Under present conditions the organic world repays nearly all of this debt each year via respiration and decay. The formation of new fossil fuel deposits withholds at most only 100 million tons of carbon dioxide, or less than .2 percent of the annual amount used for photosynthesis....

...The earth's hot springs and volcanoes pour about 100 million tons of carbon dioxide back into the atmosphere per year. The earth in turn recaptures approximately the same amount each year by the weathering of the rocks....

...Quite accurate records of the amount of fossil fuel consumed in the world each year show that in the past 100 years man has added about 360 billion tons of carbon dioxide to the atmosphere. As a result the atmospheric concentration has increased by about 13 percent...

...If fuel consumption continues to increase at the present rate, we will have sent more than a trillion tons of carbon dioxide into the air by the year 2000. This should raise the earth's average temperature 3.6 degrees...."
--G. N. Plass.

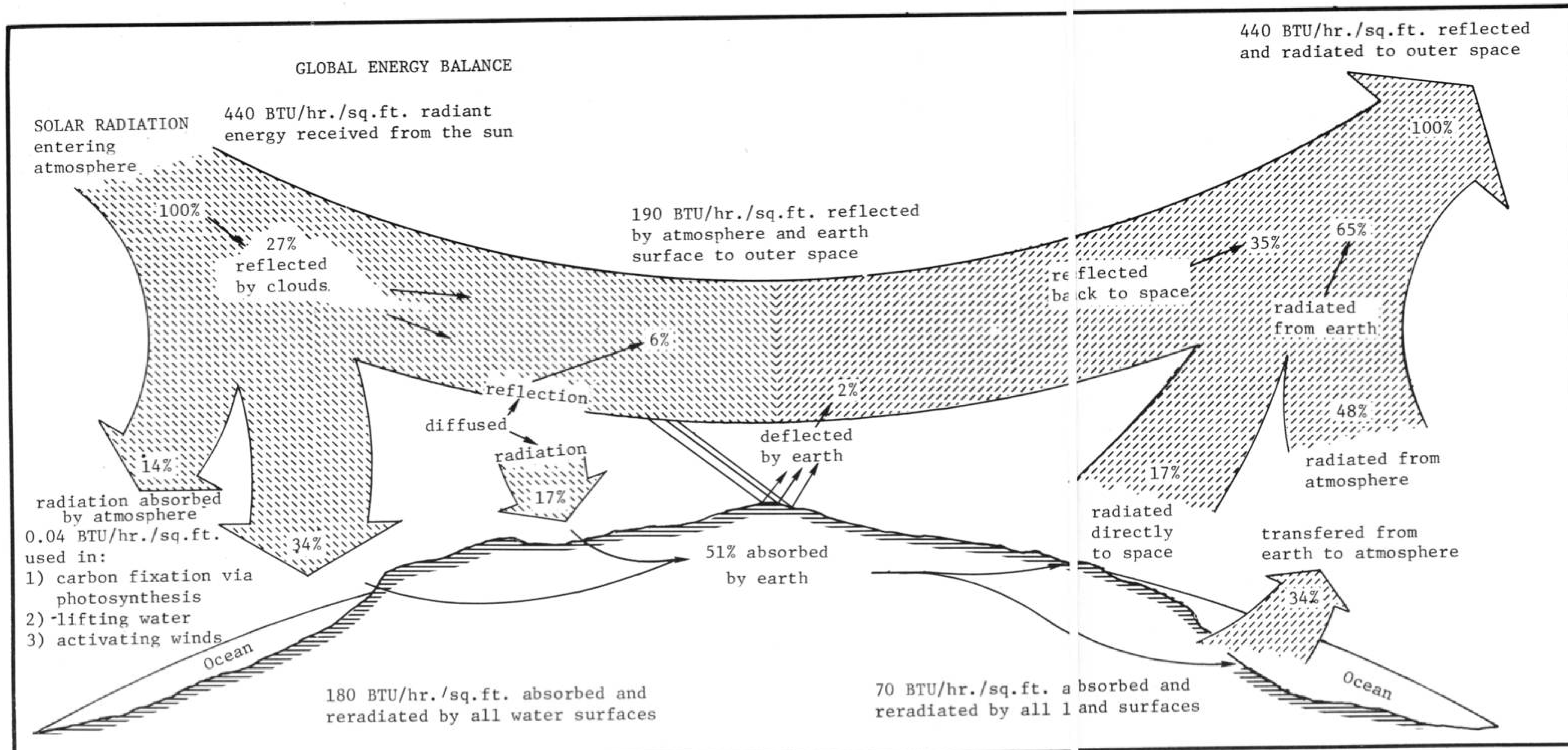


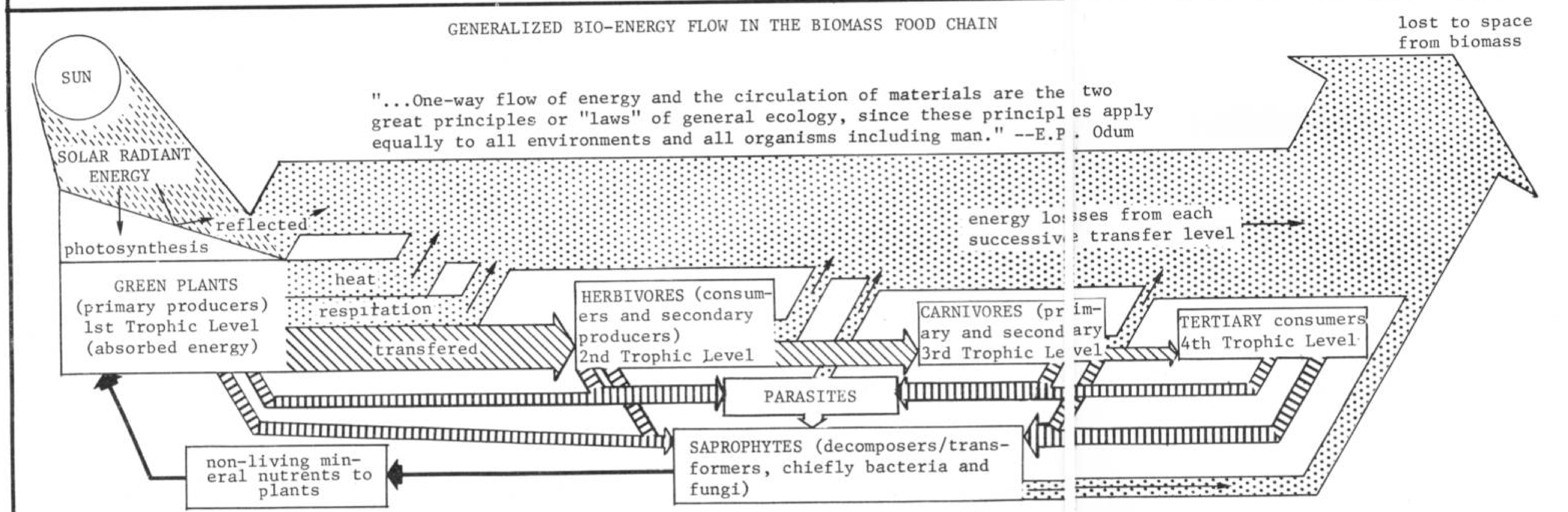
"Each year the plants of the earth combine about 150 billion tons of carbon with 25 billion tons of hydrogen, and set free 400 billion tons of oxygen. Few are aware, that perhaps as much as 90 percent of this giant chemical industry is carried on under the surface of the ocean by microscopic algae. Only 10 percent of it is conducted on land by our familiar green plants.

...A tiny fraction of the organic material synthesized by plants is later utilized as food by animals. A much larger amount is used in the respiration and other life activities of the plants themselves. The greatest part, however, is decomposed into water, carbon dioxide and mineral salts by the decay of leaves and dead plants on land and in the sea.

...The organization of atoms in the biosphere are distinguished from those of the inorganic world by two characteristics: chemical complexity and high energy content....One thing, however, all the multi-various organic molecules have in common: they are all combustible, i.e., they have an affinity for oxygen. When oxidized, they release an average of about 100 kilocalories of heat for each 10 grams of carbon they contain. Thus all organic matter contains a considerable amount of "free" energy, available for conversion into mechanical motion, heat, electricity or light by gradual or sudden combination with oxygen. Such oxidations are the mainspring of life..."
--E. I. Rabinowitch.

Sources: (1) "Carbon Dioxide and Climate, Scientific American, Vol. 216, 1967, pp 3-8. (2) "Photosynthesis," Scientific American, Vol. 79, August 1948, p. 25. (3) The Realm of Carbon, Horace G. Deming, (New York: John Wiley & Sons), 1930, pp. 259-261.





The nearer the consuming organism is to the beginning of the food chain the greater the available food energy. In human terms, the fewer intervening 'converters' used the greater the food potential.

EARTH ENERGIES

"Of the solar energy received by our globe, practically all of it is re-radiated to outer space within a few hours. Only a minute percentage of solar energy goes to vegetation, lifts water from the oceans or stirs up the winds. Solar radiations that arrive in the form we normally think of as light, have the highest intensity; but the wide range of heat or infrared radiations reaching the earth comprise the largest quantity.

"Photosynthesis holds the biological key to life. Through the catalytic action of chlorophyll, solar energy sparks the chemical combination of carbon from the air with hydrogen from ground water, to form the carbohydrates of plant fibers. This provides the fuel for all forms of animal life -- food. Without food all animal life would perish. But carbohydrates also combine to yield a cellulose fuel that can release heat energy by the process of combustion." --"Solar Radiation Power."

"The transfer of food energy from the source in plants through a series of organisms with repeated eating and being eaten is referred to as the food chain. At each transfer a large proportion of the potential energy is lost as heat. The number of steps or "links" in a sequence is limited, usually to four or five. The shorter the food chain (or the nearer the organism to the beginning of the chain) the greater the available energy which can be converted into biomass (=living weight, including stored food) and/or dissipated by respiration. Food chains are of three types: the predator chain, which, starting from a plant base, goes from smaller to larger animals; the parasite chain, which goes from larger to small organisms; and the saprophytic chain, which goes from dead matter into microorganisms. Food chains are not isolated sequences, but are interconnected with one another. The interlocking pattern is often spoken of as the food web. In complex natural communities, organisms whose food is obtained from plants by the same number of steps are said to belong to the same trophic level. Thus, green plants occupy the first trophic level, plant-eaters, the second level, carnivores which eat the herbivores the third level, etc... A given species population may occupy one, or more than one, trophic level according to the energy actually assimilated. The energy flow through a trophic level equals the total assimilation at the level which, in turn, equals the production of biomass plus respiration." --E. P. Odum.

Sources: (1) "Solar Radiation Power," POWER, September 1957. p. 24. (2) Fundamentals of Ecology, Eugene P. Odum, (Pennsylvania: W. B. Saunders Co.), Second Edition, 1962. pp. 46-47. (3) "Energy Resources," M. K. Hubbert, National Academy of Sciences.

to cause gross climatic changes -- even reduce the polar and other ice cap areas. Whether accurate or not, such calculations do enable us to pose more precisely oriented questions regarding the long range consequences of our technological directions. They underline, also, the interrelated aspect of all environ design considerations at every level.

Where certain of our past and present practices may misuse the atmospheric patterns, more consciously applied knowledge and design initiative can enable us to make more gainful use of the tremendous, and constantly renewed, circulatory patterns. In the atmospheric environ, which we contaminate through extraction of energies at relatively low conversion rates from fossil fuels, great wind energies are available for 'tapping into'. For centuries windpower was the principal energy source for ocean traffic, and on land, prior to the introduction of other mechanical energy converters, windmills were the prime motive power for many basic operations.

Terrestrial

Treated here as land environ, this occupies only about a quarter of the earth surface and is the primary ecological habitat of man -- from which he extracts most of his food and other energies and upon which, until recently, he conducted most of his environ transactions.

Most of the material resources contained within the land surface have been built up over long periods of geological time. The great metal and mineral deposits upon which human society is dependent for its extended technological systems, have taken millions of years to accumulate in the earth surface. As a side glance at our present use rate of these non-renewable resources, the following rough figures are instructive.[1]

	Geological time Required to produce 1 ton (millions of years)	Man's Removal Rate (Millions of tons per year)
Petroleum	250	600
Coal	1,000	2,000
Iron	2,000	200
Lead	4,000	4

Of course, in the case of the metals, these, though not renewable in the strictest sense, are cycled through successive use/scrap processes. The fossil fuel extractions are of a more seriously depletive nature.

The dry land usable by man, which also sustains large animal populations, is less than a quarter of the available land space -- the rest is desert, jungle, ice cap or mountain peaks, etc. The usable agricultural area provides food through direct use of edible crops or through other animal food converters. In terms of traditional food yield uses, this is confined to a thin depth of topsoil where most of the plant nutrients are present in a relatively critical distribution balance. This is a renewable resource base dependent on the various geochemical and climatic cycles; in recent historical time, however, the rapid growth of population, its aggregration in great densities and the pressure upon the food soils has lead to misuse and relatively permanent loss of great areas of this vital soil base.

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[1] World Balance Sheet, R. Doane, New York, p. 27, (Harper 1957).

One of our most critical present limitations remains biological and terrestrial, in this sense, as human society is still almost wholly dependent on the plant/animal food yield from a relatively 'fixed' area of arable land.

Recent calculations[2] suggest that the present maintenance of three billion humans in the biosphere requires a plant yield sufficient to accommodate 14.5 billion other consumers. These others, the animal populations, are an essential element in maintaining the humans by acting as intermediate processors for many plant products indigestible by man. Pigs, for example, consume as much as 1,600 million people, when measured on a global scale; the world horse population has a protein intake corresponding to that of 650 million humans -- the population of China.

Marine

Covering more than 70 per cent of the planetary surface, this is, in terms of planetary space, food, and other material resources, like having several more environs at human disposal. The comparatively shallow areas of the continental shelves alone, are about half the area of the earth lowlands where most of humanity lives.

Our knowledge of the oceans is rudimentary. As man's locally, most hostile environ for centuries, only the surface has been travelled upon and the depths not at all investigated until quite recently. Barely one per cent of all sea organisms have been studied and the cyclic migrations of its larger creatures have been little charted.

Also pertinent is the fact that about four fifths of the planet's animal life and the bulk of its vegetation are underwater -- yet, comparatively little of these are used as food. In this regard, the ecological recycling of such resources in the oceans is much more frequent than on land. Fish and other organic populations have higher growth rates; ocean crops have less variable 'weather' problems for possible cultivation and harvesting than the land.

The other material resource potentials of the oceans have hardly been tapped. Vast deposits of pure metal ores have recently been located on the ocean bed and the waters themselves are a rich source of extractable materials.

> The ocean is the ultimate depository of everything eroded from the continents. Over 40,000 million tons of materials are washed into the oceans every year by rivers. The winds also transport millions of tons of materials per year.[3]

The use of ocean waters for direct irrigation of the land has also been considerably pioneered in recent years. As specifically applicable to the sandy 'desert' soils, such

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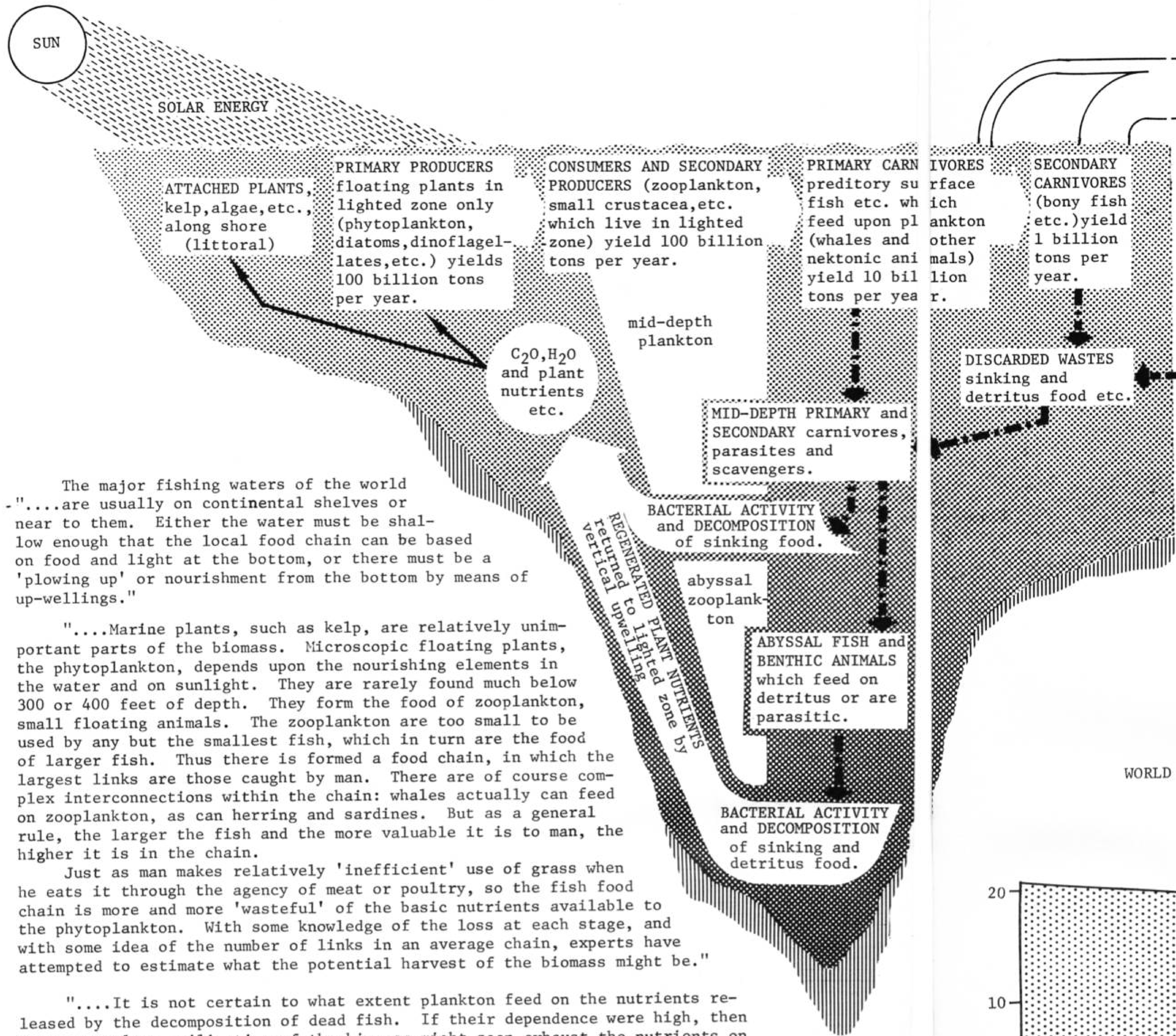
[2] "The Human Biosphere and Its Biological and Chemical Limitations", G. Borgstrom, Global Impacts of Applied Microbiology, ed. Mortimer P. Starr, (John Wiley and Sons, Inc., New York, 1964).

[3] "Mineral Wealth from the Ocean Deeps", J. L. Mero, Discovery, July, 1964.

OCEAN FOOD CHAIN: FISH & FISH PRODUCTS

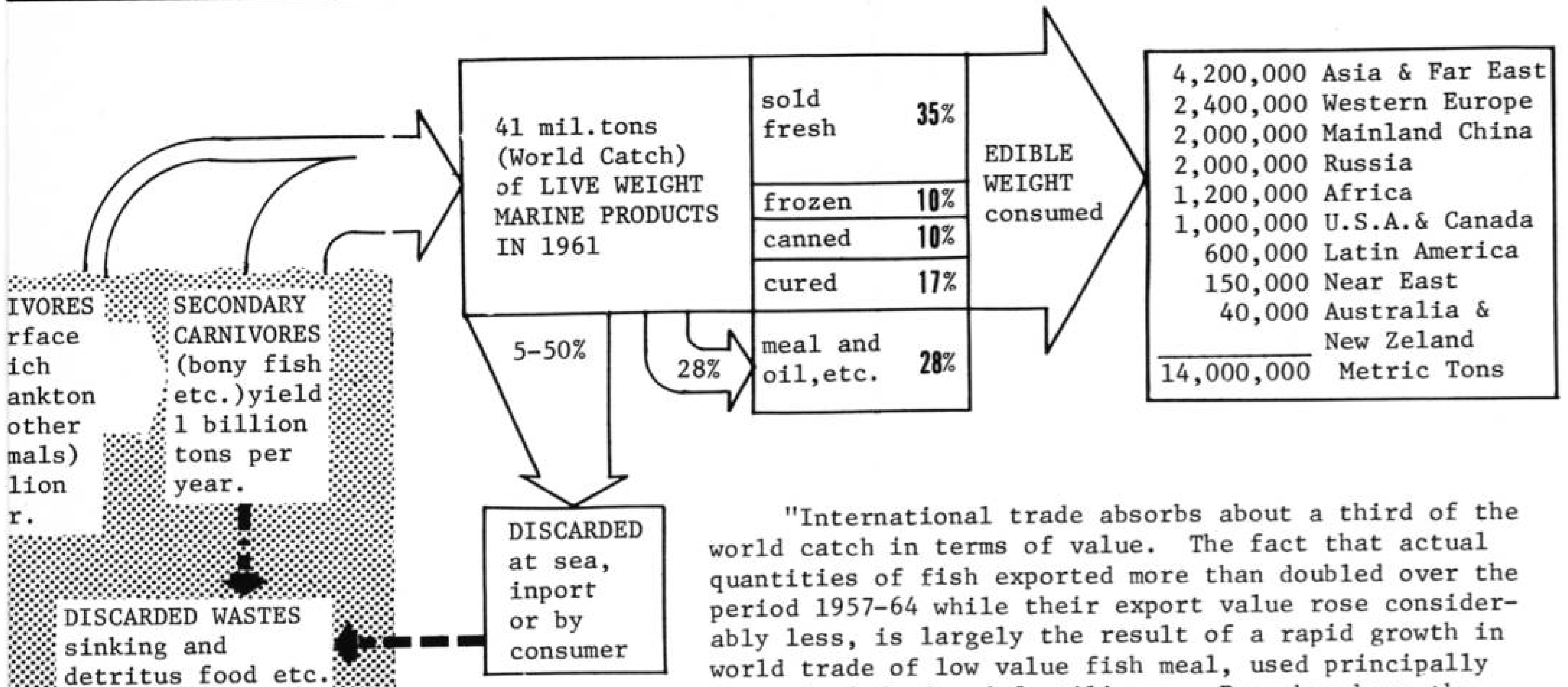


The major fishing waters of the world -"....are usually on continental shelves or near to them. Either the water must be shallow enough that the local food chain can be based on food and light at the bottom, or there must be a 'plowing up' or nourishment from the bottom by means of up-wellings."

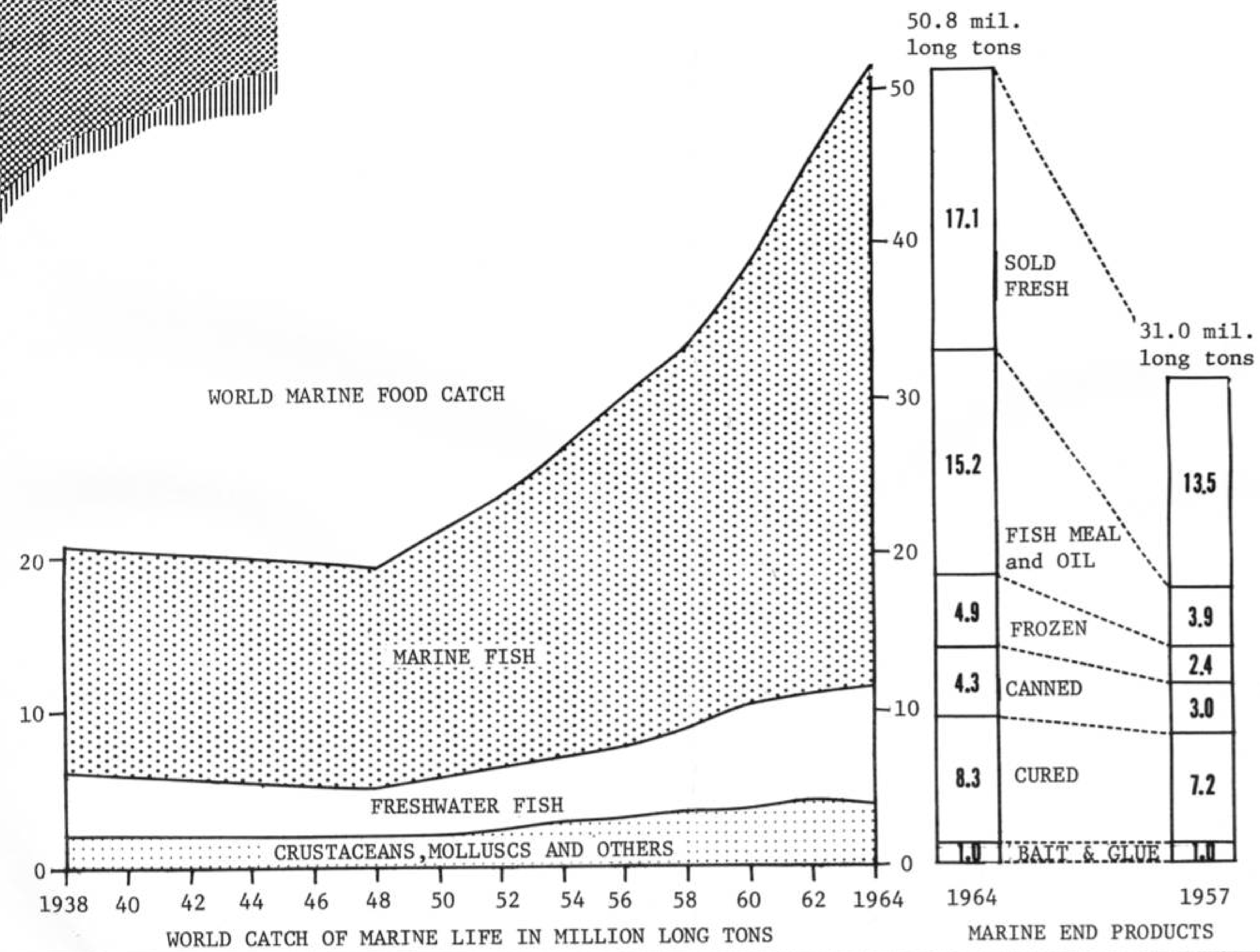
"....Marine plants, such as kelp, are relatively unimportant parts of the biomass. Microscopic floating plants, the phytoplankton, depends upon the nourishing elements in the water and on sunlight. They are rarely found much below 300 or 400 feet of depth. They form the food of zooplankton, small floating animals. The zooplankton are too small to be used by any but the smallest fish, which in turn are the food of larger fish. Thus there is formed a food chain, in which the largest links are those caught by man. There are of course complex interconnections within the chain: whales actually can feed on zooplankton, as can herring and sardines. But as a general rule, the larger the fish and the more valuable it is to man, the higher it is in the chain.

Just as man makes relatively 'inefficient' use of grass when he eats it through the agency of meat or poultry, so the fish food chain is more and more 'wasteful' of the basic nutrients available to the phytoplankton. With some knowledge of the loss at each stage, and with some idea of the number of links in an average chain, experts have attempted to estimate what the potential harvest of the biomass might be."

"....It is not certain to what extent plankton feed on the nutrients released by the decomposition of dead fish. If their dependence were high, then a more complete utilization of the biomass might soon exhaust the nutrients on which the food chain now depends. The estimates assume that relatively full utilization of the seas would not significantly alter the store of basic nutrients upon which the chain depends."-- A. D. Scott.



"International trade absorbs about a third of the world catch in terms of value. The fact that actual quantities of fish exported more than doubled over the period 1957-64 while their export value rose considerably less, is largely the result of a rapid growth in world trade of low value fish meal, used principally for animal feed and fertilisers. Peru has been the main contributor to this sector of trade."-- Barclays Bank Review.



Sources: 1) "Biology and Human Environment," C. H. Waddington, 2) "World Fishing," Barclays Bank, Barclays Bank Review, February 1967. 3) "Food and the World Fisheries", Anthony D. Scott, Natural Resources and International Development, ed. Marion Clawson, (Washington D. C.: Johns Hopkins Press), 1963.pp 134-37.
Ekistics, Vol. 21, No. 123, February 1966.

research is of extreme importance in the critical area of world food production.

> Arid and semi-arid regions cover a third of the land's surface . . . many of (these) sandy regions could be made productive with salt water irrigation . . . any advance in making sandy soils productive adds to the resources available for the production of food. And any such addition can be a factor in the effort to keep the production of food abreast of the growth of population.[4]

Desalination, the production of fresh water from sea water, also forms part of the growing use of the oceans. The most promising developments are those combining nuclear power/fresh water generation plants in the same productive units. Such units in present use around the world have a desalting capacity of about 50 million gallons per day -- an increase of 100 per cent over the past two years.

In view of these great potentials, it is hoped that planned use of the oceans may come about in time to reduce the spoilage which has already occurred in many areas, particularly of the key coastal shelves. Indiscriminate sewage and industrial wastes have already ruined future developments of considerable areas for some time to come. This process is further increased by the discharge of fuel oils from sea tankers which contaminated beaches for years and wrecks heavy toll of sea birds and other ocean organisms. Old sea mine fields still render large areas of the coastal waters unsafe, and are now accompanied by the new hazard of radioactive waste disposal in offshore areas. Overfishing and hunting has led, not only to greatly reduced catches in many previously well populated fishing zones, but also the near extinction of certain ocean species like the great sperm whale and the fur seal.

The 'ecologically' designed use of the oceans could provide man with an enormous expansion of his environs, which would also solve many of his most pressing terrestrial problems of food, scarce and depletible land resources, and increasing water requirements of agriculture and industry. The recreational potential and challenge of exploring the oceans may also become a new and almost illimitable frontier.

THE MAJOR CYCLES

We have referred, in passing, to the complex interchange patterns of air, water and other constituents of the biosphere. Between the environ and the human system, it may be appropriate to introduce some brief notes on what are generally termed the <u>biogeochemical</u> cycles. These, representing the basic material element exchanges in the ecosystem, may suggest paradigms for the conscious design of more 'naturally' efficient cycling of energy and materials in our man-made systems.

Of the inventory of chemical elements in the universe, between thirty and forty are known to be essential to life forms. Some are required in large quantities -- carbon, hydrogen, oxygen and nitrogen -- others in minute or trace quantities. All are in more or less constant circulation within the biosphere and, though local 'shortages' may occur, as in the loss of critical soil components, all elements are potentially inexhaustible as recirculating in the eco-cycles or 'in reserve' in the great reservoirs of the ocean, air and earth crust.

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[4]"Salt Water Agriculture", H. Boyko, <u>Scientific American</u>, February 1967.

It has been suggested, in this regard, that man is unique in his use of the elements. He not only employs in his internal metabolism the range of approximately forty elements essential to biophysical maintenance, but, in his external metabolism of extractive, productive, and redistributive processes of agricultural and industrial activities, he employs all the other naturally occurring elements in the universal inventory, as well as their isotopes.

Man is, however, only one of the species of organic life in the biosphere, and like all life forms, exists only in interrelation with all others. The precise degree of interdependence may seem remote and tenuous between a briefly viable colony of micro-organisms, in a large area of virgin jungle on one side of the globe, and a community of human beings on the other -- but it is, nonetheless, real. Plants, animals, men and their environs are bound together in a complex web of relations. Animals depend on plants and other animals for food; man depends on both. The plants draw nutrient elements from the soil and these are, in part, returned from various stages in the food chain. The soil-plant-animal-soil cycle is only one aspect of the larger cycling of essential elements in the system. The soils themselves become exhausted of various elements, through repeated plant/animal populations, and it has long been man's practice to fortify the natural cycling of essential soil elements with 'natural' or 'chemical' fertilizer elements. One of the greatest revolutions in human society, the agricultural revolution, comes through increased understanding of the fundamental growth patterns of plants and their relation to the natural cycles of energy and materials in the ecosystem. The second and more recent wave of industrial revolutions was also predicated on increased understanding and gainful advantage of the energy cycling principles.

The major cycles in the biosphere are, therefore, of key importance to our environ re-design considerations. Almost all of our major societal undertakings are affected by or, more importantly, affect the natural cycling of energies and materials in the system. In some cases the cycling patterns are so large and their 'reserves' and compensating mechanisms of sufficient latitude to correct any maladjustment through human intervention. Others are naturally 'imperfect' cycles, and require careful attention to avoid serious disequilibrium and, locally occurring, disparities in the essential elements with which they are concerned.

Apart from the hydrological, carbon and photosynthesis cycles already discussed or illustrated, it may be pertinent to give two other key examples.

The Nitrogen Cycle

Though one of the most abundant elements in the atmosphere, nitrogen requires chemical change to enter the soil and be utilized by plants in the food cycle. A further series of changes return nitrogen to the atmosphere and completes the circular process. We may view the pattern from any point in the cycle.

a) it is emitted into the air from nitrogenous compounds in organic materials which are broken down by a chain of specialized bacterial actions. Some of this reduced nitrogenous material is taken up by plants, e.g., as nitrate, some used in other forms by other organisms.

b) the above reduction of nitrogen bearing materials is complemented by the return cycle of nitrogen from the atmosphere and other sources by the action of nitrogen fixing bacteria, fungi and plant forms in the soil, pond waters, etc. This aspect of the cycle is a relatively closed, self-regulating pattern.

c) further nitrogen exchanges occur, e.g., in the atmosphere as ammonia and nitrates are formed by electrical discharges, in the earth from excretion/decay cycles, and in the marine environ.

We may note that the complex regenerative pattern of even this single element requires interaction from each level and every component of the ecosystem, including both living and non-living forms of matter.

The major importance of nitrogen for the food cycle of plants, hence, animals and man, cannot be exaggerated. The increase in agricultural plant yields through the application of 'artificial' nitrogenous compounds to augment and increase the cycle locally is now marked. Adequate protein supplies for the present world population are thus no longer predicated entirely on the natural cycle, but require over 13 million tons of nitrogen fertilizer produced by the chemical industry. This is a particularly clear-cut example of the ways in which the extended industrial metabolism of man is interlocked with the natural cycles to maintain his increased requirements.

> Approximately one sixth of the world population is presently dependent on artificial nitrogen for its survival. It can safely be assumed that the world's soils via residues and soil micro-organisms can hardly be expected to take care of more than half the additional 3000 million people expected before the end of the century. This would imply that in the year 2000, the world would need artificial support along the nitrogen front of no less than 50.5 million tons . . . The annual production of 1 million tons of nitrogen requires at least 1 million tons of steel and no less than 5 million tons of coal, calculated as energy equivalents. This is a most crucial factor for the energy-poor parts of the world.[5]

It may be noted that in terms of solutions to the 'food problem' such industrial components are not so closely gauged. Further, with the added amount of other agri-industrial support chemicals, in the year 2000, the amount required would be closer to 500 tons. Stating the problem in these terms, one can calculate more accurately the logistical parameters of the problem -- the increase in fertilizer production, in energy/plant expenditures, transportation, distribution and the ancillary requirements of raw fertilizer materials, extraction processing, transport, etc.

Whereas, in the above cycle the element is returned to, and circulated within, the soil in large amounts by natural means, other elements have less locally regenerative cycles. They may be 'lost' through leaching or erosion to the oceans or redistributed in unfavorable balances through human or other agencies in the system. One such critical case is given below.

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[5] Op cit., Borgstrom.

The Phosphorus Cycle

As there is no 'free' elemental phosphorus occurring in nature, this element is only available to plants and animals in its compounds -- mainly through the mineral phosphates. The movement of the element occurs in two main patterns -- in the earth and marine cycles.

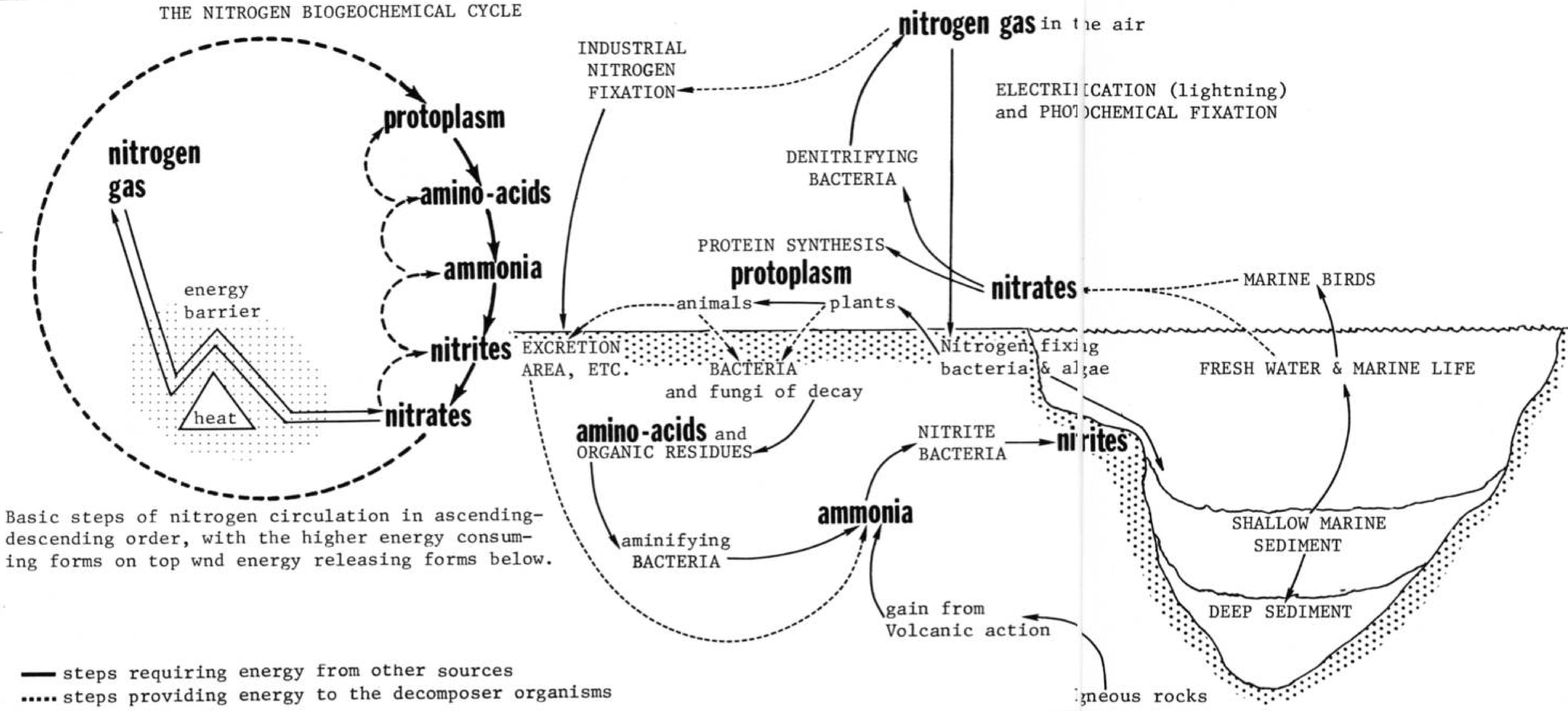
Soil phosphorus is taken up by plants and animals from that made available by phosphatising bacteria working on the organic compounds in the earth. In the absence of 'artificial' phosphates, the main cycle source of such compounds is through plant and animal decomposition and excretion materials returned to the soil. High yield crops such as certain cereals extract up to 10% of the available phosphorus to the topsoil -- hence, if regularly harvested without artificial phosphate or 'decay' replacement, soils may become locally depleted. Animals also take up relatively large quantities and, again, if 'cropped' off a given soil in repeatedly large numbers their bone phosphorus is lost to its original location. Some soils and vegetation tend to 'lock up' phosphorus in temporally inaccessible forms, causing local shortages. The main reservoir of phosphorus is not in the atmosphere as is the case with nitrogen, but in geological deposits. These add phosphate compounds to the system, as they are eroded, but much is washed off into the rivers and eventually to the oceans in the process. The land cycle of phosphorus is, therefore, an 'imperfect' one from our temporal viewpoint.

In the marine aspect of the cycle, the initial phosphorus intake is by algae and diatous, the plankton group, which utilize solar energy to convert this and other elements present in sea water to their nutrient requirements. This process is similar to the plant photosynthesis on land. Phosphorus is then ingested by the fish and other organisms in the other links in the ocean food chain. Fisheries return about 1% into the man/land pattern, but little to the actual cycling pattern. Guano birds are a source for fertilizer return to the soil via their excreted phosphorus, but this is locally restricted. The process of local decay, which on land returns phosphorus to the upper levels of the soil, in the oceans allows it to sink to the ocean floor where the photosynthetic process is not operable. Thus, much phosphorus, in this stage, is taken out of the cycle and accumulates where it is not available for other than limited use by ocean floor organisms. In some regions, inversion of upper and lower levels of the ocean waters return phosphorus and other elements to the surface cycle, but in others this is not of regular occurence -- apart from geological uplift.

Present knowledge suggests that phosphorus availability, through its role as key plankton nutrient, 'controls' the entire life cycle in the oceans -- and is also of critical importance to man in the biosphere. Human extraction of phosphorus from food is relatively high but, again, in our period of high population concentration with the discharge of sewage directly into rivers and oceans the loss of phosphorus in this part of the food chain is very great. Large amounts are flushed away annually to the seas and rivers in sewage -- e.g., equivalent to about 60 million tons of phosphate rock each year in the United States alone. Although the eleventh most abundant element in the earth's crust, about 0.12 per cent, and combining readily with many metals, most of the 'available' phosphorus is found in one group of mineral compoounds, the apatite, phosphate rock. As the first artificial fertilizer introduced about the middle of the Nineteenth Century, phosphates have since expanded dramatically in production and world distribution. From a total world production of about 11,000,000 metric tons in 1964, the required increase by 1970 is estimated at almost double -- 18,000,000 metric tons. When we consider the projected population increase for the next 100 years, we can view a phosphate requirement of well over 5 times this latter amount. The critical importance, <u>one</u>, of available phosphate rock reserves, <u>two</u>, of increasing the cyclic reuse of sewage phosphorus and other modes of phosphorus conservation, may be easily gauged.

NITROGEN AND PHOSPHORUS CYCLES

THE NITROGEN BIOGEOCHEMICAL CYCLE



Basic steps of nitrogen circulation in ascending-descending order, with the higher energy consuming forms on top wnd energy releasing forms below.

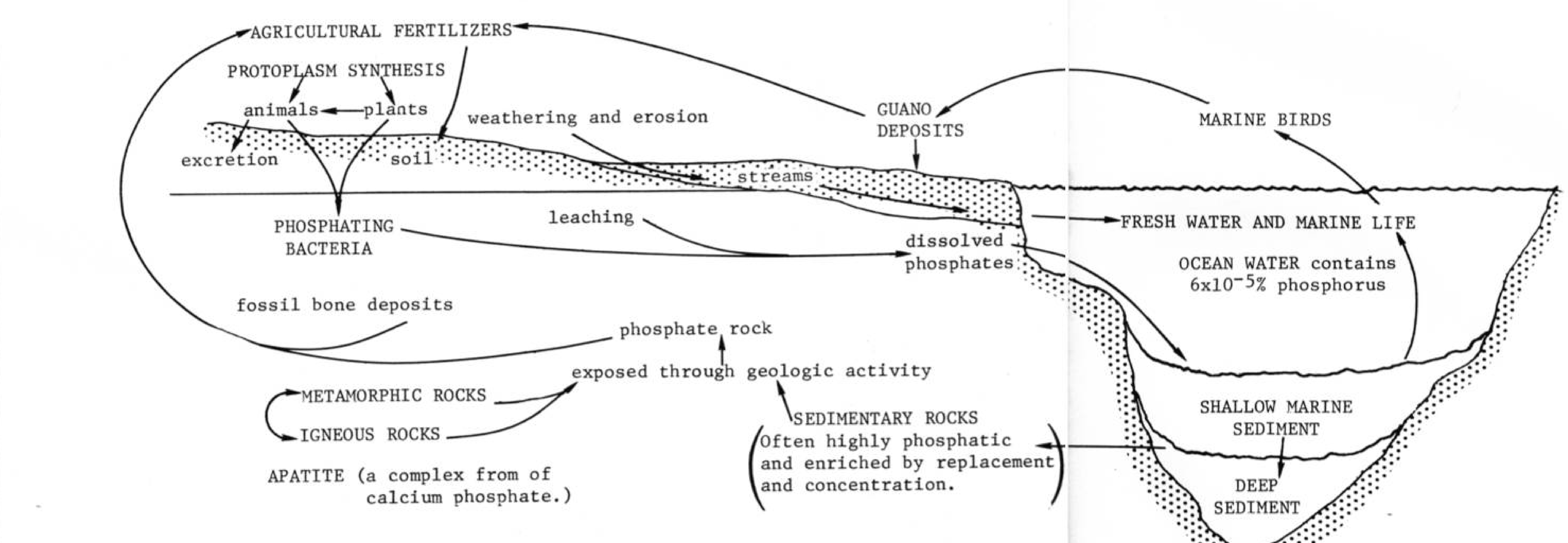
—— steps requiring energy from other sources
····· steps providing energy to the decomposer organisms

"It has been calculated that a ton of wheat extracts on the average from the soil about 47 lbs. of nitrogen, 18 lbs. of phosphoric acid and 12 lbs. of potash: and unless these losses are replaced the fertility of the soil is decreased." --W. R. Jones

"The self-regulating, feedback mechanisms, shown in a very simplified way by the arrows, make the nitrogen cycle a relatively perfect one, when large areas or the biosphere as a whole is considered. Thus, increased movement of materials along one path is quickly compensated for by adjustments along other paths. Some nitrogen from heavily populated regions of land, fresh water, and shallow seas in lost to the deep ocean sediments and thus gets out of circulation, at least for a while.... This loss is compensated for by nitrogen entering the air from volcanic gases....

"According to Hutchinson (1944a), the amount of nitrogen fixed from the air (non-cyclic nitrogen) is estimated to lie between 140 and 700 mg. per square meter, or between 1 and 6 pounds per acre per year for the biological; only a small portion (not more than 35 mg. per square meter per year in temperate regions) is non-biological (electrification or photochemical fixation). Biological fixation in fertile areas may be much greater than the biosphere average, up to 200 pounds per acre, according to Fogg (1955)." -- E.P. Odum.

THE PHOSPHORUS BIOGEOCHEMICAL CYCLE



PHOSPHORUS makes up about 0.1% of the earth's crust.

"A portion of the earth's phosphorus is continually passing out of the mineral reserve into living substance, and similarly, phosphorus is continually passing out of living matter to re-enter the mineral reserve. This movement of the element has been pictured as taking place within two cycles, a land cycle and a marine cycle, or one general cycle with its complicated circulations of the element since the two cycles are definitely interrelated. Actually, the losses of the one cycle become the gains of the other. The cycle of matter is not completely reversible, that is to say, all matter is not restored completely to its original state, but it has a large measure of forward movement which permits a redistribution of chemical elements and states of matter."

"The cyclic phenomena of the life processes and the transport of phosphatic material by streams to the ocean waters give a broad picture of how biologically available phosphorus has been distributed over the face of the earth. The phosphorus content of sea water has been derived chiefly from soil erosion and the processes which dissolve fish bones, shells, and the vast amount of debris from dead tissues."

"Goldschmidt estimates that on an average, ocean water contains 6×10^{-5}% phosphorus. Authorities recognize that phosphorus is the most important limiting factor for the growth of plankton, and therefore, that it controls almost entirely the production of life in ocean waters. The quantity of phosphorus is always very small owing to its continual utilization by sea life and it is said to vary between zero and 0.07 ppm." -- Vincent Sanchelli.

Sources: (1) Minerals in Industry, W. R. Jones, (New York: Penguin Books), 1963. (2) Phosphate in Agriculture, Vincent Sanchelli. (New York: Reinhold Publication Cor.), 1965. (3) Fundamentals of Ecology, E. P. Odum, (New York: Holt, Reinhart, Windston, Inc.), 1959.

> At productivity levels five times greater than now, corresponding to the food demand in about 100 years, phosphorus removal would be in the order of 50 kgs. per hectare yearly. Full fertilization at this rate would exhaust the estimated reserves of phosphate rock in approximately 60 years, assuming no expansion of cultivated lands.[6]

The extraction of phosphorus from the soil by living organisms and its retention/fixation by certain soils and plants and its inequable return to the 'food chain' system is also paralleled by the case of various other trace elements. Local exhaustion of such elements has occurred, for example, where large herds of livestock are 'harvested' from the same pasture area over many years and shipped elsewhere for consumption. Without human intervention, the trace elements they have taken up would be returned to the local soil via the growth/decay cycle -- these are now 'lost' at their various other use/consumption destinations elsewhere on the earth surface.

Man speeds up the extraction and widens the circulation pattern of a great many materials so that in certain critical cases the local cycles are disturbed -- the process becomes acyclic. As we have so far emphasised, we are fast acquiring capacities to disturb other major cycles in similar fashion. The prime function of designed and ecologically oriented man-made systems would be that they make acyclic processes more cyclic.

Though we shall return more specifically to the problems of human population growth and food, one author, G. Borgstrom whom we have already quoted, makes the plea that research is, 'now needed on the scale of a space project . . .to broaden the potential of the biosphere'. Suggesting that we learn to operate with nature, not against it, he lists an 'action program' whose emphasis on the systematic study and utilization of the organic cycles is of key relevance to large scale environmental planning in the comprehensive and ecologically oriented sense.

A. <u>Foods</u>

a) Review the status of fermented foods to improve and broaden the use of present methods in order to find simple and cheap procedures.
b) Institute a systematic search for methionine-rich fungi or, possibly, bacteria.
c) Expand engineering studies for the transformation of sewage plants into food-producing centers (via algae, yeast, fungi, bacteria, fish, etc.).
d) Determine the nutritive contribution by intestinal flora.

B. <u>Soils</u>

a) Broaden the attack on improved microbial nitrogen-fixation in tropical and temperate climates with the specific aim of reducing artificial application of fertilizers or still better, making this superfluous. This is the greatest contribution microbiology could make to the developing world.
b) Establish more precisely the role of microbes in the mineralization process and the release of bound mineral nutrient resources, (phosphorus, calcium, etc.).

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[6] "The Planetary Food Potential", W. R. Schmitt, <u>Annals of the New York Academy of Sciences</u>, Vol. 118, Art. 17, p. 712.

C. Seas

a) Detailed mapping of nitrogen and sulfur cycles of the oceans.
b) Study of the role of nannoplankton.
c) The microbial mobilization of the non-living organic matter of the oceans.
d) The role of autotrophic microbes in the oceans.

D. Lakes

a) The sulfur and nitrogen cycles (determine the role of microbes).
b) The immunization mechanism of fish under the stress of the seasonal build-up of microbes in the surrounding waters.[7]

In terms of our present focus on energy and material usage efficiencies, it may be interesting to note certain of the energy conversion efficiencies obtaining in the naturally occurring cycles.

Estimates vary considerably, but the generalized figure for plant fixation of solar energy is given as roughly 1 per cent in the overall photosynthetic process on the earth's land surface. This seemingly low average is due, partially, to variation in plant cover -- as limited by sunlight, rainfall and the availability of nutrient elements in the soil. Of this total converted solar energy, approximately 30 per cent is used in the plant's own growth and maintenance, 10 per cent is transferred to herbivorous animals, and the remainder (60 per cent) is reduced in plant decay by bacterial composition. The overall efficiency for the oceans is estimated at 0.18 per cent of the solar energy reaching the ocean surface.

The seemingly low energy conversion efficiencies in such an overall view of the total ecosystem are not strictly comparable with those obtained in man-made energy converting mechanisms. There are great differences in physical and time scales between the two forms. The naturally occurring forms are self-renewing and self-perpetuating and achieve more 'production' growth per unit and time interval than man-made forms -- whose efficiency calculation does not include renewal, autonomous growth, repair and replacement.

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[7] Op cit., Borgstrom, p. 163.

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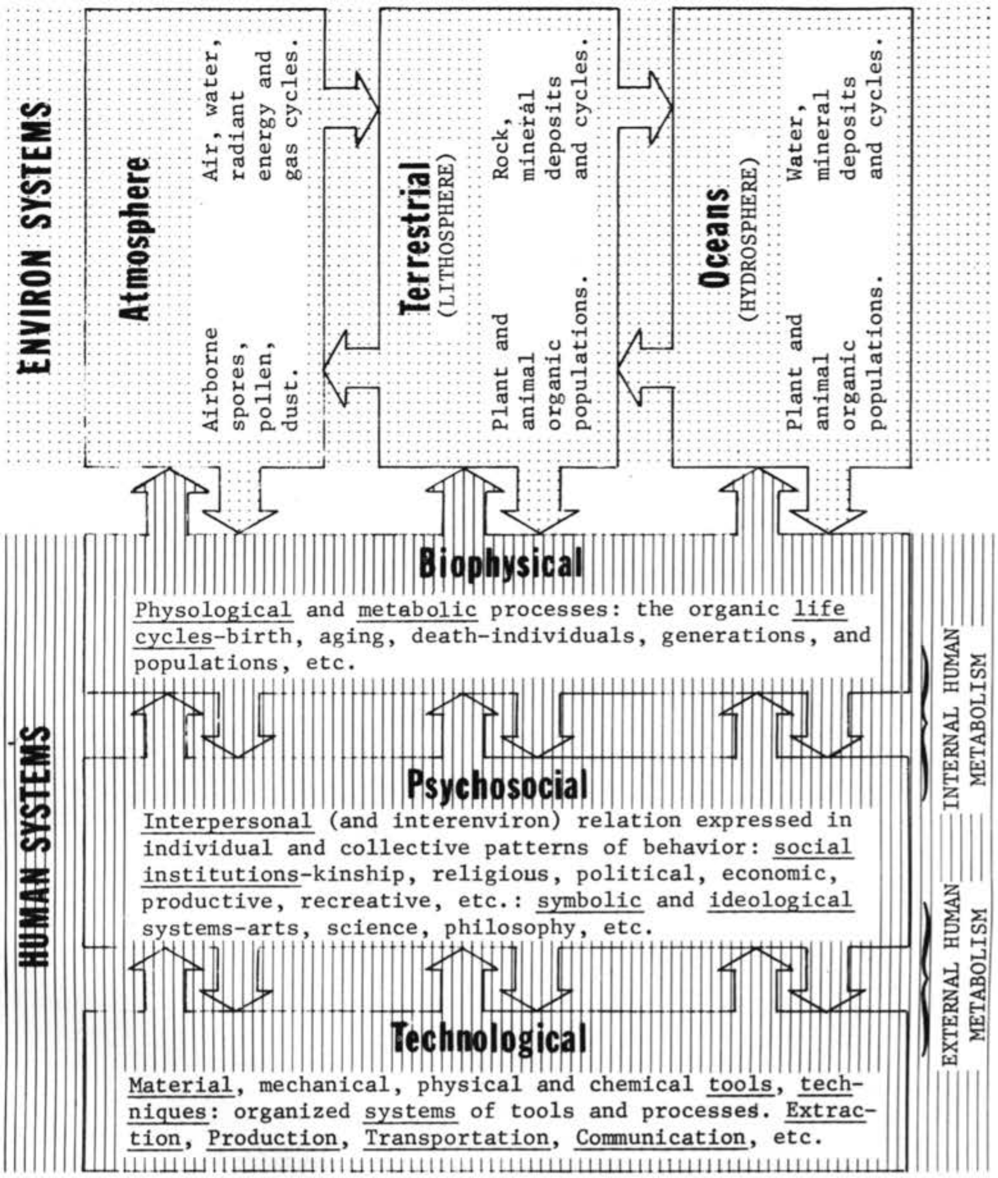
HUMAN SYSTEM(S)
Biophysical-Psychosocial-Technological

N.B. The Global System diagram on the next page has been repeated for more convenient reference to the section which follows.

THE GLOBAL ECOSYSTEM



We need to extend the physical and biological concepts of ecology to include the social behaviors of man--as critical factors in the maintenance of his dynamic ecological balance. Nature is not only modified by human action as manifested in science and technology--through physical transformations of the earth to economic purpose--but also by those factors, less amenable to direct perception and measure, which are political-ethical systems, education, needs for social contiguity and communication, art, religion, etc. Such 'socio-cultural' factors have played and will increasingly continue to play a considerable role in man's forward evolutionary trending and its effects on the overall ecology of the earth.

Source: Document 4, The Ten Year Program, John McHale, (Illinois: World Resources Inventory), 1965. p. 23

HUMAN SYSTEM(S)

Biophysical ---- Psychosocial ---- Technological

Man is a wholly integral process. As in dealing with the environ, we should emphasize the wholly denotative convenience of labelling different parts of what is an essentially integrated and dynamic whole. The use of the word 'system' should also be qualified in this regard. We need, particularly, to avoid 'mechanical' systems models here. When we deal with human activities, the complexity tends to force us back onto simplistic schema. Though these may function well as limited conceptual supports, and aid toward reducing the complexity into some neat disciplinary format, we usually end up with models like economic man, behavioral man, political man, technological man, etc. Such concepts abstracted for convenience tend to become 'reified' -- to assume an autonomous reality in themselves for which they are unfitted. This is particularly dangerous when we attempt to solve human problems in such reified terms. We often assume that many large scale problems may be solved wholly within the artificial divisions set up for intellectual convenience.

No social problem of small or large scale, and all human problems are axiomatically social, may be solved within the terms of any single field or discipline. A wholly technological solution, however logical and seemingly efficient, may fail by overlooking some elementary socio-cultural requirement. Solutions conceived solely in economic or even biological terms, e.g., in the case of population and food, may fail through lack of adequate technological considerations. The point seems an obviously simple one -- but examples could be drawn out, at length, of our present failures to solve human problems through inadequately conceived solutions.

The divisions used here -- biophysical, psychosocial, technological -- are adopted for present convenience. They overlap considerably, and are in no way suggested as an exhaustive classification of the major aspects of human activities in the biosphere.

Biophysical

From the viewpoint of biological and physical apparatus, there are few characteristics which give man any uniqueness as a life form. We could elaborate here on the specific anatomical and physiological features which describe his species position, e.g., as a mammalian primate of medium size, with certain kinds of individual variability, brain size, psycho-physical capacities, temperature/pressure tolerance, etc. This type of information is now readily available to designers in human factors studies, in medicine, and, particularly, in the detailed and comprehensive reports emanating from space and underoceans research in human support systems.[1]

Some discursive notes on basic human needs may be pertinent. The biophysical requirements for optimum maintenance of human life fall within a relatively narrow and specific range. The basic energy process, as with other organisms, is that of consuming food energies in combination with the oxidation process in respiration. Air, water, food within various degrees of temperature and pressure are the key requirements. Individuals daily needs vary with age, weight, health, activity, etc. (figures given below are for an average 140 pound male adult):

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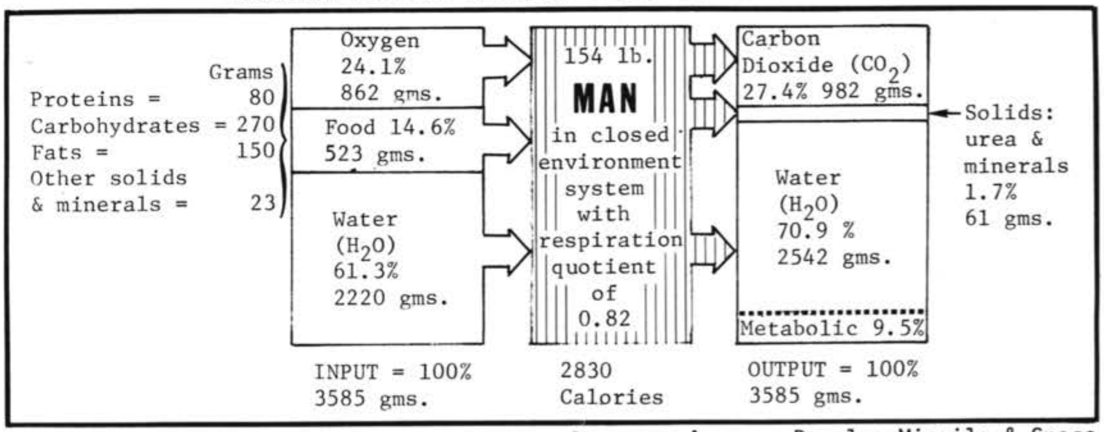
[1]For example: Handbook of Bioastronautics, NASA Report No. SP-3006, 1964, Handbook of Environmental Engineering, (McGraw Hill Book Co., Inc., 1963).

HUMAN DAILY METABOLIC TURNOVER



Source: Apogee, Douglas Missile & Space Publication No. 4, 1961. p. 8.

ELEMENTS IN MODERN MAN

IMPORTANT ELEMENTS IN MODERN MAN WHICH REQUIRE INVESTIGATION

ELEMENTS	Daily intake micrograms	Amount retained micrograms	Accumu-lation with age	Systems or tissue affected
FLUORINE	1,000	?	Bone	Bone
SILICON	3,500	4	Lung (A)	Integument
VANADIUM	2,000	0-0.2	Lung (A)	Lipids
CHROMIUN	60	0-0.3	Lung (A)	Glucose, lipids
MANGANESE	5,000	0	No	Brain, several
IRON	15,000	0	Lung (A)	Blood, storage
COLBALT	75	0	No	Blood
COPPER	2,000	0	No	Storage, liver, brain, blood
ZINC	12,000	0	No	Skin,many
SELENIUM	?	?	No	Muscle
STRONTIUM	2,000	1	Bone	Bone
MOLYBDENUM	1,000	0	No	Purines
IODINE	150	0	NO	Goitre
BARIUM	16,000	?	Bone	Bone ?
LANTHANUM	?	0	No ?	Coagulation

(microgram = 0.001 milligram)

"There are 9 essential inorganic micro-nutrients for mammals; 7 are metals and 2 are non-metals. Four have been or are being considered as causing deficiency diseases, and only 3 as causing diseases of accumulation. There are 10 trace elements with requisite capacities to act as essential micronutrients for mammals, but which have not been investigated as such, either because of ubiquity in foods or because of lack of interest; 7 are metals. There are 4 alkali metals or alkaline earths which may exert biological activities, either beneficial or antagonistic. There are 13 heavier elements to which modern man is exposed; his ancestors had minimal exposures to at least 7 of these. All are more or less toxic; 4 are known to accumulate in tissues with age, and 6 are more highly concentrated in man's present environment than on the earth's crust. Only 2 so far are considered to influence a disease." --H. A. Schroeder.

Source: "The Biological Trace Elements," Henry A. Schroeder, Journal of Chronic Disease, Vol. 18, 1965. pp. 226-27.

Air -- Life may be sustained without food and water for some time as the organism may draw upon nutrients and liquids stored in the tissues, but air intake cannot be postponed for more than a brief interval. Respiration supplies oxygen to the tissues via the lungs and eliminates carbon dioxide and other oxidation products from the tissues. Oxygen intake need per day is approximately 1.35 pounds under normal conditions, and about 2.2 pounds of carbon dioxide are exhaled -- i.e., taken up largely by plants and reconverted into oxygen and food in the photosynthesis cycle.

Water -- Though somewhat less immediate than air, the organism's need for water is still more stringent than food.

> The body can lose practically all stored animal starch or glycogen, all reserves of fat and about one half of the protein which is stored or built into body structures, and not be confronted with great danger. But the loss of 10 per cent of body water is serious and a loss of 20 to 22 per cent means certain death.[2]

The daily water need is approximately 5 pounds per day. Depending on cultural context, much larger quantities are used for various other physiological functions, e.g., as in washing, general hygiene, etc.

Food -- The various basic food requirements may be summarized briefly under these headings:

1) Carbohydrates, including starches and sugars, are the main energy fuel sources which compensate for the oxidation and heat energy losses in the general metabolism. Such 'fuel' requirements depending on activities, average about 3,000 calories per day -- to balance daily energy output/ loss of approximately the same amount.

As a general note on food energy conversion, man converts food intake into available 'mechanical' work energies at about 20 per cent efficiency. Part of the food energy intake is consumed in respiration, circulation, digestion, etc. -- part is given off as heat -- part is used in nervous system activity -- and part is indigestible and voided as waste.

2) Protein is required for the repair maintenance of organic structure and tissue. Though less in volume-demand than carbohydrate, an average of 100 grams per day (or 1.5 grams per kilo of body weight) is estimated as the minimal need.

3) Minerals, vitamins and a number of 'trace elements' are required for adequate human function. Some daily minimal quantities are:

iron	0.015 grams
calcium	0.45 grams
phosphorus	0.86 grams
salt	2.0 grams

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[2] The Ways of Man, J. Gillin, (Appleton Century Inc. 1948), p. 290.

Much attention has been given in recent years to the question of trace elements, the part played by mineral deficiencies in growth retardation, etc. Attempts have been made to correlate such 'trace' resource availability in different soils and food plants with variation in social and cultural growth rates, to the extent that this factor observably affects other animal populations. Vitamin intakes of different types and quantities are also essential to adequate function and maintenance. There is little need for detailed comment on these here.

Temperature and Pressure -- with narrow physiological adjustment to temperature variability, man can only survive within a median high range of cold heat. He is, in this sense, a 'subtropical' animal functioning best where twenty-four hour temperatures average between 63 to 73 degrees F. Function and 'survival' would be defined here in terms of health and activity output. Acclimatization plays a considerable part and through much evidence has been accumulated on higher physical activity as sustained in temperate climatic zones, this may well be due to other social and cultural factors. Pressure is also a limited adjustment area for the human organism and may be noted particularly in physiological difficulties, high altitudes or in underwater working.

Sleep requirement varies directly with age more markedly, perhaps, than other requirements in relation to body size, etc. From 18-20 hours per day when newborn, the need declines through 12-14 hours in the growing child, 7-9 hours for the mature adult and thence to 5-7 hours in later ages. There is some division of opinion on whether adult requirement for sleep varies with activity function or with cultural 'conditioning'. Sleep deprivation experiments have recorded only up to around 50 hours maximal time without sleep, and then only if the subject was kept in continuous activity of some sort.

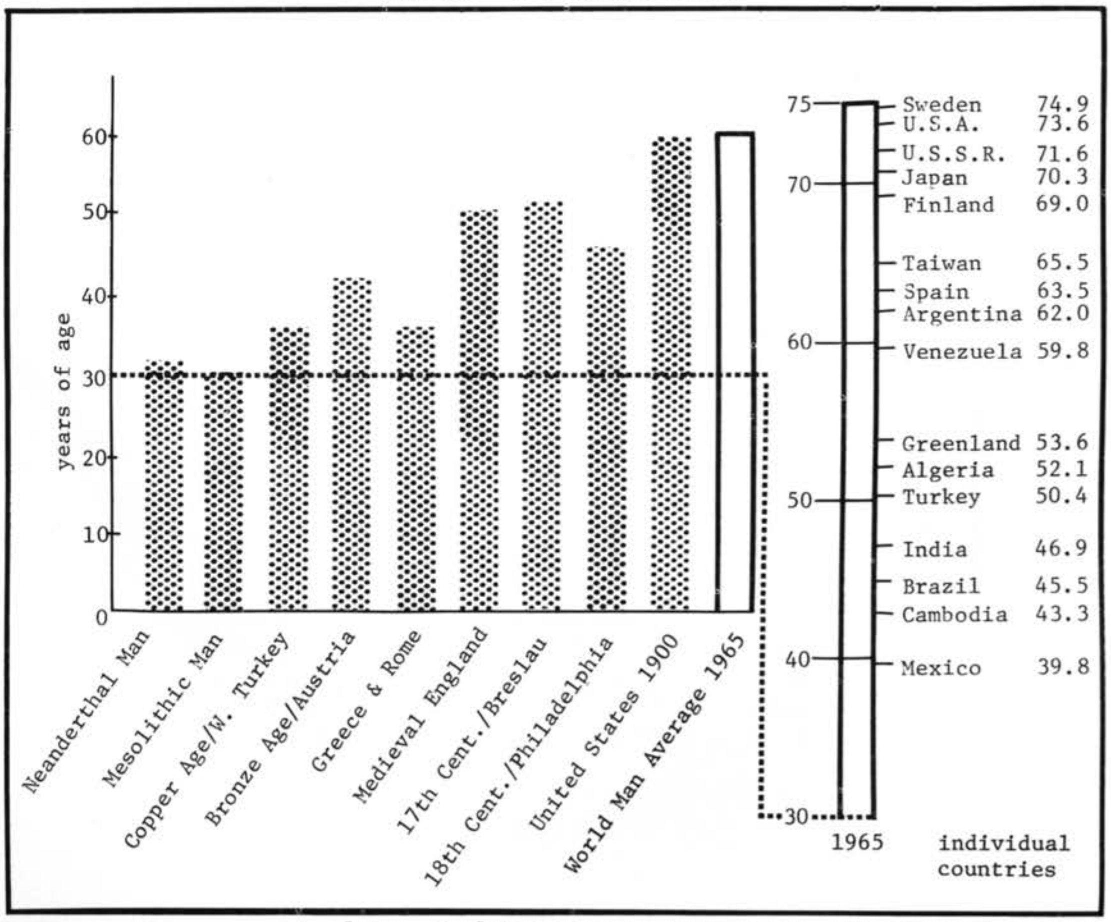
Our emphasis in the biophysical requirements above has been on basic individual physiological requirements. Even in terms of simple physiological requirement, we cannot avoid considerable overlap with the 'technological' system. Various biophysical modifications through sophisticated technical means are already routine. Artificial organs and extensions of organs are now operating as well as electronically controlled artificial limbs and 'natural' organ transplants.

The artificial limb prosthetic attachment is one of the most interesting examples, which, though produced in response to human defect through birth or amputation, is capable of much wider application. The problems of delicacy of control and requisite power of manipulative and holding action have now been largely solved. Turning the body's own energy to use, scientists have amplified bio-electrical muscle currents in limb 'stumps' to trigger servo-mechanisms for hand movements -- versatile enough to unscrew a light bulb, bend each artifical finger joint and lift up to nine pounds.

The use of electrical energy drawn directly from the body itself to power various internal and external organs directly, or to use for remote control of other mechanisms outside of the body has far reaching consequences. Apart from self-powering artificial organs, heart pacemakers, etc., it could also be used for transmitting signals for operating other controls at a distance, or acting internally as receiver/activator of metabolic control signals from remote medical centers.

With new valves for damaged hearts, synthetic tubes, clips, organs, and assists and metabolic amplifiers of various kinds, the biophysical organism may now enter a new era of synthetic regeneration. This field is now more than simply 'spare parts' medicine, but has evolved swiftly into bio-engineering.

LIFE EXPECTANCIES



Data: Health & Disease, Rene Dubos, Maya Pines & editors of Life, (New York: Time Inc.) 1965, pp. 193-195.

> Surgery is essentially an engineering discipline . . . the integration of electronic circuits into the human body as functioning and permanent parts . . . is going to become very important within the next ten years.[3]

The most striking extension of all has been the general increase in human life expectancy and improved physiological function throughout the lengthened life span -- in the advanced regions of the world. This capacity to prolong life, however, already has attendant problems in population control. We may anticipate further problems when prolongation is expanded toward genetic control of biophysical characteristics before and after birth; and when we increase our capacity to modify, by many present and emergent means, the emotional, mental and physical aspects of the human organism. Coupled with this, is the possibility of creating new types of 'living' systems based on quite different biochemical configurations.

These advancements in biophysical 'control' are specific aspects of the general advance in man's knowledge of himself -- as a biological organism. The interaction of biological, medical and engineering sciences which this entails is also underway in other areas such as water supply, waste disposal, air pollution, food preservation and public health.

We may sense, again, the growing eco-systems approach as beginning to operate at both the micro and macro extremities of human environ control -- within the human body itself and outwardly to encompass the entire planetary body.

N.B. Our emphasis in the above biophysical requirements has been on basic individual needs. We have only mentioned, in passing, the way in which these basic needs are subject to psychosocial adjustment. Though we 'hunger' biologically, we are generally 'hungry' at socially designated intervals and for a definite range of culturally defined foods prepared in quite specific ways.

> In the very process of responding to environmental stimuli, each individual human being creates his physical and mental personality from the biological attributes that are shared by all men. Human societies and culture emerged from the progressive integration of these responses.[4]

The needs may be biological, the responses to the needs, and their satisfaction, are social and cultural -- are learned responses. This brings us to our further division of the human system(s).

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[3] Electronic Physiologic Aids, A. Kantrowitz, Director, Cardio-Vascular Surgery, Maimonides Hospital, New York, 1963.

[4] "Humanistic Biology", R. Dubos, American Scholar, Vol. 34, No. 2, 1965, p. 197.

Psychosocial

All that we have to say in this text is dependent on this central aspect of man. We have noted elsewhere that 'social patterns determine biological events'. In the case of man, this is strikingly evident. Man is human by virtue of his social existence -- that he lives in, by, and for human society. This is not to devalue individual man, but to underline that man's nature, i.e., his humanity, is socially produced. Society, in this case, is not confined to local society, but to the awareness of, and sense of belonging to, the larger human society -- to the continuity of human cultural experience. Meaning, even for the individual, cannot be separated from its location within this societal context.

Man is made human by his earliest experiences of human contact. He learns to be a human being. When acutely deprived of such early periods of socialization, the organism exists, but so limited in mental and even physical development that basic survival itself is impaired.

The above preamble is necessary to further emphasize the integral orientation of all that we may discuss. Though we may stress an 'ecological' approach, this remains almost exclusively man focused -- a bias we cannot escape. We perceive the environment only in human related terms. No matter how 'objective' we may strive to be, the formulation of objectivity is itself a peculiarly human symbolic process.[5] All of our environmental transactions are conducted inescapably through such symbolic screens. Objective 'truths' about such transactions are most clearly expressed in a series of highly abstracted symbol systems, whose claim to truth and objectivity is almost in due ratio to the degree of abstraction of their symbology -- as in mathematics, the expression of the fundamental physical elements and their periodicities, the electro-magnetic spectrum, etc. These symbolic constructs are the highest 'ordering' principles which we know, and, though we refer to their 'discovery' in nature they are only apprehendable to use as conceptually 'created', and communicated, symbols.

> . . . the qualities and characteristics that constitute the visual sensations of which we are conscious . . . are not inherent in the so-called external 'things' at which we are looking. The origin of our sensations is in the prior experiences and the characteristics and qualities of our sensations are determined by our unique personal (social) history, etc.[6]

The prime behicle for all our environmental interpretation and the basis for human action is some form of language. Both verbal and non-verbal symbolic languages 'order' our perception of the environ and control the interpretation and communication of what we perceive. Language now constructs our reality.

The biological evolution of man is marked by the development of his nervous system and its associated organs for monitoring, controlling and adjusting the environ to his purpose -- from the brain to the eyes, skin, limbs, etc. It is suggested that though man stopped physically evolving about 150 thousand years ago and is now a social animal,

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[5]"A symbol is something the meaning of which is not determined by its intrinsic physical properties, nor whose meaning has been established by the neuro-mechanism of the conditioned reflex, but something whose meaning is freely and arbitrarily determined by those who use it; let the color black indicate mourning. Only man is able to use symbols in this way," "The Symbol" Origin and Basis of Human Behavior", L. A. White, Philosophy of Science, Vol. 7, pp. 451, 1940.

[6]"Experiments in Perception", Adelbert Ames, Jr., Progressive Architecture, December 1947, p. 20.

evolving only through his extensions, many of his apparently irrational behaviors are explicable as 'instinctual' responses which were biologically meaningful in early development -- but are no longer appropriate to his changed condition. Fears and insecurities, expressed in certain 'dominance, territoriality, crowd and flight responses,' etc., which had survival value in the past may often appear to act negatively in a more socially secure present. Their measurable physiological reactions are acute and often stressful. Taken as part of the total human system, they are, however, powerful sources of social energy when appropriately channelled. Language and other 'symbolic responses' are, for example, now interposed between physical stimuli and 'action' response.

We may, more accurately, characterize the key evolutionary stage of man, not as tool making or using, but as communication through symbolic languages. Though, ". . . language may be termed the first industrial tool, as it involves a plurality of men, and is a prior requirement for the integrated efforts of many men"[7], tool using in man is a cumulative and progressive activity unlike that of the tool using animals. Language as a prime tool, extends our control over the environ as demonstrably as any physical artefact -- by naming and ordering, we control as effectively. Organized information is now our major tool resource.

Man's ecological expansion has been particularly characterized by the role in which accumulated knowledge about the environ is preserved and passed on through succeeding generations. This would form part of the major evolutionary step in adaptability of the organism. Such generational transmission of socio-cultural experience, of that which makes man human, was possible only through the evolved 'family' unit -- within which a relatively fragile organism with an unusually long period of defenselessness and dependency on other could be effectively nurtured till able to survive as an individual. The period of nurture is also that of socialization, of forming the human personality. The function of transmitting social and cultural experience and of regulating social interaction also led to the complex growth of other human institutions -- to human society as we know it. There is little to suggest that human society evolved 'instinctually' in the strict biological sense. Rather, when we refer to the evolution of society, it may, perhaps, be more accurately meant in the sense of more consciously adaptive development. Animals have forms of society, but these lack the evolutionary capacity which has allowed human society to be more plastic and variable in its responses to particular environ situations. Change has been of key importance in this process and allows of the interaction of individual change agents within the society as influencing and modifying the overall societal orientation.

Social evolution, in this sense may be likened to a 'cybernetic' process, one which is oriented to its goals by 'feedback'. Increased, and more highly organized, information about the environ and the society as an integral ongoing process is fed back in due proportion so as to 'guide' forward development. As including the role of individual agents -- in monitoring the signals, suggesting and predicting the changes of course required, etc. -- we might more properly refer to 'psycho-social evolution' as more clearly defining this process.

All human action is, in this sense, social action. Contemporary social theory generally analyzes human behavior as occurring, therefore, in a system of socially interactive relationships, i.e., even where the specific interaction is with a physical resource, its form and purpose is socially determined. Further division of the psychosocial environ system would include three subdivisions to account for individual action, the society as an aggregate or collectivity of such actions and the culture as an environ continuum within

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[7] Ideas and Integrity, R. B. Fuller, (Prentice Hall, Englewood Cliffs, N.J., 1963).

which individual and societal actions take place. The symbolic processes of communication make all social action possible and furnish the matrix within which all such action takes place.

1) the personality system of the individual 'actor' as motivated toward action by his needs in terms of various goals, committments and socialized patterns of behavior. Different needs, situations, purposes elicit different roles or learned patterns of 'successful' response behavior.

2) the social system, or structured order of social actions, consisting of the basic human institutions -- family, kinship, religious, political, economic, etc. -- and their related organizations.

These consist of sets of defined roles or patterns of behavior with their attendant, and appropriate 'sanctioned', rewards and deprivations in different social systems. All human actions are related in one way or another to these institutionalized sets. They should not, however, be viewed as static forms, but as temporal configurations undergoing various rates of change according to their 'dynamic' content of idiosyncratic individual actions.

3) the culture system contains the 'heritage' of customs, habits, belief systems, etc. -- in various ideologies, values, standards. These are all expressed in various symbolic modes -- in more and less tangible physical forms as the arts and sciences, in less tangible form in the religions, mythologies, philosophies, etc. We might even include technology as a cultural artifact in this manner -- with its system of social action as a form expressly concerned with the control of the physical environ through tools. Such tools are, themselves, also 'symbolic' artifacts -- increasingly dependent upon environ information input refined through symbolic language processes.

The above divisions are, needless to say, another series of convenient abstractions from a fused process of integral human action. A prime characteristic of the psycho-social system(s) are their transmissibility through non-biological means. They are socially, rather than biologically, inherited. Culture, used in the more generally inclusive sense to describe the whole system, may be termed the ecological context which encloses and screens all human activity within (and without) the biosphere.

The social behaviors of man are now the most critical factors in the maintenance of the ecosystem. We not only modify the environ by human action as manifested in science and technology -- through physical transformations of the earth to economic purpose -- but, all social institutions play their part in orienting the direction, goal and purposes which guide such environmental transactions.

Following our line of 'evolutionary' development, it may be noted that it is only recently that we have acquired the social awareness that we may from this time forward exercise a more consciously direct control of our forward development. We generally forget the extent to which past historical societies were unaware of this, believing that such control lay more with capricious agencies external to man -- the future was predestined, cyclically returned to past forms or was oriented to life after death. In this sense, we have 'invented' the future almost as a consciously orienting strategy for our forward survival.

We have become aware that the forms of our social organizations and whole societies are also man-made and may be re-designed to fit our emergent needs and purposes. Our social 'technologies' will now require precedence as control agencies for the developed capacities of physical technology. In terms of environ control, the tribal village, the city-state and, latterly, the nation state, were inventive adaptations towards our present ecological dominance. At our present level of planetary interdependency, the nation state form, for example, may be as dangerously obsolete as the self-governing autonomous tribal and city principalities which preceded it. The necessary growth of transnational social organizations seems to indicate this. The essential organizations which maintain the human eco-system are no longer national in any real sense -- world health, communications, transportation, etc., are, by agreement, vital to all and decisions relative to their governance may not be abrogated by any local agency. The continued growth of such world organizations may not, however, be left to emergency-pressured need, but must become the object of conscious design, taking gainful cognizance of the evolutionary developments and trends towards such global forms.

We may view this trend in another aspect relative to knowledge/information. In general, human survival has been evolutionarily successful through the bias towards integrative function, e.g., the manner in which the differentiated-out and specialized organic functions are integrally directed towards the overall end purposes of the organism. Man is one of the least specialized biological organisms. Extreme specialization in evolutionary, or ecological, terms of a highly differentiated set of 'special' habitat requirements is usually accompanied by lack of adaptability. The organism tends towards extinction or remains low in the species hierarchy. Our present discussion may be phrased in these terms where the trend towards increased differentiation and specialization may be dangerous through lack of integration of our overall environ activities, i.e., as evidenced in air, water pollution, etc. The externalized functional extensions of man now 'evolute' for him -- as the microscope relieves the eye of further development of greater magnification power, so other tools and tool systems take over in duly specialized fashion. The extremely swift and relatively uncontrolled growth of our array of tool systems -- as including forms of social organization -- has not been accompanied by a corresponding extension of our integrative 'tools' and systems. Fortunately, this negative trend seems to be in the process of reversal where our very large scale environ undertakings, as in the space programs, have forced a return to consideration of human activities as whole systems. The accompanying increase in global monitoring of the earth system through satellites and the swift diffusion and interchanges in the world communications network engenders an integral awareness of the essential unity of the planetary community.

We may note here, in concluding this section, that the psychosocial extension of man throughout the biosphere has been characterized as adding to this a "noosphere" layer.[8]

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[8]First described by W. I. Vernadsky in La Biosphere, 1929; more recently discussed by Teilhard de Chardin in his various works, notably, The Phenomenon of Man, The Cloister Library, Harper 1961.

This idea of organized human thought now covering the globe as a functional part of the overall ecological system is, to an extent, physically demonstrable in our present global communications networks; in the enormously accelerated growth of human knowledge with its parallel increase in the numbers of messages, meetings, journals, etc., ceaselessly circulating around the earth.

The notion of an 'information explosion' however, is not borne out by this knowledge expansion. Such knowledge is not simply accumulated facts, but the reduction of unrelated, and often apparently irrelevant, facts into new and more compact conceptual wholes. The overall process does not tend toward greater complexity but, rather toward simpler and more 'inclusive' concepts. Recent revolutionary concepts in biology are an example of this -- the DNA/RNA formulation 'impounds' a great number of separate biological facts and relates biology via biochemistry to biophysics -- and thence, to more elegantly simpler structural hierarchies. The increasing interrelation and interdependence of other 'separate' disciplines is further evidence of this direction.

We may hypothesize that as information increases exponentially -- explodes -- conceptuality implodes, becoming increasingly more simplified.

The effect of this accelerated process on the life space and life style is quite marked. Where tribal man became disoriented when separated from his locality and early city and local state man could barely conceptualize his externally surrounding environment beyond these limits, we are now in a period when many men think wasily and casually in terms of the whole planet.

Such emerging world men are not confused by the explosion of information about the earth and its peoples, but are able to deal with this in whole terms, as easily as one previously conceived of one's neighborhood, hometown, and surrounding country.

Our basic critical impasse in global terms is, however, our inability to use our swiftly occurring knowledge. The block is to be found most often in the persistence of obsolete social forms and attitudes. This returns us circularly to earlier comments on the role of social invention as a prime re-design need. To circumvent traditional, but now inadequate modes of social action, we need to experiment with new forms of social organization -- to re-fashion the psychosocial environ as vigorously as we have transformed the physical environ in the past century.

Technological System(s)

We have referred to the basic organic enterprise as that of securing energy and materials from the environment to maintain life. A rather simple statement, but one that accounts, in part, for most historical human activities. At the lowest level of early human survival we find evidence of cultural activity, but its more durable and widespread forms are associated with access to more energies than could be provided solely by unaided human physical effort. As we have noted, language is the tool which enables men to combine together to perform tasks, or convert energy collectively, which would be impossible for an isolated man. The symbolic gesture or sign is, therefore, a first 'technological' extension. Second, perhaps, would come fire, as it is difficult to see how the knowledge of fire could be transmitted without language. Fire is a way of gaining access to stored solar energy, of extending the internal oxidation of the body metabolism to provide an external source of heat, predigest food, etc. -- also providing one of our most durable symbols in the process.

The earliest men seem to have subsisted by hunting and food gathering, simply tapping into locally available, naturally cyclic, energy supplies. Such techniques would seldom provide the energy surpluses necessary to give sufficient leisure for large scale cultural pursuits except in particularly favorable habitats. Higher sustained yields and surpluses appear to have first come from the deliberate cultivation of selected plants and the herding and domestication of animals. This would allow for more permanent settlement, storage of food energies and the leisure with which to experiment and forward further survival strategies, e.g., in association with such settlements are usually found evidence of recording of seasonal and other periodicities to allow future planning. In close conjunction with such early technologies of cultivation and domestication comes the development of boats. The extended voyages possible with food stores, animals, etc., plus the navigational aids drawn from, and giving rise to, more accurate measurement of environment periodicities -- the movements of the stars, phases of the moon, etc., added greatly to human survival knowledge. It is suggested that such ocean migration may even antedate fixed land settlement and that developed sea technologies, brought up on the land, account for the first sciences and technologies which form the bases of the early agricultural and animal domestication revolutions.[9]

Whatever the origins of technology, it is patent that the system of artifacts which this now connotes, have developed in a unitary, evolutionary manner. We have referred to this idea as presented by many contemporary thinkers, but the following quotation from La Barre conveys it in succinct form:

> Since man's machines evolve now, not anatomical man, he has long since gone outside his own individual skin in his functional relatedness to the world. The real evolutionary unit now is not man's mere body; it is 'all mankind's-brains-together-with-all-the-extrabodily-materials-that-come-under-the-manipulation-of-their-hands'. Man's physical ego is expanded to encompass everything within reach of his manipulating hands, within sight of his searching eyes, and within the scope of his restless brain. An airplance is part of a larger kinaesthetic and functional self . . . and airplanes are biologically cheap (as evolu-

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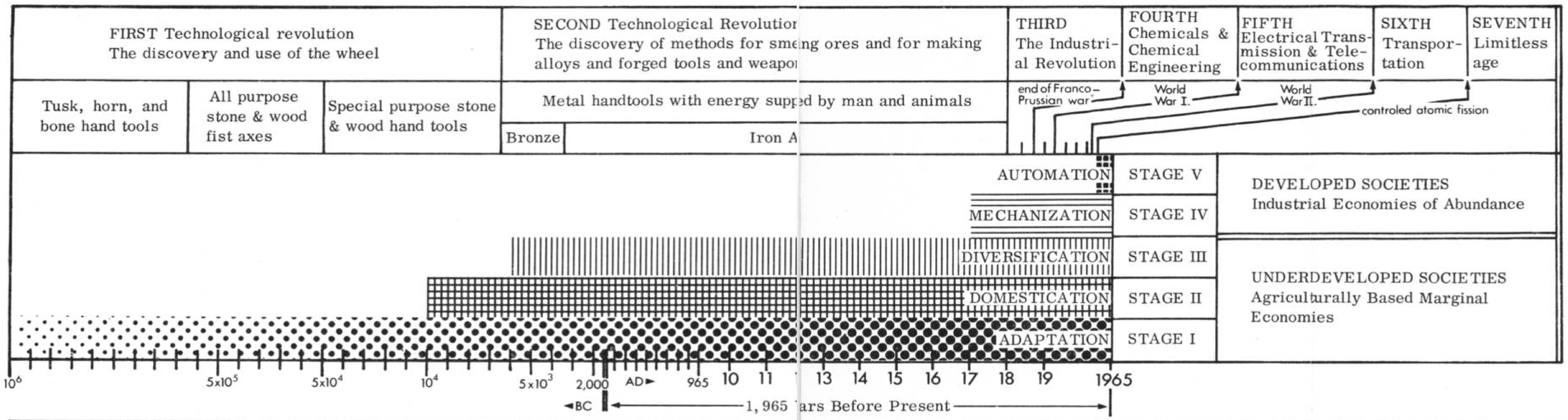
[9] Naga to Eden, R. B. Fuller (manuscript in preparation).

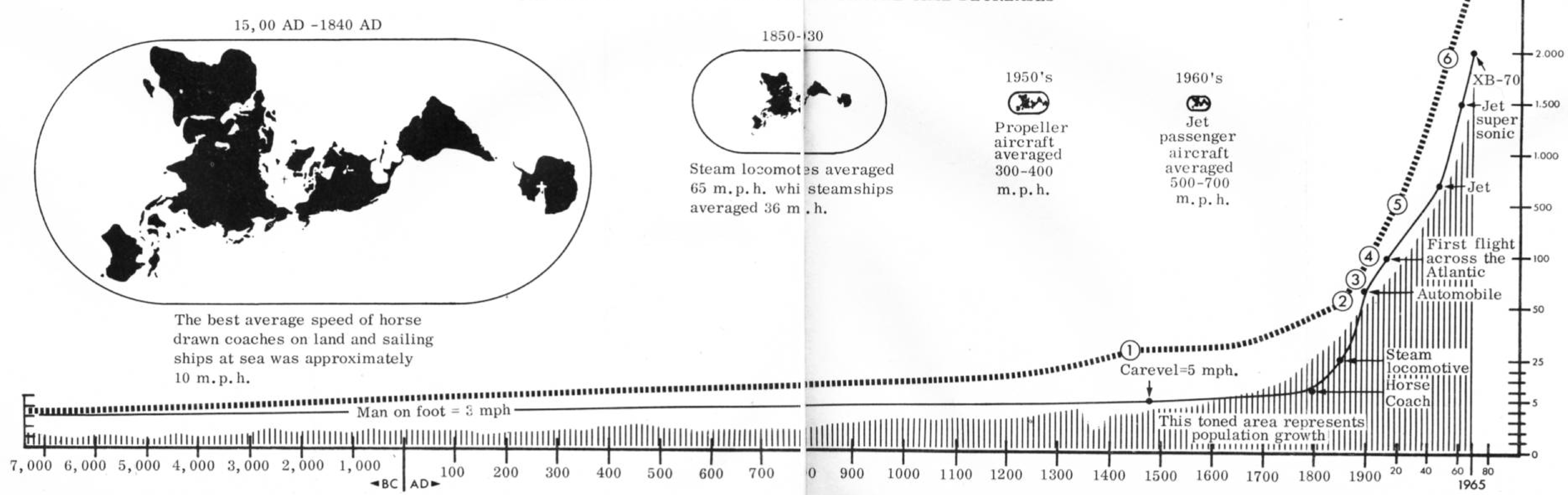
STAGES OF TECHNOLOGY



THE LINE OF HIGH ADVANTAGE MOBILE ENVIRON CONTROL DEVELOPMENT WHICH GOES FROM SHIP, TO AIRPLANE, TO ROCKET, TO MANNED SPACE VEHICLE													
MODE	Sailing Ships							Clippers	Steam Ships		Airplanes		Saturn V Rocket
TIME PERIOD	2,500 BC	500 BC	1,000 AD	1400	1500	1600	1700	1800	1900	1940	1940	1950	1965
AVERAGE TONNAGE	150	250	30	300	100-500	1000	1,000	2,100	2,500	4,500	Propeller	Jet	3,000 Tons
HORSE POWER	80	120	30-90	150-250	....	500	750	....	1,200	1,400	3,500	12,000	200,000 lbs.thrust
AVERAGE SPEED	8 knots	8 knots	12 knots	10 knots	10 knots	11 knots	12 knots	17-22 knots	16 knots	20 knots	300 m.p.h.	600 m.p.h.	25,000 m.p.h.

Communications	Word of mouth, drums, smoke, relay runners, and hand printed manuscripts prior to 1441 A.D.	1 The Gutenberg 1441 printing press	2 The rapid print W 1863 newspaper press	3 The Bell 1876 telephone	4 The Marconi 1895 telegraph	5 First commercial 1920 radio broadcast	6 National 1950 Television	7 Transcontinental T.V. with the introduction 1965 of Early Bird satellite

THE RELATIVE SIZE OF THE WORLD AS TRAVEL TIME DECREASES



> tionary devices). Without being, through specialization, a biological amputee, he attaches all sorts of prosthetic devices to his limbs. This evolution-by-prosthesis is uniquely human and uniquely freed from the slowness of reproduction and of evolutionary variation into blind alleys from which there is no retreat.[10]

The augmentation of organic capacity is, however, not confined solely to the evolution of physical tools but includes also those 'invisible' tools which have had as powerful an effect in transforming man's condition. Such invisible tools as language, number, symbol and image systems are also extensions of human internal processes and have, through the larger conceptual systems -- religion, philosophy, science, etc. -- extended man's control over environment.

We might even view the growth of social institutions as part of such psychophysical extension -- the development of cities, states, 'families' of nations. Certainly the development of the 'systems' capability of coordinating large scale and long-term complex enterprises, as in aerospace, in national and international planning, emerges as a powerful new technology. Also, where the hand tool, lathe, grinder, etc., extend physical capacities, our communication networks of radio, telephone, television and linked computer systems are extensions of the human senses and nervous system. Through his instrumented monitoring of the electro-magnetic spectrum, man can now 'see' in the infrared, ultraviolet and X-ray frequencies, 'hear' in the radio frequencies, and more delicately 'feel' through electronic metering than with his most sensitive skin areas.

As man has extended his immediate physical control over the material environment, he has also extended his range of psychic mobility in space and time -- to almost the same degree that he 'opens' up his future, he also extends himself into the past through refined archaelogical techniques and ancillary instrumentation.

The latest phases of technological development now return upon the organism itself as man begins to directly repair, restore and to replace his internal organs, either through transplantation from others or by artificial devices. His bio-technical 'tool services' range through plastic valves, tubes, filters, etc., to 'pacemakers' for the heart, external 'kidneys' and various prosthetic attachments which approach the natural limb capabilities.

Most of the extraordinary evolution of our complex industrial tools has taken place in the last two hundred years. Though the process of technological development predates history, our present accelerations may be located as taking off towards the end of the Eighteenth Century with the steam engine.[11]

The brevity of this period probably accounts for the widespread apprehension that technological developments now threaten man, that technologies are out of control, etc. Such dire prophecies possibly result from a lack of understanding of the evolutionary and organic nature of technological development which we have emphsized so much in our present discussion. The idea is, in itself, probably somewhat alien to the understanding. Man has always assumed that an 'evolving' technology would be of the mythological robotic variety -- formed in his own image. It is, rather, more difficult to observe the evolution

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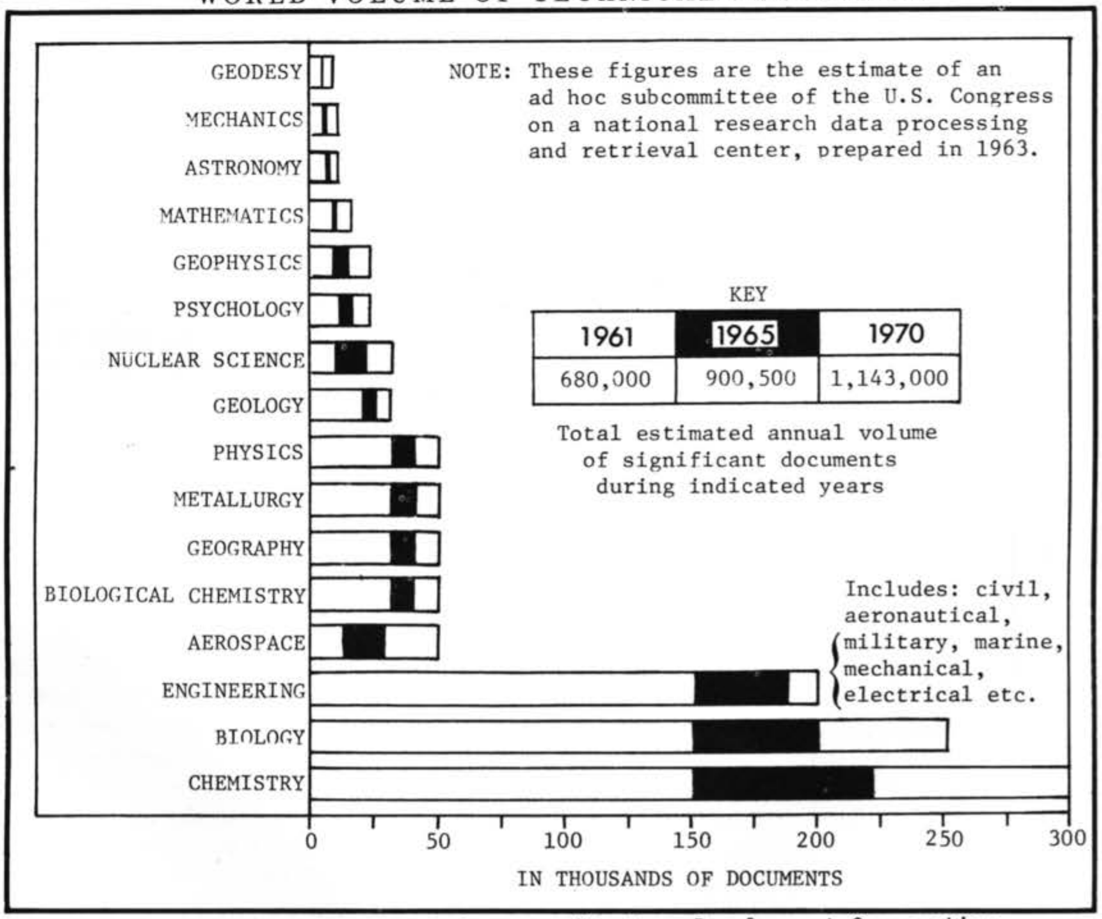
[10] The Human Animal, W. La Barre, (University of Chicago Press, 1954), p. 92.

[11] Whilst recognizing the long build up toward this point, particularly in the medieval period, the first industrial revolution is a convenient benchmark for large scale industrial and urban expansion.

WORLD VOLUME OF TECHNICAL DOCUMENTS



Source: "Systems Development Corporation, Magazine," Vol. 9, No. 2, February 1966.

of the aeroplane from single person/single engine with multiple wing surfaces, to multi engine/single wing, to propellerless jets of enormous size, speed and 400 passenger carrying capacity -- almost in one human generation. It is as difficult to equate the evolution of the family of 'extended eyes' -- from bulky, tripod, wetplate still cameras to microminiaturized television scanners spinning around the globe outside of the earth's atmosphere. We may only control and guide the further development of our technologies by applying to them some 'biological' approach that we use in studying other life forms in the ecosystem.

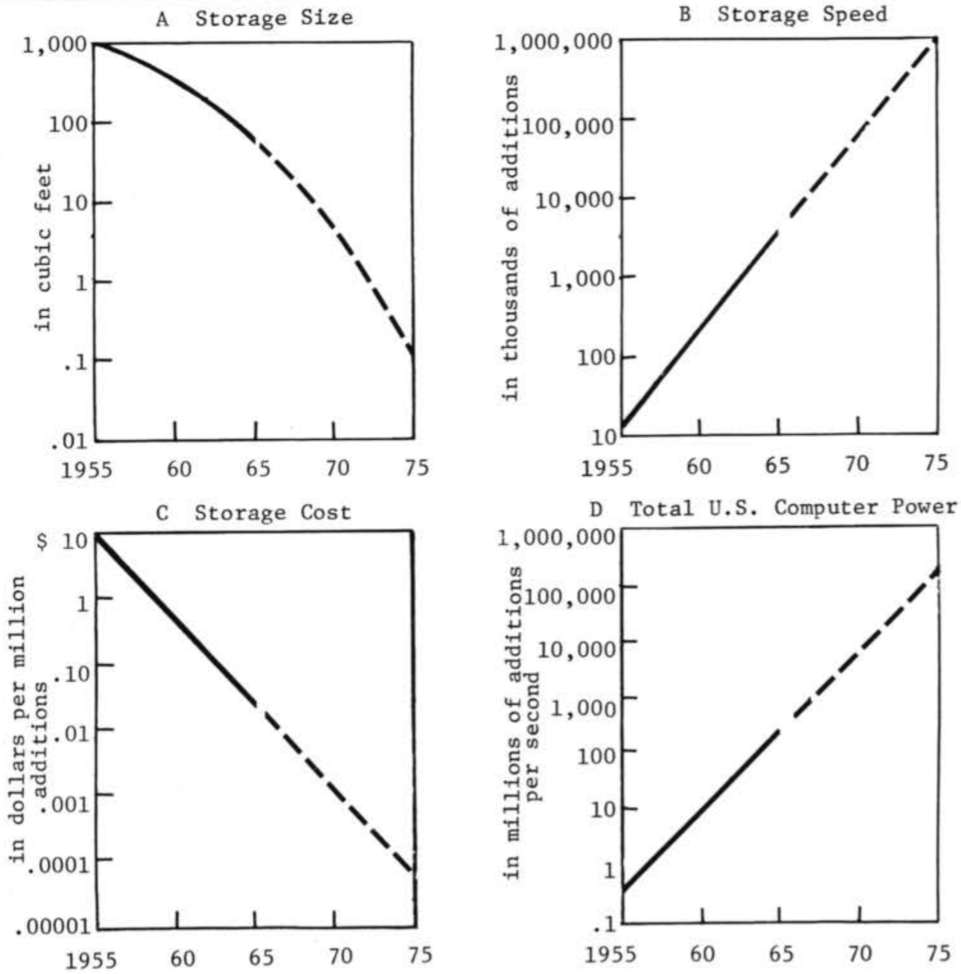
As 'powered', renewed, and ultimately directed by human life, technology is as organic as a snail shell, the carapace of a turtle, a spiderweb or the airborn dandelion seed. In many respects, it is now more ubiquitous as a functional component of the ecosystem than any organic life form other than man himself. The amounts of energy converted by machines, the materials extracted from the earth, processed, recombined and redistributed in the technological metabolism, and the gross effects of such increased metabolic rates on the ecosystem, are now greater than the effects of many global populations of other organic species.

When we come, therefore, to the question of 'control' we must seek to find, as we have not yet consciously done on a large enough scale, the fundamental principles and 'laws' which govern the evolution of physical technologies. These would include not only science and technology as related processes, but the many other organized institutions which are 'technological' by nature, e.g., cities in their aspect of extended metabolic units, social organizations as extended control units, etc. When we apparently underline <u>physical</u> technologies, we should also bear in mind the parallel growth of more intangible technological means, as implied above in urban and social organizations. Almost every ordered aggregate of human actions whose effects modify the physical environ is, in this sense, a 'technology'. The application of the methodology of the physical sciences to the systematic scheduling of series of technological operations, e.g., in the 'systems' approach, is often termed a 'soft' technology. In the same regard, historically, so was a rain dance, or the ceremonies attending crop fertility or a ritual socio-religious drama -- all systems for attaining to greater predictive understanding and extended control of the human environ.

To emphasize the organic nature of technology in this fashion, it should be noted, is not simply to pose some technological determinism as accounting for all human development and change. One could as easily suggest poetry as the determinant, and with as much validity. Rather, the purpose is to emphasize and re-emphasize the integral nature of all human processes -- whether labelled technological, economic, cultural or whatever. Given the nature of the organism and its enclosing environ, and some notion of the history of its development within that environ, we may observe certain periodicities and orders of growth. So far, our understanding of the larger patterns of the human ecological transformations has been limited by our tendency to compartmentalize our knowledge of the process. The 'periodicities and orders' of one discipline are usually left unrelated to those of another. Archaeology, a seemingly remote and quite academic field has taken the lead recently, in this manner. By bringing to bear the data and conceptual means of many disciplines -- and their ancillary techniques of biochemical and physical analysis, radiation technologies, aerial and satellite photography, etc. -- archaeologists are beginning to 'reconstruct' the past as vigorously as we now document the present and probe the future.

The most recent and spectacular area of technological evolution has been the introduction of cybernetics -- significantly, and symbolically, derived from the word for 'steering' in the navigational sense. Defined as the mechanization of sensory thought and other psychophysical processes, cybernetics is an extension of the control capacities of the

COMPUTER PERFORMANCE



Computer Weight, Volume, Power Costs: In 1953 a computer weighed approximately 5000 lbs., occupied 300-400 cu. ft. and required 40 kw. of power. Today's computer weighs approximately 50 lbs., is a thousand times smaller and uses 265% less power than the 1953 model.
(A) Storage Size: From 1955-65 the storage size of central processing computer unit (cpu) has decreased by a factor of ten. During the next decade, fully integrated circuits may reduce its size by a factor of about 1000.
(B) Storage Speed: From 1955-65 internal speeds have increased by a factor of 200 and by 1975 such speeds are expected to again increase by this amount.
(C) Storage Cost: During the first decade of the computer the cost of performing one million operations decreased from $10.00 to about 5¢. By 1975 it is estimated that this decrease will amount to an additional factor of about 300.
(D) Computer Power: The total installed computer power in the United States during 1955 had a capacity of about one-half million additions per second. By 1965 this capacity increased to 200 million per second and if growth rates are sustained through 1975 the increase in capability will be about 400-fold.

Caption: adapted from W. H. Ware, "Future Computer Technology and Its Impact," D. D. AD 631-941. Office of Technical Services, U. S. Department of Commerce.

Source: P. Armer, "Computer Aspects of Technological Change, Automation and Economic Progress," Rand Corporation, November 1965.

human nervous system into electro-mechanical devices. Without elaborating on its technological ramifications here, we may underline its importance in ecological terms. As the mechanical and chemical energy converters of the first series of industrial revolutions freed human muscle from routine tasks, so the computer revolution potentially frees man from comparable routine 'intellectual' tasks -- of monitoring, supervising, controlling many simultaneous and complex technical processes. Also, and importantly, it gives the possibility of swiftly expanding our global production, distribution and logistical support services toward satisfying the urgent material needs of large numbers of human beings still on the edge of survival.

In reducing the direct link between work and physical maintenance, automation/cybernation also obsoletes many of the basic premises for our major social and economic institutions. These have been largely borne of a past when it was necessary to persuade, coerce or otherwise 'sanction' the bulk of men into spending the greater part of their lives just producing the basic products for human physical survival. From this time forward, we may potentially produce, in abundance, all such material life sustaining requirements -- without need to 'extract' or demand human life-labor in equitable return. Instead of spending most of his years merely maintaining himself, man is potentially freed to address himself to the larger purposes and enormous range of activities implicit in the larger human enterprise.

The cybernetic revolution has occurred largely within the past two decades. It is important to underline this and to recognize its evolutionary significance in the light of our discussion above. We sense this period of change and transition as one of the most critical in human history. The specific focus of our discussion centers around our capacity to control the enormous scale of our present global undertakings in a more positive, efficient and naturally advantageous manner and to avoid the dislocations and dangerous side effects of our swiftly accelerating technological growth.

It is of key relevance, therefore, that this new change agency of cybernetics is also specifically developed for massive control and decision-making in handling large scale systems with many complex and variable factors. At the point then, where man's affairs reach the scale of potential disruption of the global ecosystem, he invents, with seeming spontaneity, precisely those conceptual and physical technologies which enable him to deal with the magnitude of a complex planetary society.

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ENERGY

Our overall contextual emphasis has been on the dynamic functioning of the ecological system and the central role of energy conversion as the key to basic life processes. The fundamental relationships governing energy input to the system and some of its main uses have been sketched, for example, in the photosynthetic and other cycles.

In this section, we are primarily concerned with energy as work and production energies -- those prime movers used in the industrial system, their fuels, and efficiency of conversion. The vast increase in the amounts of energy required to sustain our present levels of productivity and the necessary augmentation of such levels to accommodate even more men, at higher standards of living, leads to questions of the most efficient types of energy conversion, transmission and process uses. The nature of the fuels used and their possible pollutant by-products are now a considerable factor within the discussion. The amounts required in the immediate and long range future call into question certain preferential uses of specific fuels and the more economic conservation of others.

Let us consider, first, the overall supply of energy to the ecosystem. The prime sources are radiant energy from the sun, the kinetic and potential energy of the earth gravitational system and that which is radiated from the interior of the earth. Of these, our central focus is on solar energy. Gravitational energy enters into all energy transactions on the earth surface, but is considered less of a direct source other than through its secondary derivatives of water and tidal power. The interior earth energies, geothermal, have not been used on a large scale so far. To these three main sources, we might add those energies accruing from the earth spin and atmospheric circulation -- wind energies and differences in temperature and pressure related to climatic change -- now less widely used than in former periods.

In dealing with solar energy input, we note that this has been ongoing for millions of years and that successive layers of such energies have been 'impounded', or stored, in the earth from the organic energy conversions of animals and plants. These are now usually referred to as the fossil fuels -- oil, coal and types of natural gas associated with such deposits. The bio-mass, that is, the entire complex of all life forms on earth, also represents a long and continuous impounding process of solar energies.

In addition to this organic process of energy storage, both past and present, we should also consider that the materials mass of the earth itself represents a vast store of cosmic energies locked in a myriad of chemical combinations from the major geological periods of the earth's physical formation.

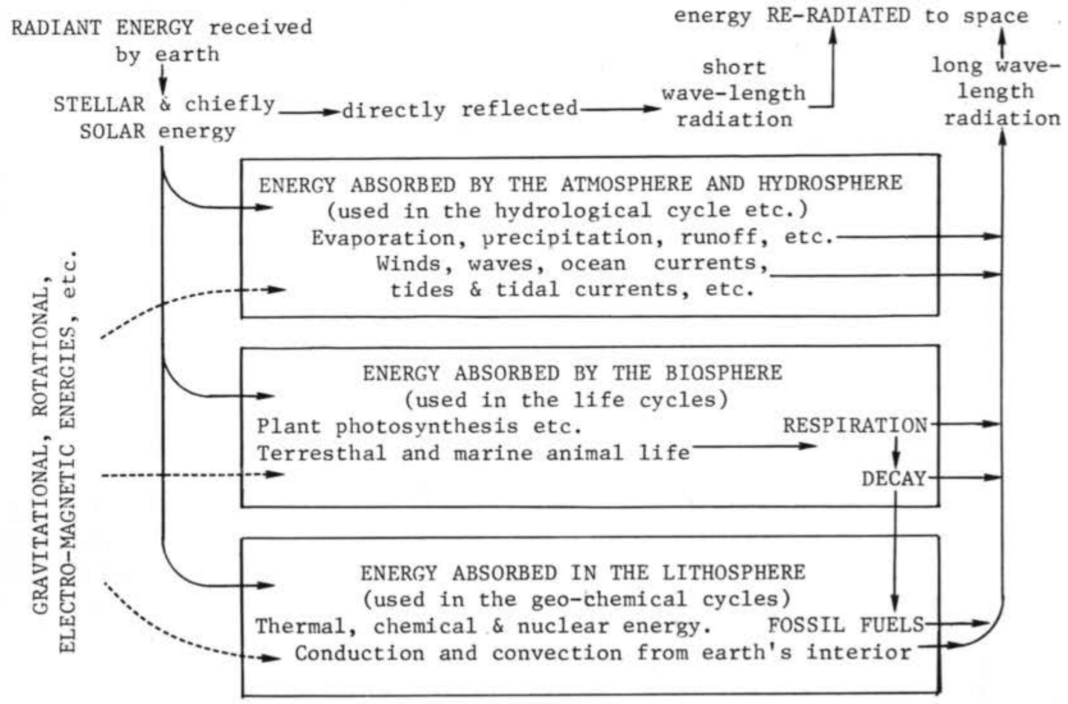
We have, thus, a division as above into <u>stored energies</u> such as the fossil fuels and fissionable elements in the earth crust, and those energies in constantly renewed <u>income</u> from solar radiation and other sources.

Before proceeding to examine the implications of this overall view of the energy system, we should consider man's role as central to our analysis. His individual unit efficiency as a food energy converter has already been discussed -- about one half to one horsepower hour per day. The development of human society has, therefore, been predicated

1) on the use of collective human energies to perform tasks beyond the individual's capacity.

2) on the use of animal energies

THE EARTH'S ENERGY FLUX



"... The earth may be regarded as a material system whose gain or loss of matter over the period of our interest is negligible. Into and out of this system, however, there occurs a continuous flux of energy in consequence of which the material constituents of the outer part of the earth undergo continuous or intermittent circulation. The material constituents of the earth comprise the familiar chemical elements. These, with the exception of a small number of radioactive elements, may be regarded as being nontransmutable and constant in amount in processes occuring naturally on the earth.

The energy inputs into the earth's surface environment are principally from three sources: 1) the energy derived from the sun by means of solar radiation, 2) the energy derived from the mechanical kinetic and potential energy of the earth-sun-moon system which is manifested principally in the oceanic tides and tidal currents, and 3) the energy derived from the interior of the earth itself in the form of outward heat conduction, and heat convected to the surface by volcanos and hot springs. Secondary sources of energy of much smaller magnitude than those cited are the energy received by radiation from the stars, the plants, and the moon, and the energy released from the interior of the earth in the process of erecting and eroding mountain ranges.

...With the exception of an insignificant amount of energy storage, the energy which leaves the earth by long-wavelength thermal radiation into space must be equal to the comined energy inputs from solar and stellar radiation, from tidal forces, and from the earth's interior." -- M. K. Hubbert.

Source: Energy Resources, M. K. Hubbert, National Academy of Sciences.

3) on the use of inanimate machine energies.

The process of development has been from low energy conversion to high energy conversion.

The use of human muscular energies, even collectively, is not very economical and, like that of animal energies, diminishes the stock of food energies necessary to maintain further energy conversion. Inanimate or mechanical energy converters were the obvious direction which gave greater amounts of work energy and did not diminish food energy stocks, thereby surpluses could be built up and further survival advantage gained.

Possibly the first large scale energy converters were ships drawing upon wind energies to move large quantities of goods and men. We have commented earlier on the importance of sea technologies historically, and this is a further example:

> The energy costs of operating a ship are only those of building, maintaining and manning it. The surplus energy derived from the sails is potentially enormous as compared with the cost of producing the sail and hoisting it . . . men, using the sailing ship came into control of very large amounts of power largely independent of plant life or of the number of persons in the population using it.[1]

As the above author details further, in his text, the most efficient sailing ships were able to produce a maximum of 200-250 times the human energy required to operate them. Land energy converters such as the water and windmills, which provided the major sources of inanimate energies up till the introduction of the steam engine did not match such levels of conversion efficiency.[2]

For the greater part of human history, until a scant few hundred years ago, most energies available to man were organic sources from his own muscles and that of his domesticated animals. Our own period is peculiarly marked off from all others as the first in which man has had access to <u>abundant</u> energy supplies from inanimate sources. Through accumulated knowledge his gain in energy has increased enormously in the past hundred years -- as the conceptual tools of science formed new technological means giving higher degrees of energy conversion than ever before. Though many men in the lesser developed regions of the world are still constrained to spend their lives as 'mechanical' energy converters dependent for survival on their own muscle power, man's role is increasingly that of a designer of high energy conversion systems -- even now passing the routine control of such systems to other electro-mechanical agents.

The gain from low to high energy converters is not confined to <u>quantity</u> only, but to the <u>speed</u> with which energy is available for a given task and the conditions under which inanimate high energy converters can operate, e.g., round the clock with no 'organic' rest required.

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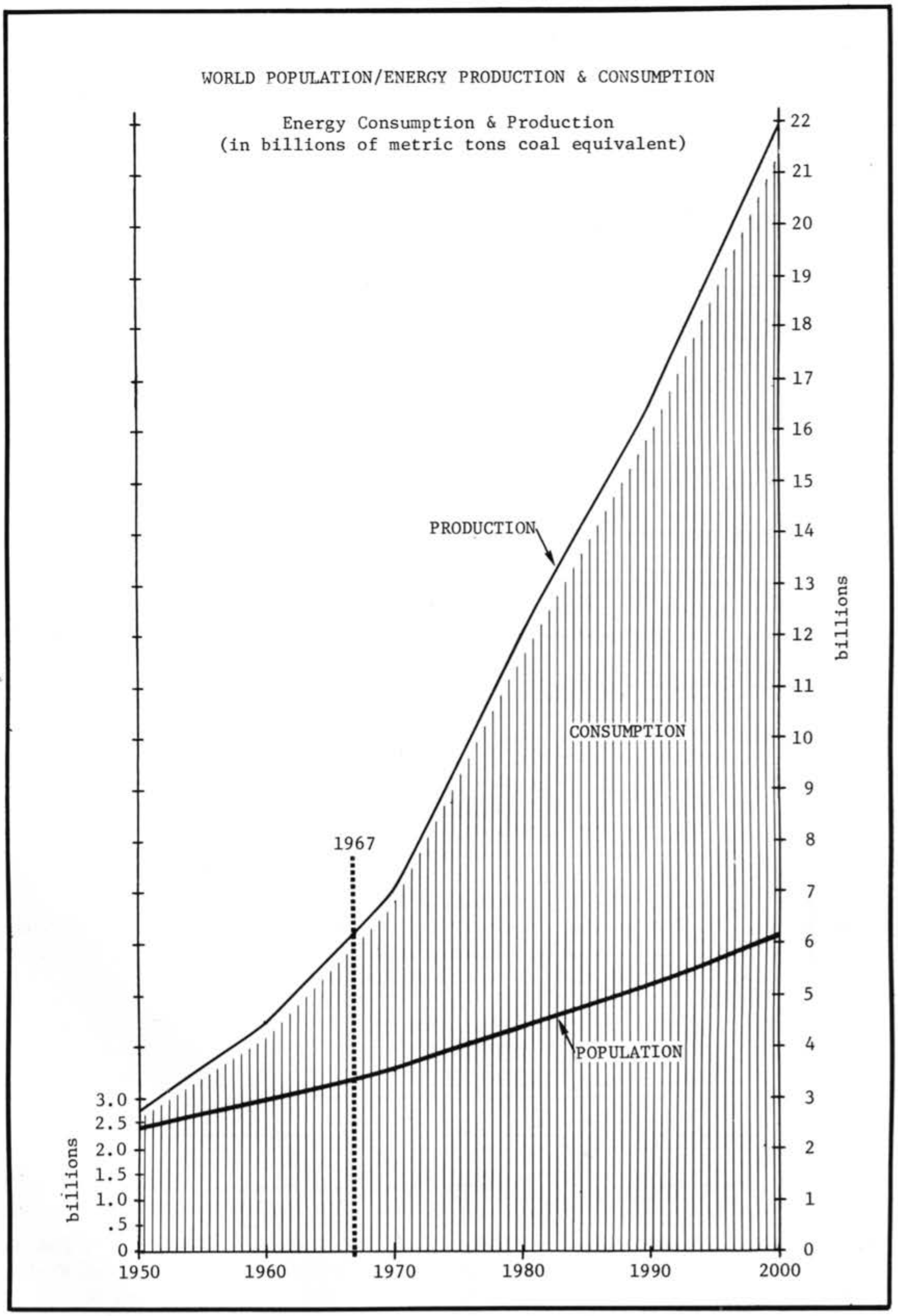
[1] <u>Energy and Society</u>, F. Cottrell, (McGraw Hill Book Co., 1955).

[2] Medieval Technology and Social Change, L. White, Jr. (This generalization is not to discount the advances in energy conversion technology which occurred in both East and West in early periods) e.g., "In 1086 the Domesday Book lists 5,624 (water) mills for 3,000 English communities." (O. U. Press, New York, 1966).

WORLD POPULATION/ENERGY



Source: Data compiled from U. N. and other sources.

Zimmerman gives an interesting comparative example of the speed and energy costs differential between wholly animate and human plus inanimate energies.

> If we assume that the building of an Egyptian pyramid required the work of 50,000 slaves for twenty years, while a skyscraper of comparable size can be built by 5000 laborers in six months, the number of workers at a given moment is as 10 to 1; but if the time element is taken into account, the ratio is 400 to 1. This means that it took approximately 400 times as much food to generate the manpower that built the pyramid as it took to feed workers who built the pyramid.[3]

Though the building manpower ratio has already been decreased, the notion of inanimate slave energy as replacing human labor is a fruitful concept which has been particularly explored by R. Buckminster Fuller. His energy slave unit is arrived at by taking the total energy income for the earth as measurably consumed by man in one year, and dividing this by 25 to give a four per cent figure of energy gainfully employed at present rates of overall efficiency. This (four per cent) net energy used, as expressed in kilowatts per year, is divided by one manpower year (i.e., the amount of energy which could be provided by the world population of the year, working 8 hours per day per year. This gives the number of electro-mechanical energy slave units available.

Such 'energy slaves' would represent the amounts of energy conversion disposed of directly by man in the form of personal appliances, heating/lighting energies, autos, telephones, etc., as well as those on the industrial network as also available to him indirectly in a variety of ways.

We may indicate the gain in such energy slave availability by noting that, in his Presidential Address to the British Association -- in 1911, Sir William Ramsay estimated that each British family then had an average of twenty energy 'helots' in its service,"[4] and comparing this to successive later periods. We may presume that Ramsay's energy helot is roughly comparable to the Fuller energy slave as calculated above. From 20 such units per family (of say, five persons) in 1911, the general European level had risen to approximately 150 by 1940 and over 400 per five person units by 1960, i.e., 81 per capita).

To appreciate the significance of such energy slaves in terms of standard of living advantage, we may show the contrast with Africa as an entire region -- whose comparable energy slave measure remains approximately 10 to 15 up to the present day.

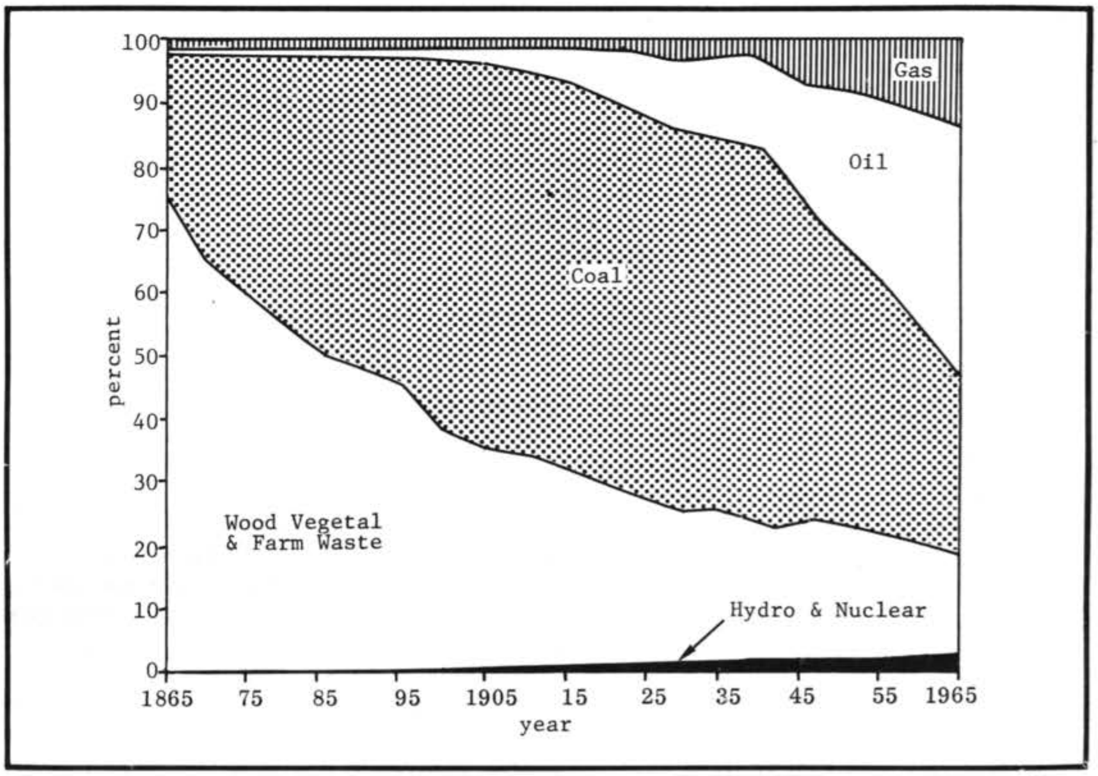
Map Areas	Population 1960	% of World Population	Energy Slaves per Capita
Asia	1,679,000,000	56	3
Europe	641,000,000	24.1	81
Africa	254,000,000	8.5	10

[3] An Introduction to World Resources, Erich W. Zimmerman, ed. Henry L. Hunker, (Harper and Row, New York, 1964).

[4] "Future Energy Prospects at Home and Abroad", A. R. J. P. Ubbelohde, Advancement of Science, September 1965.

[5] Document I,"Inventory of World Resources, Human Trends and Needs" (1963) R. B. Fuller and John McHale, Southern Illinois University

THE WORLD'S MAJOR ENERGY SOURCES



Source: Energy for Man, Hans Thirring, (New York: Harper & Row), 1962, p. 218.

WORLD ENERGY RESOURCES USED IN 1964*
(in millions of metric tons coal equivalent)

World Areas	Total	% of Total	Coal	Petro	Gas	Hydro-elect. and Nuclear
N. America	1706.706	33.51	464.650	567.169	637.831	37.056
U.S.S.R.	870.464	17.09	425.500	290.684	144.610	9.670
East Asia	400.064	7.85	373.610	11.974	2.964	11.516***
South Asia	618.357	12.14**	70.192	534.272**	10.949	2.943
Africa	159.280	3.13	49.440	107.155	1.171	1.514
Latin America	357.779	7.02	8.097	308.210	35.854	5.618
Europe	942.600	18.51	813.874	47.595	46.567	34.555
Oceania	38.107	.75	35.683	.247	.004	2.173
WORLD TOTALS	5093.357	100.00	2241.046	1867.307	879.959	105.045

*This includes non-fuel use of petrochemicals; also power 'generated', e.g. hydro and nuclear.

**These relatively large proportions can be attributed to the oil producing countries, most notably Kuwait, Iraq and Saudi Arabia.

***This relatively large figure is primarily due to hydro-electric production.

Source: World Energy Supplies 1961-1964, Department of Economic & Social Affairs, Statistical Office of the U.N., (New York: United Nations), 1966, Series I, No. 9.

A further important characteristic is that such electro-mechanical slave units, though only calculated as doing the work equivalent of humans, are enormously more effective.

> They can work under conditions intolerable to man, e.g., 5000° Fahrenheit, with no sleep, to ten thousandsths of an inch tolerance, can see at one million magnification of man's vision, have 400,000 pounds per square inch sinuosity, 186,000 miles per second alacrity, etc.[6]

All such technological undertakings are now dependent upon vast amounts of inanimate energy supplies to maintain them. Even the extraction, processing and fabrication of their mineral and metal components would be impossible without such energy inputs.

> The power produced by the Bratsk Hydroelectric Power Station alone is greater than the amount of energy that would be obtained by using the muscular efforts of the entire able-bodied population of the U.S.S.R.[7]

We may return, therefore, to closer consideration of such supplies and how we presently use them. Our earlier division of sources is a useful one -- into capital or stored solar energies, and income or renewable daily, cyclic sources of naturally occurring energies.

Major Energy Sources

CAPITAL: the stored, unrenewable energy deposits in the earth.

1. Fossil Fuels: Coal, Natural Gas, Oil (including shale and oil sands).

2. Nuclear Fuels: Those elements which may yield energy through nuclear fission and fusion processes.[8]

The main fossil fuel deposits have been built up over a 500 million year geological time period. Their presently prodigal use, with its many deleterious by-product effects, suggests that we review such usages with care in that they do represent a convenient and accessible form of stored energy which could be used now, or in the future, in many different, much more economical and intelligent ways. Nuclear energies, available from the fission of heavy element isotopes and the fusion of lighter elements, though extensible toward an income energy resource through profusion of materials, is presently limited by various factors, e.g., including the disposal of its by-product wastes.

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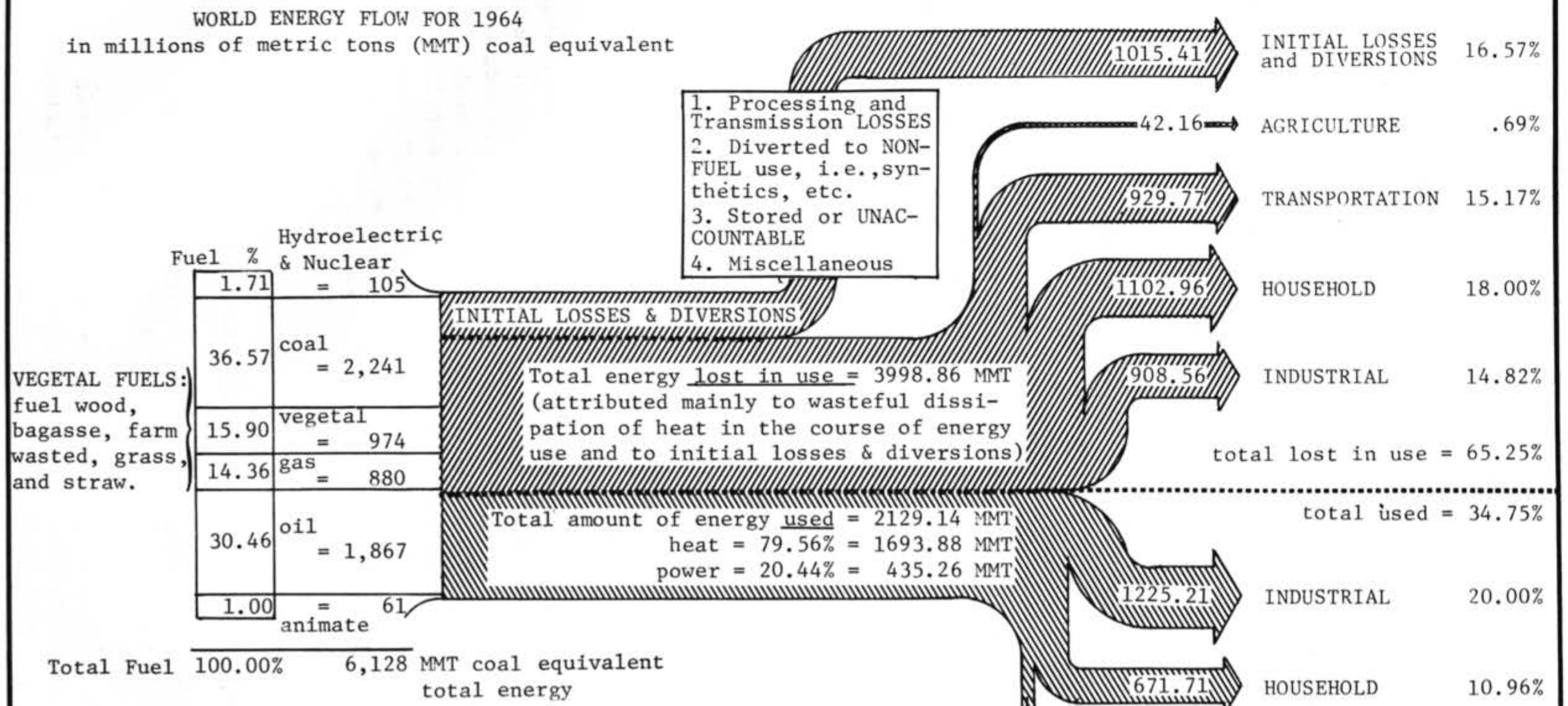
[6] Document I (World Energy Chapter) in the present series, R. B. Fuller.

[7] Cybernetics and Problems of Development, B. V. Akhlibininisky and N. I. Khralenko, (Lenizdat Publishing House, U.S.S.R., 1963).

[8] Though earth crust sources of such fuels may be viewed as exhaustible 'capital' energy deposits, the extension of the processes to ocean elements such as deuterium, might supply an almost unlimited source of energy through nuclear generation.

WORLD ENERGY FLOW SHEET - 1964



Major Data Sources:
Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Volume 1, "The World's Requirements for Energy: The Role Nuclear Energy", United Nations, N.Y., 1956.
Statistical Papers, Series J mo. 9, "World Energy Supplies 1961-64", United Nations, N.Y., 1966.

HEAT-POWER divisions in use sectors

sectors	heat %	power %
INDUSTRIAL	90.00	10.00
HOUSEHOLD	88.00	12.00
TRANSPORTATION	-----	100.00
AGRICULTURE	-----	100.00

INCOME: the naturally recurring energies available to man by tapping into the regenerative cycles in the ecosystem.

1. Photosynthesis: we have hitherto considered this energy conversion process only in its food energy cycling role. There are many other ways in which energy may be directly extracted from vegetation product cycles, e.g., through fuels from tree-wood and other sources; by microbial action in 'biological fuel cells,' etc.

2. Other Direct Solar Energy Uses: through concentrating lenses and reflectors into cooling devices; photoelectrical and photochemical fuel cells, etc.

3. Hydrological: as derived from the earth gravitational system through rivers, dams, etc., and the direct use of tidal and wave power; also, various modes of tapping into the hydrological cycle of evaporation/precipitation.

4. Wind: though this is intermittent and variable, improvements in storage capacities may enable this source to be more widely used.

5. Temperature: temperature differentials between atmospheric and earth/water surfaces yield energy potentials of considerable magnitude.

6. Geothermal: tapping directly into the heat of the earth either through naturally occurring volcanic sources of hot gases and waters or by drilling artificial vents for similar purposes.

7. Other 'Unconventional' Sources: Magneto-hydrodynamics, thermionics, etc.

The income energies summarily noted above, have fewer demerits than any of the capital energy sources in terms of pollutant by-products and other noxious side effects to humans, or as yet ascertained effects on the overall function of the ecological system. Apart from being 'cleaner' energy sources, they are also potentially inexhaustible as renewed by the sun, or as occurring in the naturally cyclic ecosystem's operation. In terms of environ re-design they afford many experimental and innovative directions which are relatively unexplored through our over-dependence on the fossil fuels. Aerospace technologies have already given considerable lead here in their utilization of self powered communications and other systems dependent on fuel cells of different types.

Present Energy Use Distributions

Our major problem, as stated, is to generally increase the availability of energy so as to further advantage the more than half of humanity who are presently far below the industrialized standard of living. This will mean considerable increases in:

1) the generation of energy

2) its conversion efficiencies

3) the transmission and distribution of energies to where they may be readily available around the earth

It is instructive to compare the location of our present world tension/local war areas and the correlation which exists between these and low energy conversion availability, population and food pressures. The key to many of our present world problems lies within the global energy distribution pattern.

Our past and present uses of industrial energies, and the prospects forward from such continued fuel uses, underline the critical nature of world energy availability both for the developed as well as the under-developed regions.

The production of world energy (which parallels, but does not exactly match consumption figures due to various indirect uses, losses in transmission, etc.) has increased at the average rate of 3 1/4 per cent annually from 1860 to 1958 with various growth periods when levels rose above five to six 'per cent'. From 1958 to 1961 this annual increase rate has risen considerably. The world's consumption of industrial energy from all sources increased by approximately 19 per cent during the period 1961 to 1964.[9] This was an unprecedented rise to a new level which we may expect to be sustained, -- with higher increase in the present years, due to population rise and the rate of industrialization of underdeveloped regions.

Energy production rose by the same figure during 1961-64, and significant rises were in the area of fossil fuel uses.

Much of the rise in energy consumption was accounted for by increases in the high energy economies, e.g., the United States consumed about one third of the world's total industrial energy for less than seven per cent of the world's population; Europe and the U.S.S.R. showed corresponding increases:

> The industrial regions dominate the consumption of each of the industrial fuels . . . consumed 77 per cent of the world's most important energy source -- coal -- in 1963; 81 per cent of world's petroleum; 95 per cent of all natural gas; and 80 per cent of hydroelectricity and nuclear power . . . the non-industrial world with 71 per cent of the world's population used 77 per cent of all human energy; 87 per cent of all animal energy and 73 per cent of total fuel wood and waste in 1963.[10]

In round terms, the total energy supply in 1964 was an average of 1.6 short tons, (coal equivalent) for each person in the world. The increase in the high energy economies further dramatizes the gap between these and the low energy developing regions -- in per capita terms, the more fortunate individual in the former, consumed more than fifty times the industrial energy of his counterpart in the poorer regions.

What this means in other measures may be gauged by the following: The United States is used as a comparative example as recent figures are more readily available.

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[9] U. N. World Energy Supplies 1961-64.

[10] The Geography of World Energy Consumption, R. A. Harper, (Key to Geographic Understanding), Department of Geography, Southern Illinois University, 1966.

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Steel Production	one fourth of the world total
Autos	three fifths of all the world's cars
Trucks	two out of every five
Surfaced Roads	third of the world total
Electricity	uses third of all electrical power produced on earth
Railroad Freight	one quarter of world total
Civil Aviation	half the world mileage[11]

When this disparity is compounded with expected population increases in the next few decades, it may be viewed in energy terms as a two-fold dilemma.

Firstly, world population is expected to double by the year 2000, i.e., in thirty-three years. No matter what types of controls may be sought or imposed, this figure of approximately 6 billion is unlikely to be much reduced within the time at our disposal. Even given the present distribution of population and energy resources and the increases in energy conversion efficiencies to be expected from improved technologies, this will still require more than double our present energy production and consumption.

At first glance, this may particularly entail a doubling of present fossil fuel uses -- with parallel side effects, unless stringent filtering and more efficient burning is accomplished. The increased use of such fuels raises serious doubts, not only about their reserve capacity, but about the wisdom of using up such an accessible, but swiftly exhaustible, store. With a world increasingly dependent on inanimate energies, it seems crass stupidity to clean out the cupboard (or bank balance) before checking on future income or unforeseen emergencies. Given that we maintain our present use level, it may then require more than 10 billion tons of coal equivalent energies annually.

Secondly, however, it is calculated that to maintain double our present world population by the year 2000 will require not double, but about five times more energy. Though the rate of industrialization is slow in the developing regions, some already showed a growth rate of electricity consumption of 15 to 22 per cent between 1963 and 1964.

Our present problems, therefore, call for the swiftest increase in the use of other than fossil fuel energies. This may be particularly applicable to the lesser developed regions which are lowest in these resources, but correspondingly high in access to solar, hydro and tidal power sources. The latter two may be most applicable to systems of large scale electrical generation with the corresponding increase of industrialization. Augmenting this, we require:

1) the selection and preferred use in such regions of high energy conversion means.

2) the extension via enlarged transmission networks of electrical power from the presently available, and increasing, concentration of generating plants in the industrial regions.

3) the swift development of locally autonomous power sources, e.g. from solar, wind and hydropower to fuel cell and nuclear power plants for local agri-industrial usage, communications, transport and other needs.

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[11] U.S. News and World Report, March 6, 1967.

PROJECTED WORLD ENERGY CONSUMPTION

PROJECTIONS OF ENERGY CONSUMED IN THE YEAR 2000 COMPARED TO
1960 ACTUAL BY WORLD AREAS
(Billions of metric tons of coal equivalent)

Energy consumption in year 2000 **if**

Areas	Actual comsumption 1960	Trend in world consumption from 1950 to 1960 continues (1)	World consumption is at US 1960 per capita level (2)	World cosumption is at W. Europe 1960 per capita level (3)	N.America, Europe, Oceania & USSR are at US 1960 per capita level & all other areas are at Europe 1960 level (4)
World Total	4.20	22.40	55.30	17.70	25.10
Per Capita*	1.39	3.65	9.02	2.88	4.09
Northern America	1.55	2.68	2.61	.84	2.61
Latin America	.14	3.18	5.22	1.67	1.67
Western Europe	.79	2.98	3.45	1.10	3.45
East Europe & USSR	.90	4.6?	4.49	1.44	4.49
Communist Asia	.40	5.0?	14.40	4.60	4.60
Non-Communist Asia	.24	2.90	20.00	6.40	6.40
Africa	.08	1.00	5.31	1.70	1.70
Oceania	.05	.10	.24	.80	.24

*Per Capita figures are in metric tons of coal per person." Population, based on U.N. figures, is estimated to be "6,129,000,000" persons for the year 2000.

Source: World Prospects for Natural Resources, J. Fisher and N. Potter, (Baltimore, Maryland).

4) the more efficient and continual re-design of our environ facilities, and their prime mover energy converters, towards extraction of maximum performance per unit of energy invested.

The latter set of requirements may be the more pressing and the most accessible to immediate design solutions:

> . . . quite small amounts of power could do a great deal of good. It is interesting to note that the old Dutch wind mills developed only about 2 horsepower apiece, and yet, a relatively small number of these, working steadily, reclaimed large areas of Holland from the sea. An Indian economist has indicated that for a village of 1000 persons, a power source of slightly more than 100 KW would suffice in the early stages of mechanization, and less than 10 per cent of this would be used for domestic purposes. By contrast, a single American household might require a power supply almost half this size to handle the daily peak loads.[12]

We may also note in relation to the above that such relatively small power sources may supply energies which can play a key 'change' role in giving power not only for augmenting food production, etc., but for vital communications -- radio, T. V. and small transmitters. In thinking about power for such regions, we often forget the range of power required for various purposes, e.g., from a jet airplane at 30,000 horsepower and automobile at 100 horsepower, we go to a household refrigerator 1/2 horsepower, fluorescent lamp 1/20 horsepower and a transistor radio, only 1/1000 horsepower.

The key relation between a high energy industrial economy and population growth stability also suggests that we pursue the solution of immediately pressing problems such as population and food supply and distribution on as many levels as possible. Increasing food production in every possible way with the presently massive logistical support which we already use in war, increasing the rate of local industrialization at both small and large scale levels of deployment and concentration, education at all levels and in every type of skill and understanding appropriate to the necessary but abrupt social, cultural and economic transition.

Power is now the key to expanding food production, as the most immediately pressing problem in the highly populated, less developed, regions. Their need is not merely the stop-gap aid of food surpluses or fertilizer shipments, but energy for transport, communications and distribution facilities, for local fertilizer production, for industrialization and education.

> The emergent countries with their dense populations living in small towns and villages need energy badly for light, for village industries, for the irrigation of crops and drainage and for the local processing of their harvest of sugar, cotton and jute. Energy for transport is also essential for their development. The solution of their energy problems should, therefore, be one of the first objectives of technical aid, if the gap between the developed and emergent countries is to be reduced.[13]

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[12] Power for Remote Areas", H. Z. Tabor, International Science and Technology, May 1967, pp. 52-59.

[13] Sir Harold Hartley, F.R.S., "World Energy Prospects", World in 1984, Vol. I, ed. Nigel Calder, (Penguin Books, 1965).

Simple sharing of existing fuel supplies and industrial machinery would not be enough , however, to alleviate the present imbalance in living standards between such lesser developed regions and the industrial regions. To bring underdeveloped regions up to industrial parity by building up their industires on the same pattern of fuel and major materials consumption which obtains in the developed industrial regions is not possible in present terms. In addition to the required extra energies, it is doubtful if the supply of major metals, for example, would suffice. Progressively lower grade metal ores are now having to be mined, e.g., 100 years ago copper ores used were not less than 10 per cent copper content, today the world average is 1.5 per cent. Even given that metals extracted are progressively recycled, the amount of metals per capita required, at present industrial use levels, would not be available to bring the other 60 per cent of the world's people up to full industrialization.[14]

In terms of the fuel energies necessary, this would entail an approximate 60 per cent rise per year, for example, in our overall use of fossil fuels. Even with our projected reserves as presently known, continued population increase and concomitant energy use increases would amount to sharing such fuels for about a century or so until presently accessible reserves were exhausted. Though oil and natural gas potential deposits are known to be relatively more enormous than coal, the energies required in processing lower grade mineral ores would be greater as would the parallel demand for non-fuel uses of oils and gases.

Extrapolating present and projected rates of its use and given that industrialization is not so expanded, coal may not supply the world energy needs by the year 2000 level for more than 150-200 years. Proven oil and natural gas reserves are much greater than the extent of our present knowledge; oil reserve estimates are roughly forty times the world total consumption figures for 1960. Oil, shale and other sources increase estimates further. The 'extent of our knowledge' is the critical factor in projecting such reserves and their utilization. We not only discover more deposits, but our knowledge of how to extract more energy from them also increases.

The existence of very large untapped oil fields on the continental shelves and delta lands of South East Asia, rivaling those in the Persian Gulf and Caribbean, has been noted in a recent paper:

> Actually it has, by now, become obvious (1) that the world's effective reserves of oil will run into trillions of barrels; (2) that a large part of these reserves exist in the shallow water and delta coastal-plain areas of the Western Pacific and of the Southeastern Asian nations; and that the development of these resources can be of immense benefit to hundreds of millions of people, pending the further 'break-through' in connection with the harnessing and use of atomic and thermo-nuclear energies.[15]

One may also speculate as to the relevance of such large scale oil sources (extending as they do through South Korea, Taiwan, Philippines, Malaysia, Burma, Cambodia and

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[14]Hence the emphasis, in our present discussion, on increasing performance per unit of invested resources as the only possible way in which this can be done. In terms of industrial energies and materials the solution may only be sought through prior attention to such technological facts.

[15]Major Oil and Gas Deposits of the World's Coastal Lowlands and Continental Shelves -- with special reference to those of the Western Pacific, (Unpublished paper, May 1967, W. Taylor Thom, Jr., F.W.A., President, American Institute of Geonomy and Natural Resource.

the two Viet Nam's) with regard to the present power struggle being waged in this area. Unfortunately, there is as yet no world "resource authority" which might decide such conflicting claims in terms of the real needs of the human community.

The point may still be stressed, however, that even with such reserves, both in resources and knowledge, we patently cannot continue our present energy policies with regard to such fuels generally. Apart from by-product effects and extravagant valuable deposits in 'storage', the petrochemicals and those which may be derived from natural gas are now the basis for innumberable different products, including the swiftly developing range of plastics. Recent advances in microbial research also suggest the bio-synthesis of food materials from such fossil fuel bases. Burning up potentially valuable construction materials, and an enormous food and medical supply reserve seems even more prodigal than when the oils and gases are considered solely as industrial fuel!

Resource and Use Diversification

Overshading all other considerations, then, in this regard is that of diversifying our overall world energy economy -- of more swiftly developing our 'income' energy sources on a massive scale, and of investigating new sources, means of storage, transmission and more efficient process use.[16]

Hydro-electric power represents less than 10 per cent of the world's energy consumption. Its potential and efficiency of generation are extremely advantageous, particularly as those regions which are poor in other indigenous fuel sources are often well situated to benefit from the use of locally untapped water power. This vast renewable energy resource is obtainable by 'tapping in' to the hydro-cycle in combination with the earth gravitational field. Its only demerits for the lesser developed areas are the 'energy costs' involved in large scale harnessing of such power -- cost, in terms of trained manpower and material resources allocation, transportation, equipment, etc., all of which are in equally short supply in the emergent regions.

Though supplying less than a tenth of the world energy consumption total, its regional use as per cent of total contribution goes as high as 99 per cent in countries such as Norway, down to a low, 5 per cent, in countries such as the United States which are rich in other fuels.

With the level of transnational undertakings increasing, many large joint hydroelectrical schemes are planned or already underway. One, for example, due for completion in 1970, as a joint venture between Rumania and Yugoslavia, is expected to meet more than 15 per cent of the energy needs of both countries. A number of such programs are presently underway around the world, e.g., the Aswan and Upper Volta dams in Africa. At the largest and most hopeful scale is that of the proposed uses of the Mekong River, "twelfth largest river in the world, 2,600 miles in overall length, draining in its lower basin an area larger than France, with a population (in the four countries of Cambodia,

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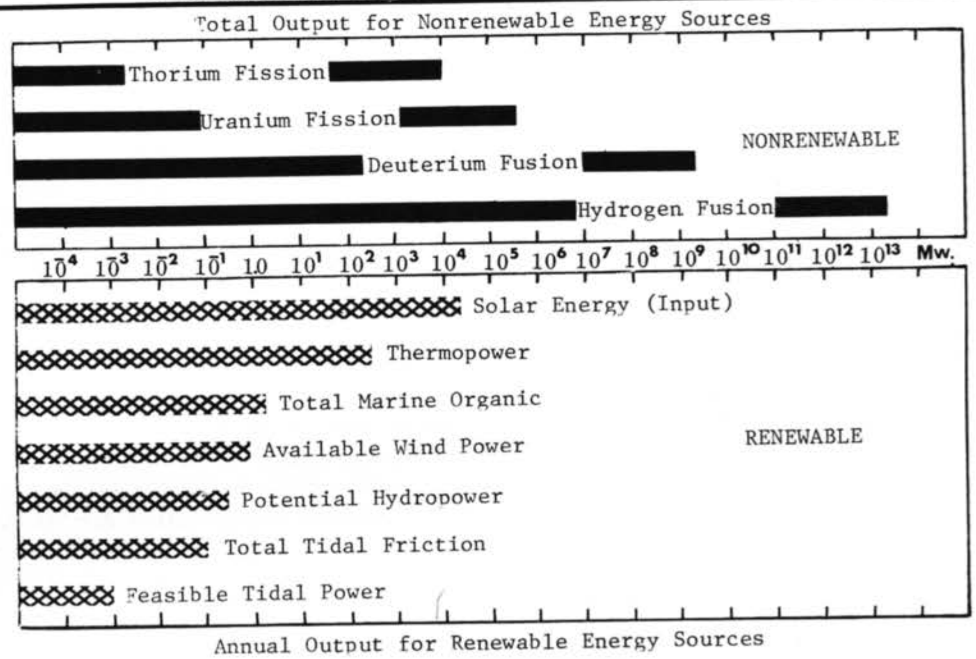
[16]We might underline here that the impetus toward this has already been emergency pressured by local ecological malfunction in the advanced regions. The amounts of aerial, water, soil pollution from current fuel uses now enforce these directions. We might hope that the extension of such ecological regard for human health and survival may be extended to the whole planetary community.

POTENTIAL MARINE ENERGY SOURCES



"...the sea harbors far more non-renewable energy than the land, in the form of the potential fusion energy of its hydrogen and deuterium.

"The power demand of the world in 2000 has been projected as 14 million megawatts....the ultimate fission and fusion of energy content of the oceans is shown in terms of multiples of that anticipated annual demand.

"Thorium and uranium fission could, in principle, supply this 1.4×10^7 MW for some 700,000 years, whereas deuterium and hydrogen fusion can supply it for times that are greater than the age of the solar system. Although terrestrial sources of fissionable materials are probably greater (and more economical) than the marine, the sea is clearly the predominant source of fusible deuterium and hydrogen.

"Feasible tidal power can supply a tenth of one percent of the total need, but even the entire tidal dissipation in all the oceans of the world represents only ten percent of the total need." --Robert Colbarn, ed.

Source: "Earth Science and Oceanography," Robert Colbarn, ed., Modern Science & Technology, 1965. p. 622.

Laos, Vietnam and Thailand) of some 50 million people . . .(presently) less than 3 per cent of the lower basin is irrigated and almost no hydroelectric power is drawn from the river."[17] Such world water power harnessed in projects of this scale could provide over ten times more energy than our present coal production. Europe has about 50 per cent of its extimated hydro potential already in use, North America about 45 per cent, though Canada has considerable unused potential over this figure. Africa, for example, with the largest estimated potential, presently uses less than 1 per cent.

In terms of overall hydropower use, it has been calculated that about 13 per cent of the estimated potential is presently being developed. If all were developed, however, at present conversion and use rates, it would still not provide more than a part of the world's annual fuel needs.

Tidal Power from many of the great river deltas and coastal bays is another powerful hydro source as yet almost untouched. "At present, the only scheme to reach the construction stage is on the Rance estuary near St. Malo, France . . .planned to generate electricity equivalent to annual saving of 400,000 tons of coal."[18] Wave power and the general use of the massive movements of water energy in the oceans we seem to have no direct ways of tapping at his time.

Geothermal Power, though used historically, in the form of hot springs and other features of recent surface volcanic activity, has been little exploited directly as a large scale energy source. In various areas of the earth the interior heat layers are close enough to the surface for drilled well tapping of steam and hot water fields. The technique is similar to oil and natural gas, but more advantageous in the degree of energy heat more immediately available. Recent pioneer development in the United States[19] has a number of such 'wells' operating. An additional important feature of these is their natural occurrence in relation to rich mineral resources, thus providing power for processing, e.g., potash fertilizer, one of our currently critical needs.

Wind Power has proven itself as an excellent 'income' source of energy for centuries -- and could be used more widely today, for generator conversion, where small quantities of electricity are required for various local purposes. Rapidly improving storage capacities may make this an excellent autonomous source for more remote areas of emerging regions. Many different 'aerogenerators' have been developed experimentally and this is an area particularly suitable for pilot projects in our present program.[20]

Solar Energy development has received considerable attention in recent years as the world's total energy balance sheet has become clarified and general agreement reached on the need to find alternative energy sources.

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[17]U.N. Office of Information, November 1966. (N.B. Present conflict in this area will, no doubt, hold up this scheme considerably).

[18]Man and Energy, A. R. Ubbelohde, (Pelican Books, 1963), p. 68.

[19]Magma Power Co., (Los Angeles, California), reports vast deposits of steam, chemicals, minerals -- at 380,000 parts/million and approximately 700-800 F. -- correspondence: B. C. McCabe, President.

[20]"The Use of Income Energy", R. Buckminster Fuller, Prague 1967 Newsletter, World Design Science Decade, November 1966, Southern Illinois University, Carbondale, Illinois

GROWTH OF NUCLEAR POWER

ESTIMATED GROWTH OF NUCLEAR CAPACITY AND GENERATION

Total net electricity generation[1] (1,000 million KWh)	1960	1970	1975	1980
North America	955	1,780	2,380	3,140
Europe	535	1,120	1,570	2,150
Japan	110	300	420	600
Total	1,600	3,200	4,370	5,890
Total output capacity (1,000 million KW)				
North America	192	375	500	650
Europe	131	290	400	540
Japan	23	65	90	130
Total	347	730	990	1,320
Nuclear output capacity (1,000 million KW)				
North America	...	7	30	90
Europe	...	10	40	90
Japan	...	1	5	10
Total	...	18	75	190
Annual nuclear generation[2] (1,000 million KWh)				
North America	...	50	210	630
Europe	...	70	280	630
Japan	...	5	35	70
Total	...	125	525	1,300
Oil equivalent of nuclear heat released (in millions of tons)	...	31	120	305

[1] These figures do not include power stations' own consumption.

[2] Assuming an average annual utilization of 7,000 hours.

Source: Energy Policy: Problems & Objective, Organization for Economic Cooperation & Development, 1966, p. 61.

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The annual earth receipt from solar radiation is, "about 35,000 times the present yearly energy consumption . . . one ten thousandth (of this) converted directly into power would increase world energy production by about 250 per cent.[21]

One acre of the earth's surface receives energy at the rate of about 6,000 horsepower on a clear sunny day. Such conditions vary, of course, around the earth -- but, as one writer has observed, that if we speak of nuclear reactors, 'we should also consider a vast reactor located safely 93 million miles from the earth in space -- the sun.'[22]

The problems in the use of solar radiation are obvious; intermittency, low density difficulties in storage, conversion, etc. But many of these have been overcome technically and various types of radiation concentration devices have already been proven in direct use of the sun's rays for cooking, cooling, etc. Cooling is also an important and obvious factor as areas where the sun is most plentiful and constant are those in need of coolants -- a key consideration when the use of solar energy is identified most often with the lesser developed areas, e.g., India[23]. Solar water heating has been in use for a long time and a number of 'solar' houses utilizing direct and indirectly channelled energies have been built. Many of these intermittent, but plentiful income sources of sun and wind power await only more efficient storage for their wide applicability for many of the smaller scale energy tasks.

The most promising overall area of development, and use, is in aerospace work. The solar cell converting sunlight directly into electrical energy has made possible much of the space exploratory data collected so far. One system of almost 30,000 cells covering 70 square feet, powered all instruments including cameras and other recorders in a satellite track lasting seven months and covering 325 million miles. Such units in the near future may, therefore, be powering the entire satellite-routed global telecommunications system already partially in operation!

N.B. With all of the above ancillary power sources, we still need energies of sufficient high density of concentration, possible speed of installation, conversion, and of a 'continuous' character which might obviate present storage and transmission barriers. Nuclear energy appears to satisfy many of these urgent conditions. The forecasts of the 'Geneva Conference on the Peaceful Uses of Atomic Energy' in 1955, regarding the technical and economic feasibility of its employment, have been considerably fulfilled.

Nuclear Power has been much emphasized as the fuel source for the future. As we have noted though, this is presently based mainly on the uranium ores in the earth, so it could be termed a 'capital' energy use. But, theoretically, as both fission and fusion processes may be extended to a wide range of elements, nuclear power comes closer to being an income source utilizing a wide range of materials. As one pound of fissionable uranium is equivalent in energy to 650 tons of coal, it affords a performance many hundreds of times greater than equivalent fossil fuel use. Linked also, by its nature, to most advanced technology, ancillary gains via this field may be considerable in the use of radiation ener-

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[21] "World Patterns of Energy Production", E. W. Miller, Journal of Geography, U. S., September, 1959, p. 277.

[22] "Power Equals Power", Xerox Pioneer (U.S.), Fall 1965.

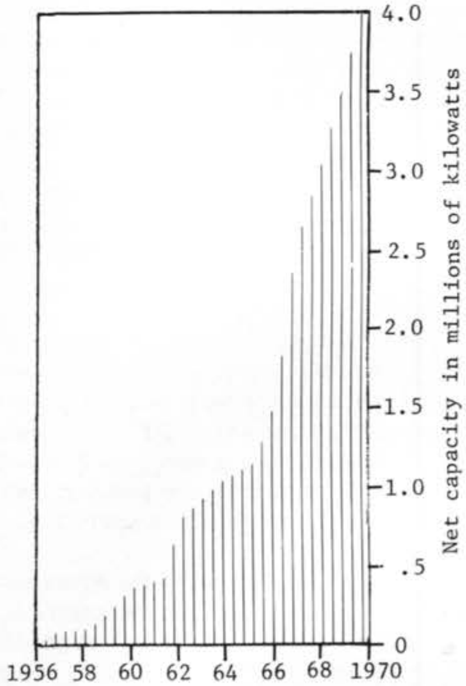
[23] A solar refrigerator unit has already been prototyped by one student group in the WDSD program, as part of their work in this phase, Nottingham School of Architecture, (U.K.), 1966-67.

WORLD NUCLEAR POWER

WORLD PRODUCERS OF NUCLEAR POWER IN 1965

Location by country	Total power in M.W.*	No. of stations
United Kingdom	7006	11
United States	5382	23
France	1580	6
USSR	877	5
Italy	620	3
India	580	2
W. Germany	324	4
Canada	220	2
Belgium	200	1
Spain	153	1
Japan	150	1
Czechoslovakia	150	1
Sweden	148	2
E. Germany	70	1
Netherlands	48	1
Norway	20	1
Switzerland	7	1
Greenland	2	1
TOTAL	17,537	67

CUMULATIVE GROWTH OF NUCLEAR POWER IN U.S.A.



*Estimates vary according to sources. These include nuclear power plants operating or under construction. One megawatt (M.W.) = 1 million watts = 1,000 kilo watts (K.W.).

"There are only 3 commercial nuclear power stations in the whole of Asia, 2 in India and 1 in Japan. A site for a third Indian station has just been chosen, near Madras.

The U.S.A. and U.K. are the main suppliers of commercial reactor units to other countries. So far U.S. manufacturers have obtained 8 contracts and U.K. 3." - Dr. Peter R. Mounfield

Sources: (1) "Nuclear Power in the World Today," Peter R. Mounfield, (notes from lecture given at S.I.U. May 9, 1967). pp. 4-5.

(2) "Environment Contamination from Nuclear Reactors," Malcolm L. Peterson, Science & Citizen, November 1965. p. 1.

gies in medicine, agriculture, etc. Part of its present limitation lies in manner of use, i.e., to produce steam, and thence to electrical generation, rather than directly producing electricity. Despite these developmental limitations, nuclear reactor installation and successful economic operation has increased considerably.

It's advantages for the underdeveloped regions of the world have been succintly stated by one distinguished engineer:

> It can function anywhere. It is independent of geography, climate and the general cultural level of the inhabitants. Upkeep is minimal . . . Needed amounts of nuclear fuel are easily transported, and the consumed weight is negligible. Operation is automatic and can be managed by a limited personnel. And because initial costs are high (and nuclear fuels are and will remain government property), installations will continue to be planned and financed by national or multi-national agencies. They can therefore be placed where they are needed.[24]

This author also draws attention to the facts that the nuclear revolution -- of dispersed autonomous power centers as well as those providing large concentrations of power -- would be a less difficult transition for developing peoples than the introduction of traditional fossil fuel based industries . . . "Where the airplane is supplanting the bullock cart or dog-sled, where radio (and television) directly superseded the village drum for communications, and where manufacturing goes from handicrafts all the way to automation without having to pass through the states symbolized by the steam railway and the assembly line."[25]

As we shall later discuss, the more easeful, swifter and reasonable patter of such development may be via nuclear energy, plastics and electronics -- rather than coal, steel and steam! Experience has shown that even if a research reactor initially appears to be a drain on a country's resources, it stimulates overall scientific and technical development in a variety of fields and assists materially in aiding economic and technological take off.

The advantages of nuclear power, particularly, lie in their independence of geography; due to the compact and 'long duration' fuel source, plants may be built for use far from the sources of fuels, and located autonomously without need for 'continuous' fuel inputs. Portable nuclear reactors have already been constructed for military use. One such type, reported in 1966, weighed less than 15 tons, produced more than 400 kilowatts and could be transported in an ordinary truck.

Though as compared with present fossil use, it is a 'clean' power source, the disposal of radioactive wastes has been and remains a problem -- the emergence of nuclear power as a 'competitive' source in the advanced regions will, however, probably accelerate solutions to this. Recovered wastes from uranium fission have also been used in other types of power plants specifically designed for use in remote areas, e.g., in space and for

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[24] "The Impact of the Nuclear Age", Boris Pregel, America Faces the Nuclear Age, (Sheridan House, New York, 1961), pp. 28-29.

[25] Ibid.

unattended Arctic Weather Stations. The use of such radio-nuclide fuels leads into other types of more direct energy conversion -- thermo-electro and thermionic devices. Fission wastes may then be "viewed as a prime source of such radioisotope fuels . . . (and) the anticipated problem of waste storage may be alleviated if this source of useful energy can be exploited and some of these wastes converted into fuels"[26]

Energy Conversion Efficiency

The efficiency with which energy is converted in various processes is a crucial aspect of the overall energy picture. Present world efficiency is suggested as attaining only about six to eight per cent -- at best up to 20 per cent[27] -- when we deduct friction, heat, engine wear and malfunction, poor fuel oxidation, losses in transmission, overweight in loads as presently designed (e.g., as in household uses), wastage in non-use 'idling' periods, etc.

A great deal may, therefore, be accomplished by increasing our overall energy conversion efficiency. More rigorous systems design of present uses could more than double the performance per unit of energy invested in many areas.

The automobile is a particularly inefficient example: of the energy in crude oil, 87 per cent remains after refining; 3 per cent is used in transport to consumer; 25 per cent is converted to work in the engine, but only 30 per cent of this is transmitted to the road (after losses to friction and auto auxiliaries) and further decreases occur through gears and tires. The overall efficiency of the automobile is about 5 per cent -- though air drag, braking and idling reduces this in actual operation.

Other engines represent higher work efficiencies, on paper, but closer calculation would probably reveal similar types of loss of energy, even if considerably less than the auto. An interesting example here would be to calculate the duplication and overall loss of energy efficiencies in the average 'appliance-equipped' house, as often operating cooling, heating, cooking, lighting, from separately functioning, and different, fuel sources.

A useful case of specific energy efficiency gains may be elicited from a recent transportation study.

> In 1950, Soviet railroads carried just over 600 billion ton-kilometers of freight traffic and appeared to be straining the upper limit of the possible in doing this. Fifteen years later, they carried more than three times as much traffic with only a modest increase in route mileage, very little rise in the operating labor force and no increase at all in the number of locomotives.[28]

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[26]"Energy for Remote Areas", J. G. Morse, Science (U.S.), Vol. 139, No. 3560, March 1963, p. 1175.

[27]"The World Power Conference of 1964", article on main theme of World Power Conference, London 1964, The Times, London, September 9, 1964.

[28]Soviet Transport Experience: Its Lessons for Other Countries, Holland Hunter, (Washington, D.C., The Brookings Institute, October 1966).

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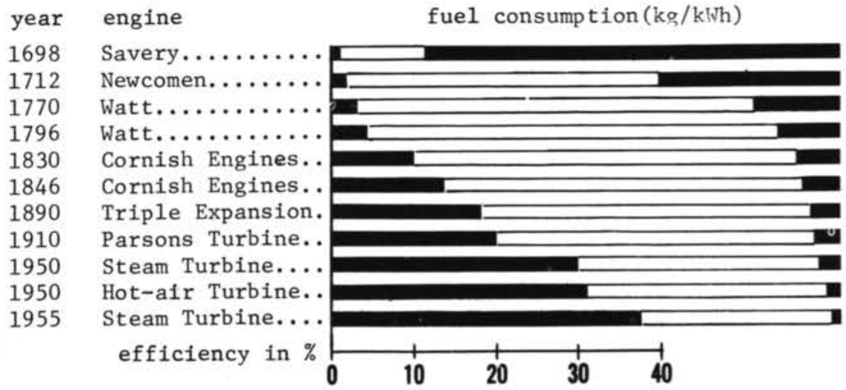
ENERGY CONVERSION EFFICIENCIES

A. PROGRESS IN EFFICIENCY OF STEAM-ENGINES



A. "The left-hand side of the diagram gives the efficiencies, the right-hand side the fuel consumption, which is inversely proportional to the efficiency."-- H. Thirring

B. OTHER ENGINE EFFICIENCIES

engine type	efficiency in %
Steam Locomotive	7
Automobile Engine	12
Ram Jet (at 1,300 m.p.h.)	21
Reciprocating Aero Engine	23
Turbo Jet (at 40,000 ft.)	24
Gas (general)	30
Diesel Locomotive	35
Steam Turbines	40
Fuel Cells (potential)	80
Hydro-elective Turbine	90

Sources: (A) Energy In Man, Hans Thirring, (New York, Harper & Row), 1962. p. 54.
(B) Document 4, The Ten Year Program, John McHale, (Illinois: World Resources Inventory), 1965. p. 53.

As the study further indicates, this was accomplished by switching from steam to diesel and diesel-electric locomotives, which are more continuously available for work, require less servicing for longer distances, etc. The same gains in efficiency might be adduced for diesel electrification of other national railway systems, but the above example shows the swiftest gain over time -- which is of critical importance to our central theme.

The division of energies between their various uses -- in industrial production, transport, communications, distribution, etc., -- is presently difficult to assess accurately in world terms. In the United States, transportation via trucks, automobiles and trains has been calculated to require four times the amount of fuel than that required for electrical power generation. In more recent years, with the rapid expansion of air transport, this may be many times higher, e.g., 1966 figures give an estimate of 11,000[29] airplanes in the United States air-space in any twenty-four hour period. The general rise of air transport using large quantities of fuel is an obvious factor in our overall energy use increase. This is offset, partially, by the more precise attention to higher fuel use efficiencies in such advanced technological instruments and their extraction of the highest performance-per-unit-invested, versus weight of equipment, cargo, etc.

When we consider only single engine efficiencies, however, the inherent re-designing possibilities are obscured. Such engines only operate within, and as functional components of larger systems complexes. Possibly, for environ planners, the urban city complex may be a better starting point. We have elsewhere commented that few overall energy budgets are prepared for building, e.g., for dismantling as well as construction. Few detailed energy systems analyses have been applied to urban and other human ecological aggregates, in terms of their overall energy metabolism. Present attention to the malfunction of the auto in cities could be fruitfully extended to lighting, heating, household and public energy uses, including sewage and waste disposal systems, etc. Industry, though wasteful of energy in the strict sense, is extremely efficient when compared, even casually, with the average energy systems management of our urban complexes.

Electrical power generation is probably one of the sectors of industrial energy conversion which has shown most continuous improvement and capacity to switch flexibly from one type of generating fuel conversion to another. Notable in recent years has been the introduction of nuclear powered generating plants with their highly favourable ratio of fuel input to energy generated.

A recent report from French engineers[30] suggests that we may now design a generator substation at one tenth the size of the present type of unit. This possibility of 'miniaturizing' the substations, which are an essential feature of power distribution networks, is accompanied by the additional possibility of extending present transmission radii through ultra-high voltage -- carrying power over longer lines with less loss.

Ultra High Voltage transmission with 'miniaturized' substations could span enormous areas of the earth and bring electrical power within reach of the energy-poor nations. Many European countries are already running such lines up to 600 miles. The United States and Canada are also concerned with this possibility in transmitting power across sparsely settled plains and mountain areas; "the U.S.S.R. is experimenting with high voltage D.C.

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[29] Life, Vol. 60, No. 15, April, 15, 1966. p. 40.

[30] "Shrinking the Power Centers", New Scientist, (U.K.), June 16, 1966.

ENERGY SYSTEMS

Stellar Energy Sources Chiefly Solar

Income Energies — Continuous or renewable energy receipts of light, heat, gravity, cosmic rays, etc.

Energy Conversion (naturally occurring)	Energy Conversion (human agencies)	Merits	Demerits
Indirect Inanimate — Molecular movement (temperature differences between atmosphere, earth & ocean), geothermal heat & tidal forces.	Sails, waterwheels, wind generator: hydro-electric generators, drying process, geothermal steam and tidal power conve ion facilities	Winds, temperature differences geothermal heat etc. are continuous & have few inherent pollutients	Difficulty of controls, periodic surges, geographic disproportion etc.
Indirect Animate — Photosynthesis, microbial energy conversion.	Food, human labor, draft animals, fmentation & alcohol extraction from vetation, wood fuels, dung, etc. controlled mrobial action in agri-industrial processes	Self regenerating systems. Microbial action may be used in waste reclaimation cycle.	Large volumes of heat energy disipated in direct metabolic processes.
Direct — Photo-Chemical, Photo-electrical, Thermo-electrical.	Heat and electrical energy yielded rough electro-chemical reactions & opticaconcentrations of light, etc.	Direct energy transfer, may be stored bio-chemically or electro-chemically but on a relatively small scale.	Presently not capable of economic application on wide scale or large volume range.

Capital Energies — Exhaustible or unrenewable energy sources stored over extended periods of time.

Energy Conversion (naturally occurring)	Energy Conversion (human agencies)	Merits	Demerits
Fossil Fuels — Coal, petroleum, natural gas, shale oil, tar sands, etc.	Heat and electrical energy yielded rough combustion in various chemical procses and mechanisms	May be stored, transported and controlled with ease and in large volumes.	Excess waste heat, gasses & pollutents effect biogeochemical processes.
Fissile Fuels — Radioactive fissionable elements.	Heat and electrical energy yielded hrough acceleration of atoms in combinati with electro-mechanical systems.	Independent of geography, minimal upkeep, by-product wastes may be used as other fuels.	Large investment in shealding and fuel refinement, disposal of radioactive waste is a present key problem.
Bio-geochemical — Cycling minerals such as nitrates, phosphates, etc.	Heat yielded through chemical reaions, etc.	May be stored, controlled, and used as fertilizers in other food energy processes etc.	Used in explosives etc. Primarily destructive energy use.

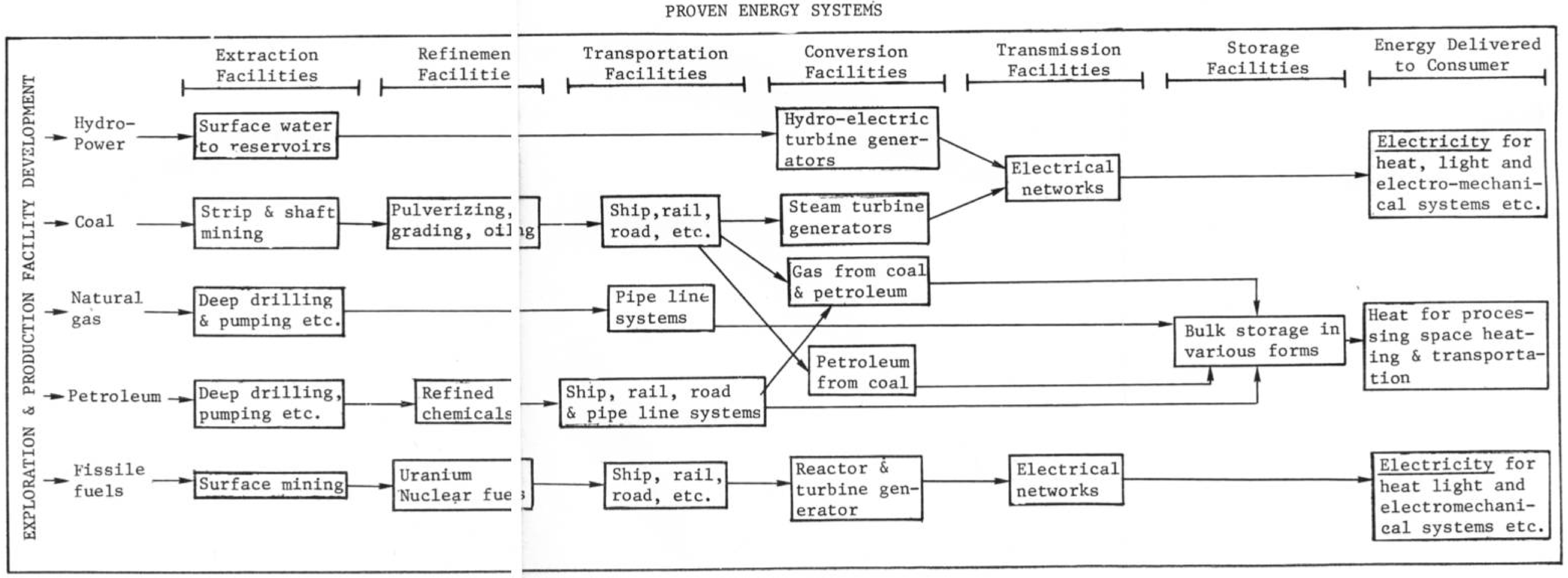
Human Utilization

Cooling food, preserving food, cooking food, space heating, space cooling, pumping water, air & gasses, motive power, lighting, communications, industrial heating, conversion and forming of materials, etc.

DEVELOPING ENERGY SYSTEMS

- Controlled thermonuclear fusion
- Fast breeder reactors
- Magneto-hydrodynamic generators (MHD)
- Thermionics
- Thermo-electricity
- Direct conversion of solar energy
- Shale-oil & tar-sands
- Coal liquification & gasification
- Fuel cells & bio-chemical energy
- Aerogenerators
- Geothermal energy
- Tidal energy

PROVEN ENERGY SYSTEMS



Adapted fr: 1) "The Nature and Sources of Energy," Zimmerman, Introduction to World Resources. p. 68. 2) Energy R. & D. and National Progress, Inter Dept. Energy Study, Washington D.C., 1964. p.40.

current as part of its plans to transmit power all the way from Siberia to industrial areas in Western Russia."[31] If across Russia, then feasibly from Europe to India or to Africa! The tendency for power networks is to seek the largest interconnectibility for maximal sharing of differential loads at varying peak periods.[32]

In addition to the projection of large scale technological projects of industrialization for the developing countries, e.g., hydro-electric and nuclear power generation, etc., it should be borne in mind that:

1. Electrical power 'storage' on a large scale is not yet feasible; power must be generated and used within a given transmission grid and large amounts can be efficiently used only if the industrial system is there to use it. Increasing capacities in long distance transmission of electrical power, mentioned above, offset this economic dependence on locally available industrial use, but the point is an important one.

2. Both ends of the power scale must be kept in proportion. The desired results of eventual large scale industrial advantage can also be aided considerably by the more immediate and plentiful supply of small and medium scale generators and plants. These can supply power for increasing food yields through irrigation, etc., community utilities, and production facilities of many types. Importantly, also, they can be a key 'orientation' agency in speeding the transition from an agriculturally based society to an industrially based one.

An earlier source[33] cited provides a useful typology for the power needs of remote underdeveloped areas as follows:

Group 1 -- Units delivering a fraction of a watt up to several watts, such as power supplies having roughly the capability of a standard flashlight battery and slightly larger, can run radios, transistorized T. V. receivers and small transmitters -- providing news, education, entertainment as well as vital communication linkage where telephones and other units are not available.

Group 2 -- Units from several watts up to one kilowatt, with the capability of an automobile battery, might be used for a microwave relay station, for refrigeration, and for larger communications apparatus.

Group 3 -- Units comparable to the power of a gasoline lawn mower engine or larger, providing power for the pumping of water and other agricultural and productive purposes.

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[31] "Cheaper Power Through Higher Voltages," K. Hamill, Fortune, June 1959.

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[33] Power for Remote Areas, H. Z. Tabor, International Science and Technology, May 1967. (N.B. see also: Direct Use of the Sun's Energy, ? Daniels, (Yale Univ. Press, 1964), Power from the Wind, A. Putnam, (Van Nostrand Co. 1948), Solar Energy Quarterly, Arizona State University, United States.

This source further stresses the possible uses of income energies of wind and sun used in three classes of devices -- wind generators, photo voltaic cells and thermal engines converting heat (including solar heat) to electrical or mechanical power. The U.N. has also recently issued a 215 page study handbook to this area of autonomous small scale generation of power for the underdeveloped regions.[34]

In general, we have to avoid the stereotypes of development, e.g., that lesser developed regions must necessarily follow the growth patterns of the present high energy regions. The simple biological parallel of 'ontogeny recapitulating phylogeny' may have no real relevance to such development. There are various stages of development, obviously, but we may already observe the reality of emerging countries moving into industrial era forms without retracing the earlier stage developments of the advanced regions. Reference is usually made here to cultural barriers, but electric light, cinema, telephone, transistor and television could not have been more eagerly adopted wherever they have been made available -- even in the most traditionally oriented societies. We may note that there appear to be no social and cultural barriers in the transfer of advanced military technologies.

The most pragmatic attitude towards the re-design of development is a 'both/and' one -- rather than strict evaluation in either/or terms. The presently advanced countries are characterized by the plurality and variable scale of their energy production and consumption systems. The process of development should also share this plural approach. There are no fixed rules which must be followed -- other than those of speed, urgency and that the most immediate advantage be gauged within a framework of future consequences and contingencies.

There is, for example, the growing trend toward a shared pool of the large scale world technological instruments, even where this is masked by local 'brain drains' and the balance of competitive markets. Advanced global services go increasingly beyond the capacity of even the most powerful countries to wholly sustain and operate -- satellites, telecommunicating, world airlines, large scale energy generation and distribution systems, etc. No country has all the necessary resources to develop these entirely alone; few manufacture all the items necessary for their maintenance. They are, by their nature, systems which operate most efficiently in the service of the largest possible numbers of 'customers'.

We may question, therefore, the often assumed need in the developing process for the prior build up and duplication of 'heavy industry' in national units. In some, by reason of size, it is obviously impractical, in others, it may be due to 'prestige' need rather than actual operative value. This may also apply to large scale energy production. Rather than wait for the build up of specifically national industrial bases, we may need to go further ahead with both variable scale, locally autonomous, energy generation <u>and</u> large scale regional generation and distribution. Recent developments in ultra-high voltage transmission also suggest that we may increasingly extend our present transmission of energy from concentration in the high energy areas to those lacking in energy.

Generally, we need to assume that no matter what the artificial constraints may be -- those which are customarily put forward such as exchange economics, balance of payments, etc. -- we can no longer afford the disparity between the energy rich and the energy poor regions of the world. The present costs in global tensions are already great -- the future costs are likely to be ecologically enormous.

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[34] <u>Small Scale Power Generation</u>, U.N., pub. 1967, 11. B.7.

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2. Both ends of the power scale must be kept in proportion. The desired results of eventual large scale industrial advantage can also be aided considerably by the more immediate and plentiful supply of small and medium scale generators and plants. These can supply power for increasing food yields through irrigation, etc., community utilities, and production facilities of many types. Importantly, also, they can be a key 'orientation' agency in speeding the transition from an agriculturally based society to an industrially based one.

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In general, we have to avoid the stereotypes of development, e.g., that lesser developed regions must necessarily follow the growth patterns of the present high energy regions. The simple biological parallel of 'ontogeny recapitulating phylogeny' may have no real relevance to such development. There are various stages of development, obviously, but we may already observe the reality of emerging countries moving into industrial era forms without retracing the earlier stage developments of the advanced regions. Reference is usually made here to cultural barriers, but electric light, cinema, telephone, transistor and television could not have been more eagerly adopted wherever they have been made available -- even in the most traditionally oriented societies. We may note that there appear to be no social and cultural barriers in the transfer of advanced military technologies.

The most pragmatic attitude towards the re-design of development is a 'both/and' one -- rather than strict evaluation in either/or terms. The presently advanced countries are characterized by the plurality and variable scale of their energy production and consumption systems. The process of development should also share this plural approach. There are no fixed rules which must be followed -- other than those of speed, urgency and that the most immediate advantage be gauged within a framework of future consequences and contingencies.

There is, for example, the growing trend toward a shared pool of the large scale world technological instruments, even where this is masked by local 'brain drains' and the balance of competitive markets. Advanced global services go increasingly beyond the capacity of even the most powerful countries to wholly sustain and operate -- satellites, telecommunicating, world airlines, large scale energy generation and distribution systems, etc. No country has all the necessary resources to develop these entirely alone; few manufacture all the items necessary for their maintenance. They are, by their nature, systems which operate most efficiently in the service of the largest possible numbers of 'customers'.

We may question, therefore, the often assumed need in the developing process for the prior build up and duplication of 'heavy industry' in national units. In some, by reason of size, it is obviously impractical, in others, it may be due to 'prestige' need rather than actual operative value. This may also apply to large scale energy production. Rather than wait for the build up of specifically national industrial bases, we may need to go further ahead with both variable scale, locally autonomous, energy generation <u>and</u> large scale regional generation and distribution. Recent developments in ultra-high voltage transmission also suggest that we may increasingly extend our present transmission of energy from concentration in the high energy areas to those lacking in energy.

Generally, we need to assume that no matter what the artificial constraints may be -- those which are customarily put forward such as exchange economics, balance of payments, etc. -- we can no longer afford the disparity between the energy rich and the energy poor regions of the world. The present costs in global tensions are already great -- the future costs are likely to be ecologically enormous.

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[34] <u>Small Scale Power Generation</u>, U.N., pub. 1967, 11. B.7.

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MATERIALS

In considering industrial resources, we may again approach these most usefully from the ecological viewpoint. Though our main emphasis will be on industrial materials, this is an aspect of the global ecology which has only recently come within more generalized review. The processes of metals and minerals extraction, distribution, use and circulation in the world industrial networks are now a major subsystem of the biosphere.

As these industrial process cycles begin to approach those naturally occurring in the environ, both in complexity and magnitude of ecological effect, we have been able to identify more clearly the 'organic' nature of our physical technologies and their evoluting patterns of growth. We may, with some conceptual accuracy, refer to the phenomena of industrialization as the externalization of our metabolic systems -- as now operable at a global scale in extracting, digesting and circulating the various major ingredients necessary to the sustenance of our extended human systems operation. We might more fruitfully examine the progressive extractions, flows and recyclings of such materials in terms of overall 'metabolic' or ecological efficiency rather than confine ourselves within the customary economic, fiscal and trade terms.

The flow of industrial materials and technologies is now as essential to the ecological maintenance of the whole human community as the 'natural' flows and cycles of air, water and light energy. Our present modes of conceptualizing the operation of the industrial eco-networks relate more to a pre-industrial past than to the realities of a critically interdependent global system -- whose advanced facilities may only be produced by drawing upon the full array of world resources and only function efficiently when extended to the service of the greatest numbers of men. We still operate large sectors of this system in terms of the restrictive barter practices of local agriculturally-based societies in marginal survival relations to their environs. Such obsolete modes of accounting and control now clog the efficient operation of the global industrial ecology. They may be as dangerous to its forward and 'healthful' maintenance as glandular malfunction in the internal human metabolism or large scale pollution in the overall ecology.

When we focus upon the historical development of materials, the importance of conceptual orientation becomes clearer. Most of the industrial resources presently in use were not even 'conceptually' recognized as such a hundred years ago. Aluminum was a scarce metallic curiosity, radioactivity a laboratory phenomena and many of our present key metals were regarded as 'waste' impurities in other ores. Our material resources and capacities are dependent on the way we view our environment -- they are ultimately as we conceive them to be!

We refer to industrial raw materials as those generally found in the earth crust -- the ten mile thick shell of geologically formed deposits of metallic and non-metallic ores which we may regard as accessible to extraction and processing within our present technologies. Additional to these crust materials are the elements of the atmosphere and ocean also used in the industrial process. Eight elements make up 98.6 per cent of the earth crust:

Oxygen	46.6 percent	Cadmium	3.6 percent
Silicon	27.7 percent	Sodium	2.8 percent
Aluminum	8.1 percent	Potassium	2.6 percent
Iron	5.0 percent	Magnesium	2.1 percent

RELATIVE ABUNDANCE OF METALS

RELATIVE ABUNDANCE OF METALS IN THE EARTH
(present in more than .0009 parts per million)

	P.P.M		P.P.M		P.P.M
SILICON	277,200	COLUMBIUM	24	HOLMIUM	1.2
ALUMINUM	81,300	NEODYMIUM	24	EUROPIUM	1.1
IRON	50,000	COBALT	23	ANTIMONY	1
CALCIUM	36,300	LANTHANIUM	18	TERBIUM	0.9
SODIUM	28,300	LEAD	16	LUTETIUM	0.8
POTASSIUM	25,900	GALLIUM	15	THALLIUM	0.6
MAGNESIUM	20,900	MOLYBDENUM	15	MERCURY	0.5
TITANIUM	4,400	THORIUM	12	BISMUTH	0.2
MANGANESE	1,000	CESIUM	7	THULIUM	0.2
RUBIDIUM	310	GERMANIUM	7	CADMIUM	0.15
STRONTIUM	300	SAMARIUM	6.5	INDIUM	0.1
BARIUM	250	GADOLINIUM	6.4	SILVER	0.1
ZIRCONIUM	220	BERYLLIUM	6	SELENIUM	0.09
CHROMIUM	200	PRAESODYMIUM	5.5	PALLADIUM	0.01
VANADIUM	150	ARSENIC	5	GOLD	0.005
ZINC	132	SCANDIUM	5	PLATINUM	0.005
NICKEL	80	DYSPROSIUM	4.5	TELLURIUM	0.002
COPPER	70	HAFNIUM	4.5	IRIDIUM	0.001
TUNGSTEN	69	URANIUM	4	OSMIUM	0.001
LITHIUM	65	BORON	3	RHENIUM	0.001
CERIUM	46	YTTERBIUM	2.7	RHODIUM	0.001
TIN	40	ERBIUM	2.5	RUTHENIUM	0.001
YTTRIUM	28	TANTALUM	2.1		

RELATIVE ABUNDANCE OF METALS IN THE SEA WATER
(present in more than .0015 parts per million)

	P.P.M		P.P.M		P.P.M
SODIUM	10,561	ALUMINUM	1.9	MANGANESE	0.01
MAGNESIUM	1,272	RUBIDIUM	0.2	LEAD	0.005
CALCIUM	400	LITHIUM	0.1	SELENIUM	0.004
POTASSIUM	380	COPPER	0.09	TIN	0.003
STRONTIUM	13	BARIUM	0.05	CESIUM	0.002
BORON	4.6	ARSENIC	0.024	MOLYBDENUM	0.002
SILICON	4.0	IRON	0.02	URANIUM	0.0016
		ZINC	0.014		

Adapted from: "Metals and Mineral Processing--How Metals are Recovered," Marshall F. Sittig, Engineering & Mineral Journal, June 1958

Other materials of present importance occur in lesser percentages, e.g.,

Nickel	0.02 per cent
Tungsten	0.005 per cent
Tin	0.0004 per cent

The major concentrated deposits of these resources are inequably distributed around the earth with little relevance to natural boundaries and 'natural' ownerships. This has been an important factor in the location of industries, the growth of the 'advanced' nations and the present disparities in living standards.

Until about two hundred years ago, the numbers of known metals were quite small and the scale of their use comparatively insignificant in our present terms. There were the noble metals of gold and silver, and the base working metals such as iron, copper, lead and tin; mercury was known but little used. The main alloys were brass and bronze, but their precise combinations of copper, tin, zinc and antimony were not clearly understood until the Eighteenth and Nineteenth Centuries.

The industrial revolutions of the Nineteenth Century began the production of metals on an abruptly larger scale than at any other previous period. In the first quarter of the Twentieth Century more metal of every type was extracted and processed than in the whole of all recorded history; this output was doubled in the second quarter of the century. Ninety per cent of this production was iron-alloyed with a smaller proportion of other metals to form the range of steels which, up till now, have been the fundamental material basis for our present industrial civilization.

From this point on there are three distinct and characteristic phases of industrial growth and materials use which are of signal importance.

The first phase is marked by the localized growth of iron and steel production when large scale mechanical industry developed in those countries where supplies of iron ore, coal and limestone were available in close association with developing power and transportation facilities. The swift 'take off' of the industrially advanced nations owes much to these locally coincident factors of relative self-sufficiency in this first brief phase. Even where their own iron ore supplies had to be augmented as production increased, they had the transport facilities, political and trade power to obtain ores from nearby countries. The increased demands for such materials led to a polarity of trade exchange characterized by the flow of manufactured goods from the industrial countries in return for raw materials from the industrially underdeveloped areas. This pattern, with its latent restrictive functions, persists up to our own period.

The second phase occurred in the late Nineteenth and early Twentieth Centuries when new ferrous and non-ferrous alloy production began to require constant access to an array of metallic constituents which were relatively scarce in many of the industrialized countries. Such materials as manganese, tungsten, nickel, cobalt, etc., were further, and unevenly dispersed, around the globe -- with little relation to previously conceptualized territorial and 'power' balances. Within a few decades, the separate national systems of industrialization found themselves acutely dependent for vital alloying and other materials on distant, and often competitively controlled, sources of supply. The whole industrial network, both of manufacturing centers and raw materials areas became locked in a critically interdependent global relationship -- as no one nation could be self-sufficient in the vast range of materials now essential to the maintenance of its industrial system.

> The new century found Great Britain looking to Canada and the Belgian Congo for cobalt, to British Guinea and France for aluminum ore, to Canada for Nickel, to India and the Gold Coast for manganese, to China and Burma for tungsten. A new meaning was given to the importance of retaining command, of the seas . . .giving place to command of the air.[1]

All of the other industrial nations were in the same position; even those, such as the U.S.A., who already possessed a great range of internally available minerals deposits.

Previously neglected, and underdeveloped, regions possessing key materials deposits became the latent focus for a long series of inter-nation power struggles. It is noteworthy that the political slogans accompanying these conflicts rarely referred to their latent content, but were expressed in terms of 'living room', 'manifest destiny', 'self-determination ' and the like. We may still locate many of our present or potential tension and conflict areas by direct reference to their production or reserve supplies of key 'strategic' materials.

Another marked feature of this second phase of industrial development was that the new key metals and other materials, as such, little changed the prevailing polarity of industrial manufacturing and raw materials producing areas. As we have noted, most heavy industry centers had been developed prior to, and independently of, the newer material needs. The heavy industrial base, for example, was steel production and, where iron ore was required in thousands or millions of tons, to sustain this, the vital new alloying metals for successive steel alloy improvements were required in much smaller quantities -- less than one tenth of such amounts of iron ore. The established industrial centers retained, therefore, their prime position.

The general increase in the number of different materials required, as technologies advanced, lessened the relative importance of any one material in determining industry location -- particularly as the larger range of materials needed was more globally dispersed in its various individual supply origins. The relatively smaller quantities of additional alloying materials required less transportation energies -- this factor was further reduced by improvement in transportation and intermediate technologies. Further concentration of industrial power in the established metal working centers was strengthened by the tendency towards the use of scrap, particularly in steel making.

This polarized pattern -- in which the advanced countries continue to develop, at higher standards of living with concomitant reduction in family size and overall population pressure; and the lesser developed countries remain largely restricted to the function of raw materials depositories with much less industrial growth, lower living standards and rising population pressures -- still obtains to a considerable degree.[2] The accompanying tensions and conflicts over control of the strategic material regions is further intensified by the internal imbalance of the overall pattern. This might be viewed as an ecological malfunction with the over-concentration of highly specialized and developed areas tending

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[1] Conference on Mineral Resources and the Atlantic Charter, British Association for Advancement of Science, Vol. II, No. 7, 1942.

[2] For example, regions such as South East Asia, Bolivia, Nigeria, and Congo have long produced together almost 90% of the world's supply of tin, but have had no industrial means for using it internally to their more direct advantage. Advanced countries such as the U.S. consume more than 35% of the world's tin without any major tin mine within their own boundaries.

toward a latent parasitism on the lesser developed. One key 'over-concentration', we may note, has been on steel production as the primary industrial base paired with heavy dependence on coal and oil fuels as the energy resource for such industries.

The third phase, into which we are just entering, is characterized by the possible displacement of steel as the prime industrial material (for structural, machine, transport and other major uses) by other metals, 'composite' materials and plastics. The forward pattern of development may lie in:

1) the pairing of aluminum/magnesium/titanium as prime metals with electrical power from hydro or nuclear sources.

2) in the increased use of metallic and non-metallic composites and plastics in conjunction with similar power sources.

Such trends are already visible, as we shall later discuss. Their future developments could swiftly diversify and alter the present industrial power balance and possibly turn the present prior investment advantage of the older established industrial regions into a restrictive disability. The speed of technological change no longer favors long term 'stable' amortization in heavy plant as a standing advantage. The rapid recovery of those 'industrial countries whose capital plant equipment had been largely destroyed in World War II (e.g., Germany and Japan) and their subsequent rise to industrial parity and competitiveness with the other advanced industrial nations, within two decades, is striking evidence of this trending.

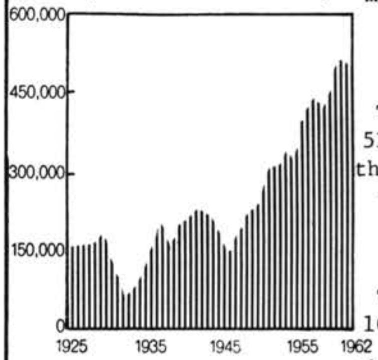
In the above synoptic review, we have devoted most attention to metals and metalworking as the prime materials and technologies of industrialization. Many other materials and technologies played major roles in this development, but the main structural and other technical advances have been closely interwoven with, and dependent upon, metallurgical processes. These, in turn, depended upon the general growth of industrial chemistry which changed manufacture from being predominantly 'mechanical' in nature toward diverse modes of chemical, electro-chemical and electro-mechanical industrial transformations.

Our present emphasis on metals is based, therefore, on this continuing centrality of their position within the industrial ecology and, even more importantly, on the critical aspects of overall metal resources in our current transitional period. Until other materials are more fully developed and available in the same abundance with the necessary ranges of tensile stress, hardness, durability, energy conductance, forming capacities, etc., we are heavily dependent upon the key metals. The high living standards afforded by advanced technological facilities are predicated largely on the amounts of metals and inanimate energies available. As the amount of metal used in maintaining such living standards increases in overall consumption with the numbers of persons served by an increasing range of industrial facilities, the amount of metals actually available per capita decreases.

Within the immediate range of our present technologies we are dealing with a relatively limited amount of metal resources. Alloying chemistry extends the number of their combinations and provides an increasing range of qualities; the reuse of the metals and their alloys through progressive cycles of scrapping and refabrication in different products means that they are not "lost" or used up. In the long run, when we consider such factors, metals are inexhaustible. But, if we wish to increase our immediate forward advantage industrially -- to serve more men to higher living standards, we can only do this in the shortest possible time by extracting more designed performance from each unit of metal used.

IRON ORE

WORLD PRODUCTION
(thous. short tons)



RESERVES — in millions of metric tons — Total 29,541 million tons

Other	China	Sweden	Canada	Brazil	France	U.S.A.	India	U.S.S.R.
5,345	1,376	1,393	1,754	1,797	2,682	2,554	3,394	9,246

PRODUCTION — in thousands of long tons — Total 513,661 thousand long tons

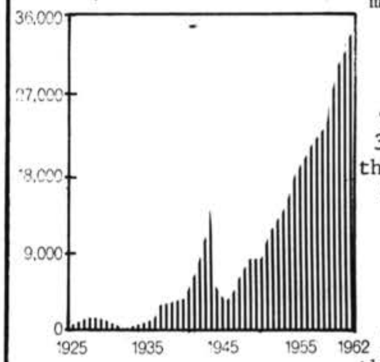
Other	Canada	China	France	U.S.A.	U.S.S.R.
186,466	26,914	34,400	56,978	73,599	135,304

IMPORTS — in thousands of short tons — Total 161,179 thousand short tons

Other	Poland	Czech.	U.K.	Benelux	Japan	W. Germany	U.S.A.
26,700	8,434	8,938	14,666	19,192	24,392	26,220	32,637

BAUXITE

WORLD PRODUCTION
(thous. short tons)



RESERVES — in million tons — Total 5,760 million tons

Other	Yugo.	Hungary	Jamaica	Guinea	Australia
1,410	290	300	600	1,100	2,060

PRODUCTION — in short tons — Total 30,220 thousand short tons

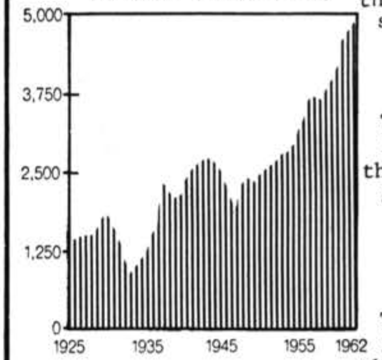
Other	U.S.A.	Guinea	France	Guyana	Surinam	U.S.S.R.	Jamaica
8,062,000	1,525,000	1,638,000	1,997,000	2,342,000	3,453,000	4,300,000	6,903,000

IMPORTS — in long tons — Total 17,330 thousand long tons

Other	Japan	W.Germany	Canada	U.S.A.
3,309,365	1,398,974	1,484,200	1,967,842	9,170,000

COPPER

WORLD PRODUCTION
(thous. short tons)



RESERVES — in thousands of short tons — Total 212,000 thousand short tons

Other	Poland	Peru	Congo	Zambia	U.S.A.	U.S.S.R.	Chile
29,600	11,400	12,500	20,000	25,000	32,500	35,000	46,000

PRODUCTION — in short tons — Total 5,210 thousand short tons

Other	Congo (L)	Canada	Zambia	Chile	U.S.S.R.	U.S.A.
1,160,989	299,097	452,558	648,239	665,951	770,000	1,213,166

IMPORTS (ore & unwrought) — in long tons — Total 3,231 thousand long tons

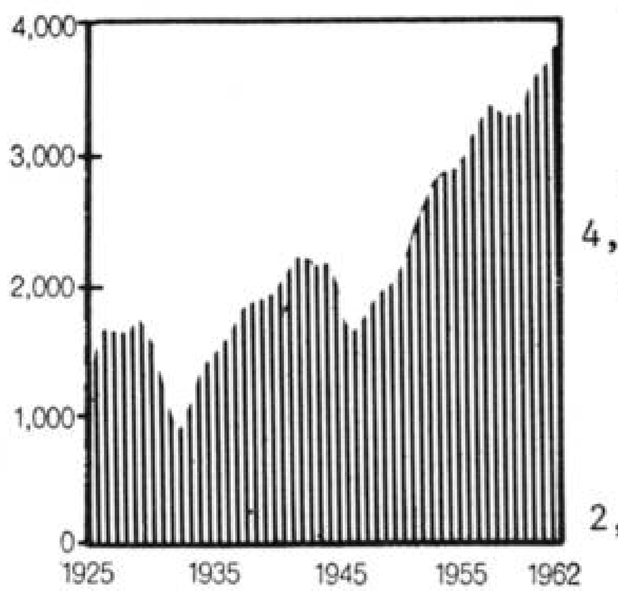
Other	France	Italy	U.S.A.	Benelux	U.K.	W. Germany	Japan
627,156	216,941	220,635	226,676	279,916	481,485	566,224	611,461

Sources: (1) "Minerals," Julian W. Feiss, _Scientific American_, September 1963. p. 131.

SELECTED METALS, WORLD: 1963
(Reserve Estimate Dates Vary)

ZINC

WORLD PRODUCTION (thous. short tons)



RESERVES — in thousands of short tons — Total 85,000,000 short tons

Other	Africa	Australia	Brazil & Peru	Asia	U.S.A.	E. Europe & U.S.S.R.	W. Europe	Canada
4,000	4,500	5,300	6000	8,000	12,200	13,000	13,000	19,000

PRODUCTION — in short tons — Total 4,636,330 short tons

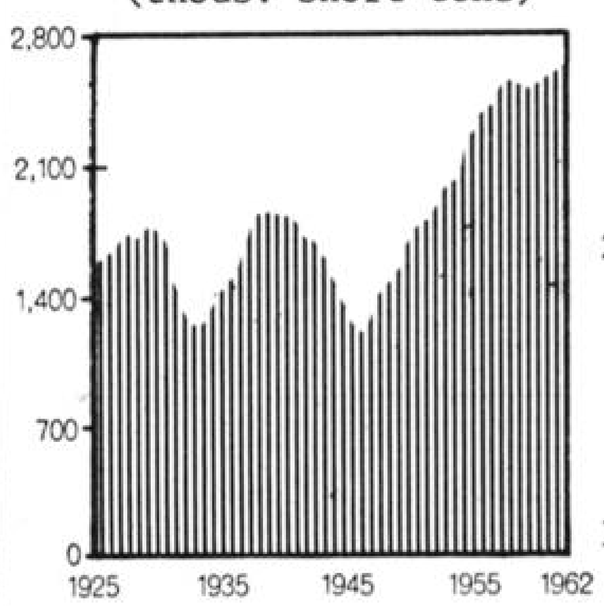
Other	Peru	Japan	Mexico	Australia	U.S.S.R.	Canada	U.S.A.
2,067,341	216,392	218,209	264,354	393,600	450,000	497,180	529,2

IMPORTS (ore & unwrought) — in long tons — Total 2,690,726 long tons

Other	Poland	Japan	W.Germany	France	U.K.	Benelux	U.S.A.
575,917	146,200	153,447	256,640	296,842	371,284	440,171	450,22

LEAD

WORLD PRODUCTION (thous. short tons)



RESERVES — in thousands of short tons — Total 48,800,000 short tons

Asia	S. Africa	Africa	Europe	W. Europe	Australia	N. America
2,000	2,500	3,500	4,600	9,100	12,500	14,600

PRODUCTION — in short tons — Total 2,805,000 short tons

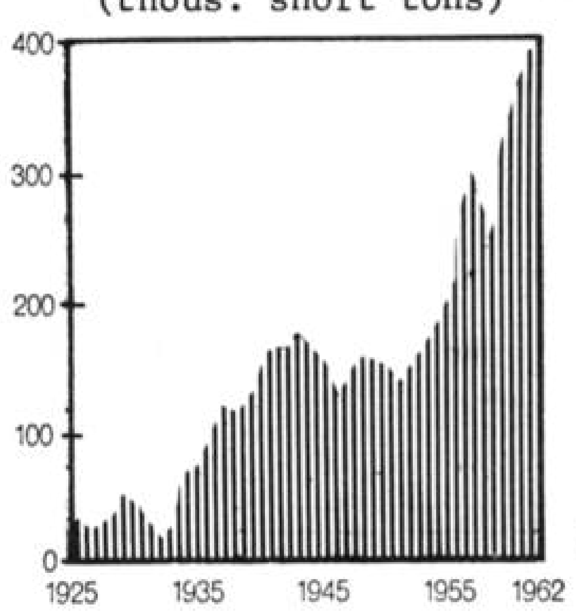
Other	Peru	Canada	Mexico	U.S.A.	U.S.S.R.	Australia
1,130,182	163,468	198,988	209,425	253,369	390,000	459,56

IMPORTS (ore & unwrought) — in long tons — Total 1,502,151 long tons

Other	Japan	Benelux	France	U.K.	W. Germany	U.S.A.
342,897	91,367	141,649	194,586	205,026	206,447	320,179

NICKEL

WORLD PRODUCTION (thous. short tons)



RESERVES — in thousands of short tons — Total 16,000,000 short tons

Other	New Caledonia	Cuba	Canada
783	4,600	4,650	5,967

PRODUCTION — in short tons — Total 395,000 short tons

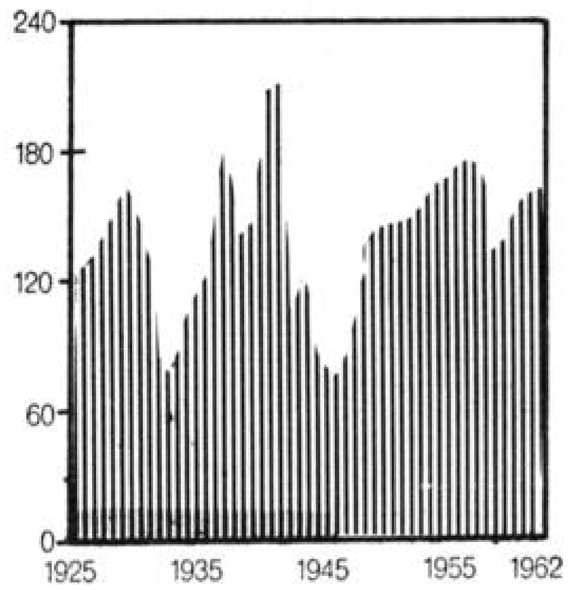
Other	New Caledonia	U.S.S.R.	Canada
43,859	41,200	90,000	219,941

IMPORTS (ore, matte & unwrought) — in long tons — Total 939,098 long tons

Other	U.K.	U.S.A.	Japan
99,970	69,106	97,200	672,822

TIN

WORLD PRODUCTION (thous. short tons)



RESERVES — in thousands of long tons — Total 5,503,000 long tons

Other	Burma	U.S.S.R.	Congo	Bolivia	Thailand	Indonesia	Malaysia
403	300	500	500	500	800	1,000	1,500

PRODUCTION — in long tons — Total 190,315 long tons

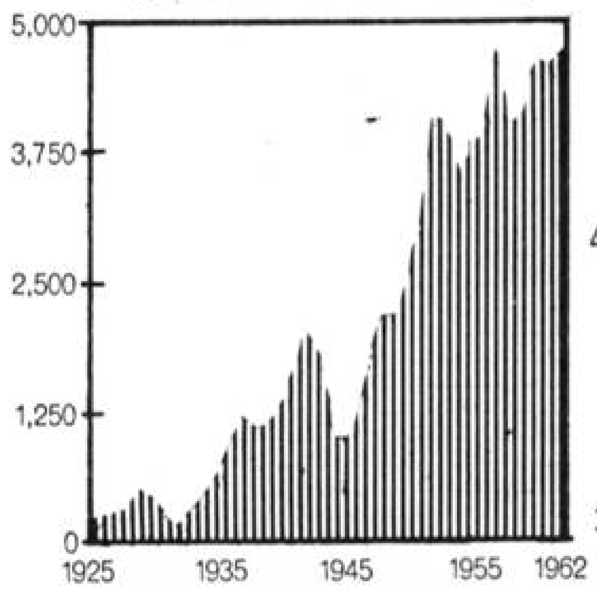
Other	Nigeria	Indonesia	Thailand	U.S.S.R.	Bolivia	China	Malaysia
22,359	8,723	12,947	15,587	20,000	22,752	28,000	59,947

IMPORTS (ore & unwrought) — in long tons — Total 233,643 long tons

Other	France	Benelux	Japan	W.Germany	Malaysia	U.S.A.	U.K.
50,381	10,998	11,047	15,866	19,962	28,140	44,624	52,625

CHROMITE

WORLD PRODUCTION (thous. short tons)



RESERVES — in thousands of long tons — Total 2,661,000 thousand long tons

Other	Rhodesia	South Africa
	600,000	2,000,000

PRODUCTION — in short tons — Total 4,355,000 short tons

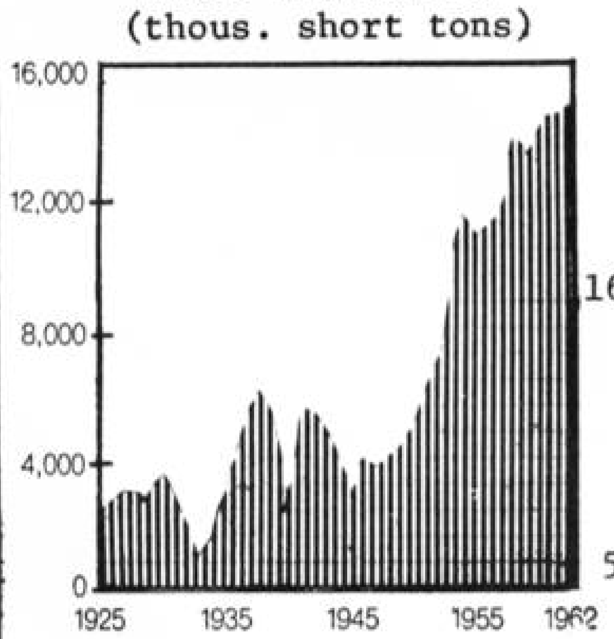
Other	Turkey	Albania	Rhodesia	Philippines	S. Africa	U.S.S.R.
572,508	312,817	322,977	412,392	506,094	873,212	1,355,000

IMPORTS — in long tons — Total 2,455,173 long tons

Other	France	U.K.	W.Germany	Japan	U.S.A.
508,221	151,235	158,971	171,740	222,938	1,242,068

MANGANESE

WORLD PRODUCTION (thous. short tons)



RESERVES — in million tons — Total 420.5 million tons

Other	China	S. Africa	Brazil	India	Gabon	U.S.S.R.
28	22.5	27	30	50	50	213

PRODUCTION — in short tons — Total 16,137,890 short tons

Other	China	India	Brazil	S. Africa	U.S.S.R.
3,566,387	1,102,000	1,300,273	1,382,727	1,441,503	7,345,000

IMPORTS (ore only) — in long tons — Total 5,557,716 long tons

Other	Poland	U.K.	Japan	W. Germany	France	U.S.A.
1,110,025	299,494	305,196	361,922	639,156	701,050	2,140,873

(2) 1964 Minerals Yearbook, Vol. I., U.S. Department of Interior, Bureau of Mines, (Washington, D.C.) 1965.

(3) Mineral Facts and Problems, 1965 ed., Bulletin 630, Department of Interior, Bureau of Mines, (Washington, D.C.) 1966.

(4) Statistical Summary of the Mineral Industry 1959-1964, Overseas Geological Survey, Mineral Resources Division, (London) 1966.

The gain of higher performance per materials use investment is a 'natural' aspect of advanced technological development. Each successive technical improvement is designed to reduce materials and energy 'costs' per function. This is dramatically evident in the progressive miniaturization of many devices; in the reduction of materials weight, prime mover and maintenance energies in advanced technologies of transportation, communication, information handling (see chart on computer performance gains).

Extending advanced industrial standards to all peoples despite decreasing amounts of available metals and other materials per capita is only feasible, therefore, through re-design towards more efficient performance in the use cycle of our major materials. Though inherent within technological development, the swift increase in the overall amounts of materials used, in the range of industrial facilities, and the greater number of users, requires that we more consciously redirect and hasten this process -- or we may be overtaken by the inevitable conflicts which our present 'have/have not' disparities engender.

KEY METALS

Some brief comment on selected key metals may be pertinent here. Notes above, on the interdependence of manufacturing and raw materials areas, and the increasing world consumption of these metals may be related to the tables of reserves, production and consumption in this section.

Iron/Steel

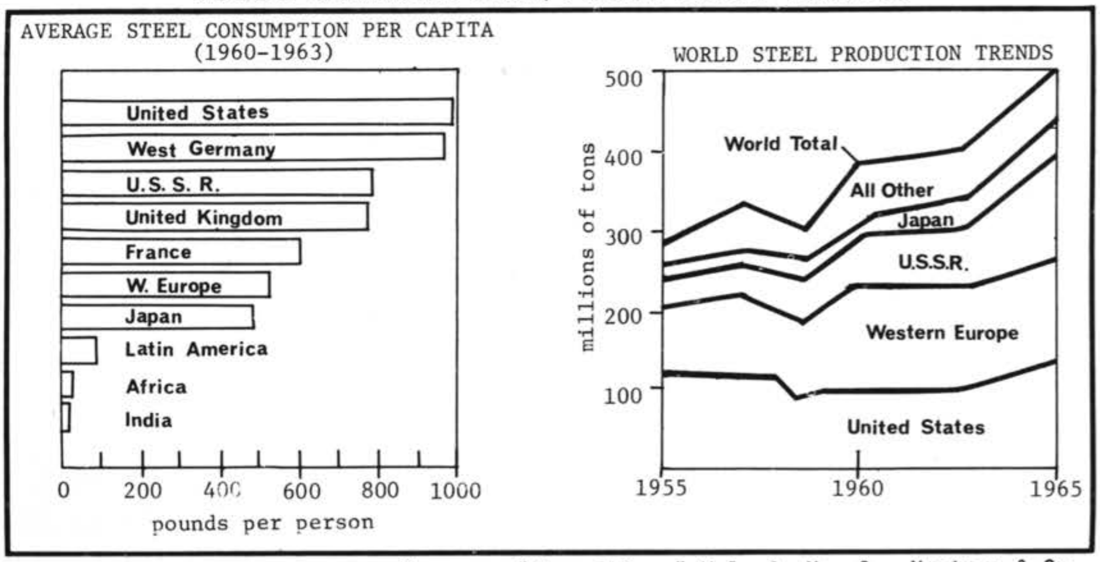
Though now constituting our main metal usage, it is interesting to reflect that this enormous dependence on iron is relatively recent. Iron came into tool and weapon use only after copper and bronze. Too soft to use in the pure state, it took many centuries for man to control the amount of carbon in iron mixtures to produce a sufficiently hard steel. Our present range of steel alloys mostly originated in the past hundred years. The development of their precise alloying techniques may be accounted one of the most important in our period -- when man was able to predict, consistently control and flexibly manipulate, the structural qualities of his major materials on a large scale for the first time.

With iron as the major component in combination with varying amounts of other metals, steels may be produced with a vast range of required properties; of great tensile strength, degrees of hardness, wear, rust and acid resistance, etc. They may be non-magnetic, of high electrical resistance, low co-efficient of expansion -- or possess these and other characteristics in various combinations.

The main alloying metals used are manganese, chromium, nickel, molybdenum, tungsten, cobalt and vanadium. Chromium and nickel are used to produce rust, acid or heat resisting steels; manganese gives particular wear resisting properties. High speed tool and cutting steels are generally formed with tungsten and/or molybdenum with lesser quantities of chromium, vanadium and cobalt.

No material presently used, and required, in such large quantities wholly reveals the range of qualities available in steels for general purposes. But, this is now changing quite rapidly as aluminum, magnesium, composites and plastics have entered the field in bulk production. A further factor influencing this shift is the limitation of steel in loss of strength, at very high temperatures, in aerospace and supersonic aircraft work, where atmospheric re-entry heats and 'lead edge' materials conditions go beyond the melting point of most steels, it has been superseded by ceramic refractory coatings and refractory

STEEL CONSUMPTION/PRODUCTION TRENDS



Source: "Transition," Vol. 8, No. 2., Nystrom & Co.

CONSTRUCTION MATERIALS

PROPERTIES OF CONSTRUCTION MATERIALS
(Ranked by Tensile Strength)

Material	Tensile Strength 1,000 psi	Tensile Modulus mil. psi	Fabricability into Complex Shapes	Corrosion Resistance
EPOXY, Unidirectionally (glass-reinforced prepreg)	100	3	poor	excellent
STRUCTURAL STEEL	60	27	poor	poor
DIE-CAST ALUMINUM	40	9	good	good
POLYESTER, (glass-fiber-reinforced)	20	0.2	good	excellent
EPOXY, Cast unfilled	10	0.5	good	excellent
RIGID VINYL	8	0.4	excellent	excellent
PHENOLIC (general-purpose)	7	0.1	excellent	excellent
POLYSTYRENE (general-purpose)	6.5	0.5	excellent	excellent
POLYETHYLENE (high-density)	5	0.2	excellent	excellent
GLASS	5	10	good	excellent
WHITE PINE (with grain)	5	1.1	poor	good

Source: 1962 Western Plastics Directory, "Plastics Primer," p. 5.

alloys of other metals. The growing usage of aluminum, other metals and plastics, in areas previously served by steel have, however, forced its development toward higher yield strengths and other properties. Current high tensile strength steels of 18-22 tons per square inch are likely to be doubled in strength yield in the next period, and the possibility of high strength steels of up to 200 tons per square inch also seems feasible within the next few decades. Recent changes in its production technologies have kept steel in a favored position by increasing production, though more direct and 'continuous' processes have also contributed. The enormous investment in steel industries and their central position in the various national economies sustains constant emphasis on steel as the key industrial base and index of economic development. As we shall later discuss, however, this might no longer obtain for newly developing countries whose major developmental direction may lie with the 'light metals' or structural plastics as the preferred developmental base.

As we have noted, the location of iron ore deposits was a prime factor in the development of our major industrial centers in the West. That the availability of local ores is now of lesser importance is evidenced by the growth of the steel industry in, for example, Italy and Japan -- as more dependent on the importation and re-use of scrap than primary ore. The scrap cycle has also steadily gained in importance in the long established centers where local high-grade ores have been exhausted or are no longer sufficient to meet demand.

Copper

Though probably the first metal used by man, copper has retained a central position relative to steel, even though it is used in far lesser quantities of high ductility, alloying qualities and electrical conductivity. Variations in volume copper use in industrial sectors and its use movement from sector to sector in power generation/transmission, communications and transportation reveal successive gains in performance per unit in various technologies. For example, where a technical advance enables more messages to be conveyed per wire transmission, or 'wire' use is superseded by wireless, etc., this is reflected in the decrease in volume copper use in that sector or by acceleration in the scrapping pattern. Other indications, such as the electrification of transportation and other systems, increase in armaments production, etc. are reflected in the shift of copper from one sector to another, etc.[3]

> About a quarter of the world's production is used in generators, motors, switchboards and other electrical apparatus; over eight per cent for transmission lines for power and lighting; and five per cent for telephones and telegraphs. Other rod and wire uses consume twelve per cent; bearings, bushes, and fittings four per cent; radio sets over three per cent; and the remaining fourty-three per cent or so serves for the various copper alloys and other uses.[4]

The main alloys of copper are the brasses of the copper-zinc group, the duralumins where copper is a minor, but key constituent, the copper-nickel and copper beryllium alloys. The uses of copper and its alloys are a critical area in industrialization, as underlined

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[3]See Copper chartings in Document 2 of this series, "The Design Initiative" by R. B. Fuller.

[4]"Minerals in Industry", W. R. Jones, (Pelican Books, 1963), p. 88.

above, and the concentration of ore production in various world regions has led to those nations with limited access to such ores to emphasize the search for substitute conducting materials. The concomitant growth in other conducting metals has also moved copper away from various prime use sectors, e.g., its partial replacement by aluminum for long distance electrical transmissions due to the lesser weight and loss of the latter metals.

Copper has a high recovery rate in its scrapping and re-use cycles, e.g., in the U.S. about 40% of the copper used in manufacture is derived from scrap, in 1963 scrap recovery equalled 80% of domestic U.S. mines production. More is recycled in the form of brass and other alloys.

Aluminum

More abundantly present in the earth's crust than iron, aluminum's volume use was relatively much less until recent years for two main reasons. One, earlier bulk production required much more energy input than iron and was a more complex technical process, e.g., one ton of aluminum required approximately twenty times more coal equivalent in extraction and processing energies than a ton of iron; second, progress in aluminum alloys did not progress as swiftly as in steel.

Today the light, strong alloys of aluminum (and magnesium, a somewhat similar case) now provide many of the physical qualities of steel at less than one third of its weight, and with relatively high electrical conductivity.

From half a million tons of annual production twenty years ago, aluminum world production is now almost 6 million tons. Its chief uses are in construction and transportation; in the latter area, its availability in high strength alloy forms has paced the development of aircraft and aerospace technologies. More and more uses are developing constantly for aluminum as its increasing volume and improvements in alloys reduce overall costs against gains in weight/performance ratios.

The consumption of aluminum in the various countries gives a useful picture of their degree of material development, e.g., for 1961 per capita aluminum use was as follows:[5]

U.S.	23 lbs.	Australia	8 lbs.
U.K.	15 lbs.	Japan	4 lbs.

Other European countries, less than 10 lbs. per person.

The extraction of aluminum from its basic ore, bauxite, requires large amounts of electrical power and, therefore, favors local primary processing close to ore sources -- where such power is, or can be made, available. The coincidence of large bauxite deposits and potential hydropower in many of the lesser advanced areas has already led to their combined development, e.g., in Jamaica, Ghana and to projected large developments in Surinam, Guinea and Indonesia. Apart from Canada and U.S.S.R., most of the other major users of aluminum are more or less dependent on imported bauxite for their needs. Scrap recovery and re-use in production is high, approximately 25% in developed industrial countries.

[5]N.B. In terms of such indexing of development, more refined indices could be prepared relating per capita key metals use; performance per unit of invested capability-- as shown by access to advanced transport/communication services; information processing equipment, etc. Such indices would go beyond the ordinary economic indicators of G.N.P., etc., to measure more accurately the degree of environmental advantage indicated by access to and use of not only material resources, but advanced technological services.

Tin

Important deposits of tin ores occur in few parts of the world and these are, significantly, in the lesser developed regions -- South East Asia (Malaya, Thailand, Indonesia), Bolivia, Nigeria, Congo -- and -- China. The main industrial powers possess little or no domestic tin ore, but consume the world's major production of tin annually. The relative importance of tin as a 'strategic' metal lies in alloying -- phosphor bronzes, so called gun metals, and importantly for bearings, valves and bushings, accounting for approximately 40% of consumption.

About twenty per cent is used in the form of solders. With such key uses, the conflicts around the control of tin ore producing areas has furnished the latent background for considerable political and economic maneuvering, e.g., the countries initially occupied by Japan in W. W. II were those producing over 60% per cent of the world's tin, and we may note that these areas still furnish a central focus for intensified internation conflict.

Various tin compounds, mainly tin oxides and chlorides, constitute a further essential and important use for this metal in industrial undertakings. Both these uses, and others above, including the extensive one of tinplating, give a scrap recovery rate of approximately 30% from all form of tin used with the least recovery from various chemical uses.

Nickel

As with tin, the occurrence of nickel ores of workable use constitute another añomaly in metals distribution around the world. More than 80% of the world nickel supply is obtained from one area in Canada. The other producing areas are again of some strategic significance, U.S.S.R. (from the Finnish mines acquired during W. W. II), Cuba and New Caledonia.

Most of the nickel is used in steel alloying. Either alone or in combination with other alloying elements, it is used to produce steels requiring great strength and durability -- for aero-engines, turbines. In specific combination with chromium for nickel-chrome steels, it provides a range of indispensible heat resisting metal alloys. Nickel-iron, and nickel-copper alloys give particular magnetic properties and electrical resistance required in telecommunications, electrical engineering and instrumentation.

OTHER KEY METALS

We could continue the above review through the extensive range of metals now essential to the maintenance of the world industrial network. Our intention here, however, is not to survey these metals in detail, such information may be found in the many excellent and comprehensive metals handbooks, but rather to sketch certain global relations of patterns of production and use, and to indicate approaches toward such metal usage which may be fitted within our ecological viewpoint. This will become more apparent when we consider in more detail the circulation and recycling patterns of materials in a further section.

Some other critical metals should be mentioned, in passing:

The Ferrous Alloying Elements

Manganese is not, strictly speaking, an alloying material, but functions much more basically in the steel making process as a 'cleansing' agent which removes various impurities in the steel melt which might otherwise impair the finished steel's properties. Some of the main deposits and main production of manganese are again, in regions which have least domestic use for the ore. The main flow is, therefore, from these areas to the industrial center regions. Apart from U.S.S.R., which has by far the largest mine production of manganese, others are India, Brazil, China, Ghana, Congo -- stressing again a dependence polarity of certain ore producing and industrial use centers.

Cobalt is another such alloying element, whose main source is the Congo Republic producing approximately eight times (60% of the world total production) more than the next bulk areas, Rhodesia, Finland and Canada. Major uses of cobalt are in high speed cutting tool steels and for high temperature engines such as jets; a second important use, accounting for over a quarter of the world production is in permanent magnetic alloys.

Tungsten afforded the first improvement on carbon steels for high speed cutting tools, armour plate and projectiles, and came early in the steel alloy development before W. W. I. Its main uses are still in this area, with tungsten carbide steels as one of the hardest known cutting metals. With the highest melting point of any metal, another important use is in electric bulb filaments. Though using less than 2% of the world's production in this form[6] it is an interesting example of high performance per unit of material. Tungsten filament is considered to be four and a half times as efficient as carbon filament for such purposes and its use has resulted in tremendous savings in electrical energies, bulbs and other materials.

The major ore producer is China, about threefold that of the next producers in order -- United States, South and North Korea, Bolivia and Portugal.

Chromium has been referred to earlier in relation to nickel-chrome alloys. Its chief use is in such corrosion resistant chromium steels, accounting for about 45 per cent of production with the remainder in the form of chromite ore used for refractory furnace linings and about 15 per cent for other chemical processes, e.g., the range of chromates in tanning dyeing, photography, etc. Major ore producers are U.S.S.R., South Africa, the Philippines, Southern Rhodesia and Turkey.

Vanadium though used in fractional quantities for forging, spring and high speed cutting steels, has become of key interest in recent years from its role in special alloys of machine parts requiring high reliability such as transmissions, gears, springs, etc.

Rare Metals deserving mention here are a group of metals usually referred to as the "rare earths". Though including tungsten, vanadium above, these were originally referred to as rare because of their difficulty of isolation in the pure state. The most familiar to emerge in recent years are molybdenum (long used in steel alloys), titanium, beryllium, columbium, zirconium, tantalum. To these we could add a long list of others which are of growing importance in a wide range of new alloys developed mainly for, and in, aerospace and military research. Titanium has now reached volume production as a major structural metal in its own right with very high strength to weight ratios outperforming columbium and magnesium alloys for many purposes, e.g., in 1965 the latest Mach 3 aircraft was one

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[6] "Less than 2 tons of tungsten metal, supply filaments for 100 million electric bulbs . . . in 1960 the total annual world consumption for light filaments was little more than 200 tons", Minerals in Industry, p. 269, W. R. Jones, (Pelican Books, 1963).

of the first all titanium aircraft and the new supersonic transports are expected to use large quantities of this metal.[7]

In this area of 'rare metals' use, we should also note the direction of development in the use of, for example, germanium and other elements in transistors, solid state circuits, semi-conductors, etc., now the basis of our massive developing communications and computer technologies. First, these are made ultra pure, then design modified by minutely controlled impurities for specific functions of the crystal lattice at the molecular level. We shall comment later upon a similar direction in the use of our 'whisker' reinforcement in a swiftly developing range of filament reinforced composite materials.

Uranium -- the successive developments of atomic weapons and other nuclear energy uses have made uranium, radium, thorium and plutonium, the most sought after metals in the past few decades. As the result of intensive world wide search, many such radioactive ore sources of different types have been located. Because of the critical nature of these, in relation to nuclear strategies, information on their distribution, production, etc., tends to be somewhat uneven and where given may be misleading. The major sources for the West are those in Canada, United States, and the Congo, but new discoveries of uranium deposits have occured in Australia, New Zealand and Japan in recent years.

The importance of these metals for future energy production may be underlined here as the potential reserve of such material will be a key factor in future years. Estimates of the uranium and thorium reserves in the United States alone are of the order of "hundreds to thousands of times greater than the world's initial supply of fossil fuels (indicating) . . . almost unlimited supplies of energy from the fissionable and fertile isotopes of uranium and thorium."[8]

Silicon is an interesting example here of the most plentiful element in the earth's crust now . . . "at the heart of many of the most explosive areas of modern growth; computers, home entertainment, military electronics, and the control of power -- not only at signal power levels, but also at bulk power levels."[9]

N.B. The introduction of these new element uses, and of the 'nuclear' elements below presage a new phase in our resource thinking which we shall discuss later. In this forward development, which we may call the fourth phase, the level of organized knowledge, i.e., research, and its capacity to 'restructure' materials to almost any desired range of physical properties will further erode all the previous notions of the need for the separate national and other groupings to compete for the inequably distributed, naturally occurring, material resources.

METAL RESERVES AND FUTURE USES

Most analyses of world resource materials deal in "years of supply in exploitable reserves" -- for example:

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[7]One of the most productive titanium ore deposits is in India, producing the third highest amounts, after U. S. and Canada, in the past two decades.

[8]Energy Resources, Pub. 1000-D, National Academy of Sciences, National Research Council (U.S.), 1962.

[9]Statement of Dr. G. Guy Suits, Director of Research, General Electric Co., Panel on Science and Technology, 7th meeting, 1966, 89th, U.S. Congress.

Aluminum	570 years	Copper	29 years
Iron	250 years	Lead	19 years
Zinc	23 years	Tin	35 years

The use of such estimates whilst useful for general economic criteria, is limited by lack of appreciation of the limited degree to which such metals are actually 'used up'. As we have noted, most of them are highly recoverable through their scrapping cycles and are, therefore, used over and over again. Our 'reserves' therefore, include all metals in present use and those recoverable from the lowest grade ore deposits in the earth crust, which are not usually accounted for in terms of 'exploitability' -- as not being economically exploitable in present terms. Of course, present availability is important, as we have stressed, in the next critical transition to full industrial parity for all men. In dealing with energy resource reserves, the key question is how we may bring the underdeveloped nations up to fully industrialized standards of living, i.e., as measured by present materially advanced regions. It may be noted, for example, 'that the U.S. with only 6 percent of the world's population, consumes approximately 30 percent of the world's total current production of minerals'. We might then ask how much more would be required to bring the total world population up to the same level of material consumption. This comes out to about five times the present world production of minerals -- far more than we can presently attain to with present levels of materials and energy performance efficiencies.

Using an ordinary example, suppose we tried to extend the 1960 level of U. S. automobile use (at roughly 1 auto per 3 persons) to the entire world population? This would require approximately 2,300 million tons of steel -- as against total world steel production (1963) of 425 million tons only.

In the same way, when we consider extending full scale electrification to the underdeveloped nations, the average use of copper per capita in fully industrialized nations is approximately 120 pounds per capita. The increase of even one pound per capita consumption in present world population terms would require about 36 per cent increase in world copper production. Even the slightest rise in living standards can require vastly increased amounts of metals use in our present terms. Again this underlines that the only way to advance the living standards of the under advantaged countries, by bringing them up to industrial parity, is through overall increase in the performance per pound of all invested resource. This is, as we have noted, inherent in the advanced technological development processes. It requires, however, to be more immediately realized and used as a design principle, in the less technologically advanced areas of our environment facilities, e.g., building as one of the crucial areas for re-design.

The above reserves table may then be viewed as a useful guide for long range future planning, as indicating where it may be more practical to concentrate on the highest extraction of performance from present above grade already mined and processed metals -- so as to keep an amount of 'exploitable' reserves in storage against future, unforeseeable emergents. In thinking about such 'reserves' of metals, it is important to keep in mind (1) their recycling nature in actual use, i.e., that they are not exhausted by use; (2) that exploitable refers only to present limits of economic return, in processing metal ores, against energy cost inputs.

Given abundant supplies of energy, e.g., nuclear, we may secure almost inexhaustible supplies of further minerals from the earth's crust and oceans plus the developing capacity to increasingly 'construct' or synthesize materials from many different element sources. The critical period lies in our present transition from one 'kind of world' to another -- of more equable distribution of life advantages.

Oceans

So far, we have hardly touched upon the potential of ocean exploration for metals and other materials. Sodium and chlorine via common salt, and bromine, have long been extracted from sea water; magnesium is already being produced on a large scale where it occurs as one part to 800 parts of water. Various bodies of sea water, e.g., in the Red Sea, have been found to contain concentrations of various elements of 1,000 to 50,000 times that found in ordinary sea water, and may be considered as fluid ocean mines. Further extraction of other materials is now projected with the development of large scale desalination plants.

The more immediate bulk production source for ocean ores may be that of the nodule deposits recently discovered on the ocean floor. In many areas, thick concentrations of high grade ore nodules have been located with manganese content up to 50 per cent, cobalt, nickel, copper to 3 per cent respectively, and other metals in varying amounts. One specifically interesting quality of these nodules is their continuing growth formation. Referring to the speed with which such nodule deposits grow, one authority has suggested that, ". . .as these nodules are being mined, the minerals industry would be faced with the interesting situation of working a deposit that grows faster than it could be mined or consumed."[10]

In terms of 'ecological design' of using the naturally occurring growth cycles, the above has interesting connotations! Further examples may be adduced which are of relevance to oceans use. A number of plants and animals have been found to have the power of concentrating elements found in sea water, as land plants and animals selectively accummulate soil elements. Seaweeds concentrate iodine from its normal dispersion of 0.001 per cent in sea water to up to 0.5 per cent; certain coral species take up iodine to 8 per cent levels. Oysters concentrate copper from sea water, and a particular sea slug has the capacity to concentrate vanadium in its body though the quantity in its environ is quite minute.

When we consider that, apart from the minerals already present in the ocean waters and floor, it has been estimated that in the United States some 200 tons of copper, in various forms, are lost to the oceans in sewage per year for each million persons, together with 50 tons each of such metals as manganese, lead, aluminum and titanium. Such naturally occurring agents could possibly be designed into processing systems for minerals concentration and recovery. Our use of domesticated land food, plants and animals, is precisely such an ongoing system for intermediate processing of food energies and materials.

A further balancing aspect relative to metals use and the general pattern of reserves and recycling of materials is the third phase shift to composites, to non-metallic and plastic substitutes for many of the previous functions of metals.

THE SYNTHESIS OF MATERIALS

Reference to 'synthetic' and 'man-made' materials is, in some senses, misleading. We do not make new materials but, rather, discover new ways to 'rearrange' the elements in various configurations and combinations which give us similar desired properties to some naturally occurring configuration, e.g., synthetic wood or stone. Or, we may re-

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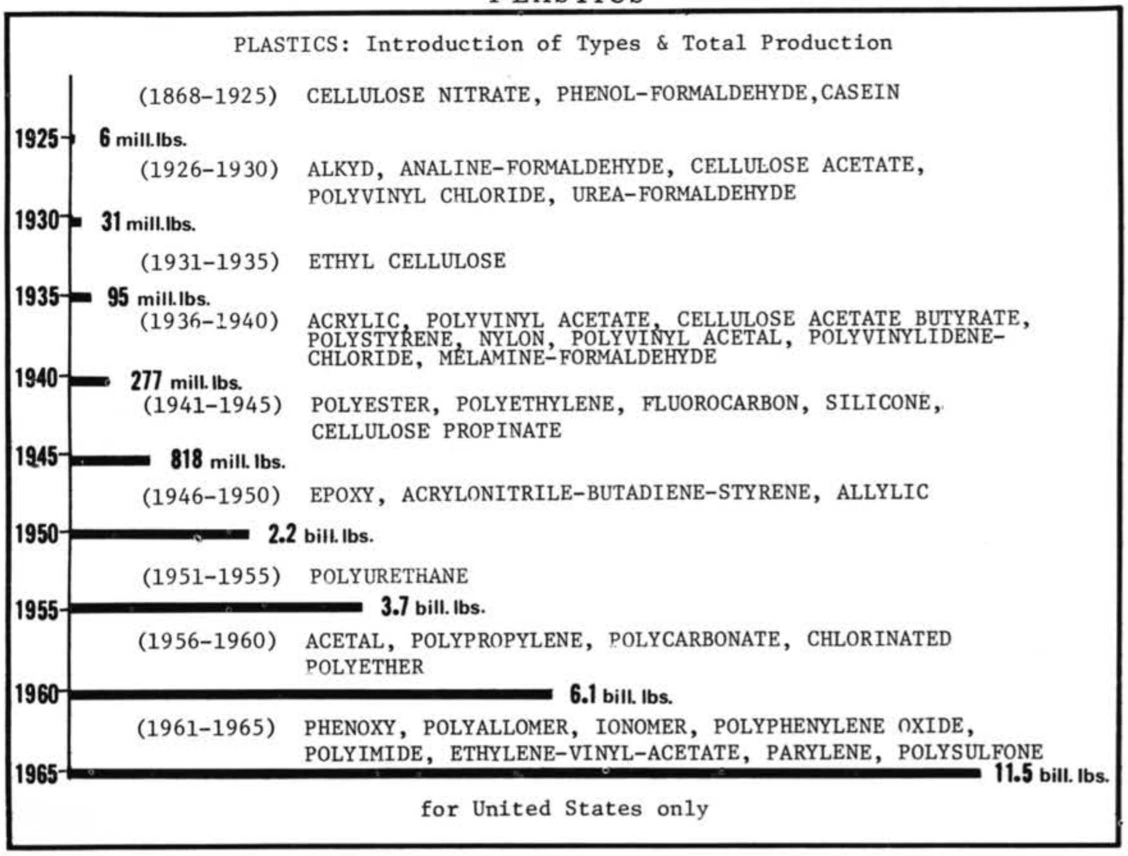
[10] The Mineral Resources of the Sea, J. L. Mero, (Elsevier Publishing Co., 1965).

PLASTICS



Data: (1) The Epic of Steel, Douglas A. Fischer, (New York: Harper & Row), 1963. p. 304.

(2) Impact of Western Man, William Woodruff, (New York: MacMillan Co.), 1966. pp. 210-13.

arrange the molecular configuration to give a range of material properties which are not available in nature, e.g., as in the plastics. Strictly speaking, man has always been 'synthesizing' his environ constituents in re-forming and re-structuring them to his specific needs -- from the earliest use of fire, foods, fibers, metals, etc., up to the latest alloys and plastics. There is no 'intrinsic' difference, therefore, between natural and synthetic materials; the one is not 'truer to nature' than the other. Our division here on the synthesis of materials merely established the degree of balance of man's restructuring and re-designing materials over that of using those naturally occurring forms.

The first commercial plastics, i.e., the cellulose nitrates or celluloids, were made in the late 1860's; though one of the synthetic resins, polystyrene, was isolated in 1831. The bakelites, phenol-formaldehyde-resins, were introduced in 1909, and, for the next twenty years, celluloids and bakelites were the major plastic materials in use. The next large volume introduction of two of our present key plastics groups, the cellulose acetates and vinyl resins, occurred significantly[11] in 1927. Polystyrene became available in bulk in 1938 and the polyethylenes in 1942. Since then, a major new group of plastics with unique properties has been introduced approximately every year. Today the volume and diversity of these groups defies any summary listing. The world total volume consumption of all such 'synthetics' in 1966 was about one third of the volume consumption of all metals, and by the 1980's it is calculated that the volume use of plastics will surpass that of all iron products.

Again, our division below into composites, plastics, etc., is somewhat generalized and artificial, as the enormous range of such materials already diffuses through many such categories. Materials synthesis, as such, now runs through so many fields, from molecular, chemical and physical transformations to the use of bio-chemical systems and microbial agencies, that it would defy even the barest cataloguing here. Our present emphasis will, therefore, remain mostly with structural materials.

Composites

This most recent class of designed materials, developed particularly in the past few decades, affords a bridge between the metal alloys and the non-metallics in the ceramics and plastics range. One group of composites may be regarded as a 'subform' of alloy, consisting of minute amounts of lower melting point metals embedded in a refractory metal to give better forming ductility to the latter without impairing its other properties. Another consists of the range of metallic and non-metallic composites reinforced with high modules fibers, or filaments of boron, graphite, beryllium, glass, etc. This class also uses pure 'whisker' reinforcements of various metals which give extremely high strength in their whisker state. Solid forms of various types, made from high melting point oxides are in development which may be glazed with refractory ceramics for superior performance to metals at very high temperatures.

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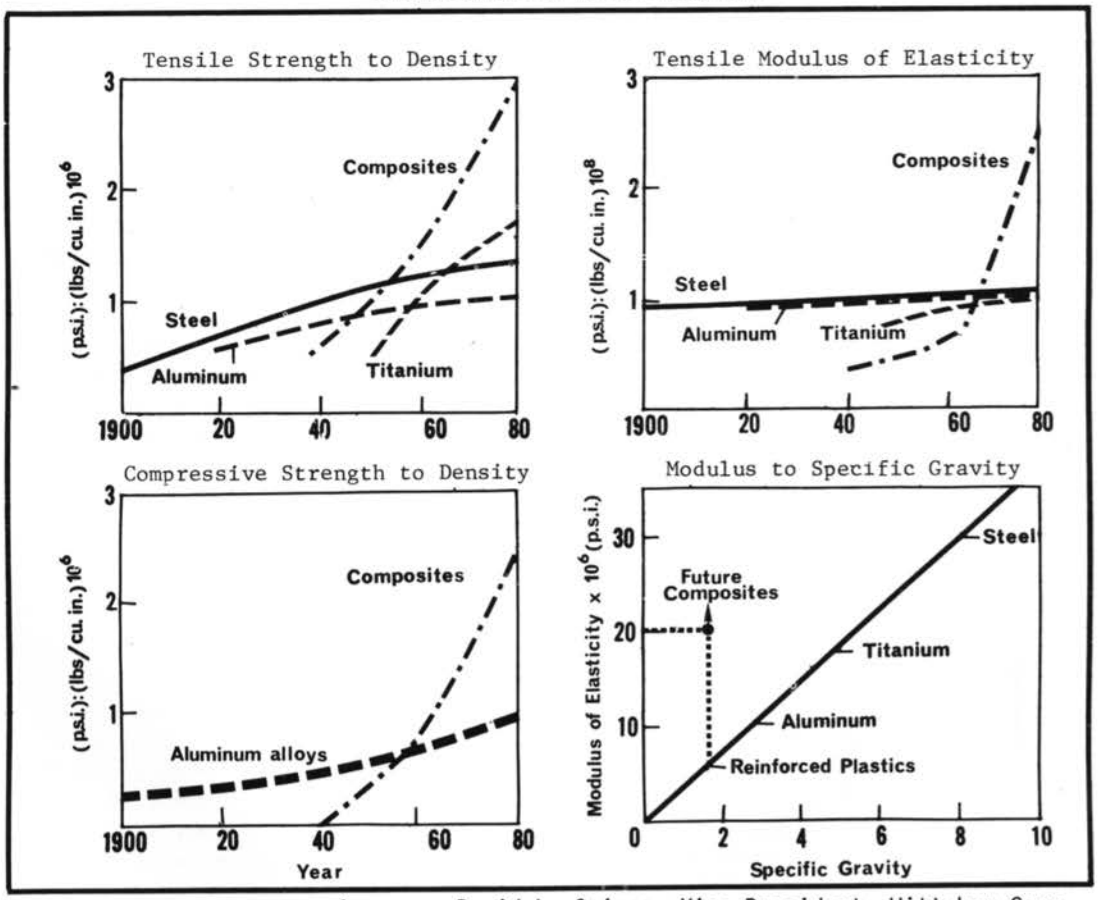
[11] Significance here refers to 1927 as the beginning of a period of grave economic and political crises which continue up through the depression years of the 1930's. The 'lack of fit' between such events and underlying 'real' developments is striking when we consider that 1932 also marked the year of completion of the elements table, the initiation and a swiftly ensueing number of scientific and technical developments, many of whose full impacts are only now emerging into economic and political 'reality'. (For more detailed discussion of this point, see Document 2, "The Design Initiative", (1964), R. B. Fuller, in the present series).

COMPOSITE MATERIALS



Source: David L. Grimes, Vice President, Wittaker Corp., San Diego, Calif.

In general, the promise of very high tensile strength structural materials through the use of these composite techniques, in particular those of the filament reinforcement type, has already been borne out in aerospace work. Metallic composites are already in such use, or in advanced development; have the inherent possibility of achieving unprecedented strengths most nearly approaching, and surpassing, the highest theoretical yield limits of their separate constituent materials. The accompanying curve charts show the predicted gain in performance over the next period based on test results of composites reinforced with high modulus filaments of boron, graphite, glass and beryllium.

Structural Plastics of the glass fiber reinforced epoxy resin, and other bases, are similar to the above group of filament composites and have become one of the most important ranges of plastic materials. The impact resistance of such fiber reinforced plastics having a given strength to weight ratio has already risen 1000% in the past ten years compared to aluminum and plywood.

Comment, of particular interest, on this range is given relative to the design of the latest Boeing 737 aircraft which used:

> 2 1/2 times more reinforced plastics on the exterior than on any other commercial jet. The result when combined with all the (plastic) non-structural sections is a savings of . . . hundreds of pounds (weight).[12]

Further savings quoted were up to 50% fewer production man hours and parts which weighed 34% less than an equivalent metal assembly.

Though accounting for fewer structural plastics than aircraft, automobiles as a lesser advanced technological sector more committed to traditional materials and techniques, are replacing metals with plastics in many areas. The United States industry now averages 35 pounds of plastics per car; Mercedes Benz more than 40 pounds and the U.K. Rover 2000 up to 38 pounds. The anticipated use for autos by 1970 is upwards of 70 pounds per car. Many sports car models have already used reinforced plastic bodies for sometime, and several, like the GRS Porsche, use plastics more extensively and additionally throughout their construction, for seats, bulkheads, panels and gas tanks.

In discussing such 'invasion' of traditional metal's areas by new materials, the rate at which this takes place is not simply gauged by 'functional' replacement, but determined rather more by the degree of investment in older materials, established plant production procedures and many other factors. The more swiftly moving determinants of forward resource use patterns now are not the established industries tied into steel, but those in the lead-edge of advanced transportation, communications, etc. Their use of materials is comparatively of less bulk weight, and extracts much higher performance per unit of material and energy investment -- factors which are not so apparent in classical economic and trade analyses.

As we come down through the uses of plastics in various industrial sectors, we might almost gauge the level of technological advance in each by its use of materials. We

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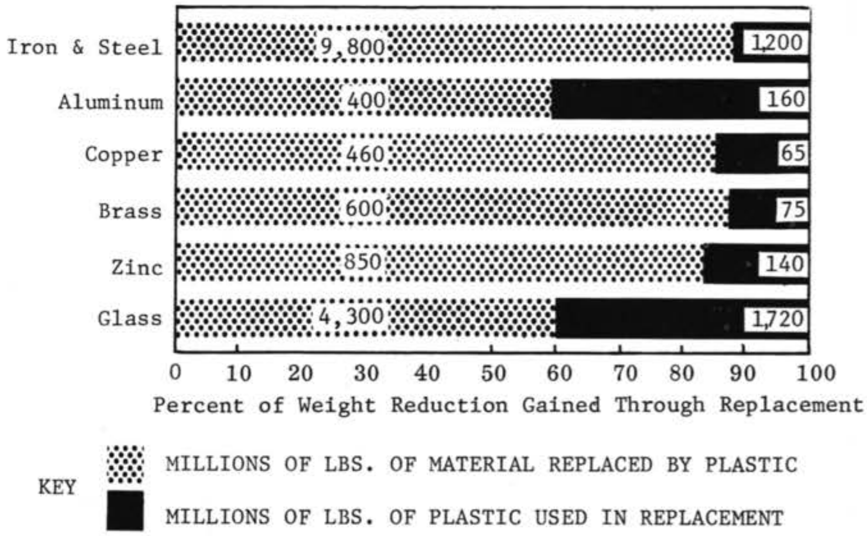
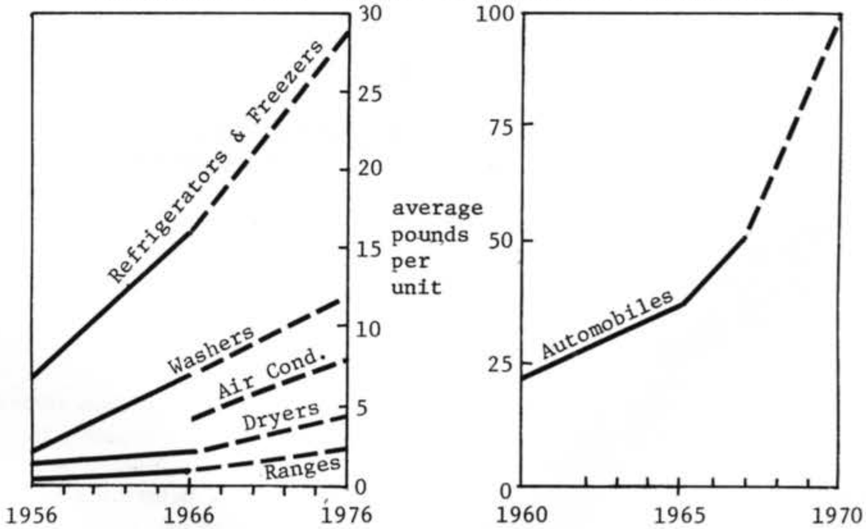
[12] "Plastics in the Boeing 737", Metals Progress, February 1967.

MATERIALS REPLACED BY PLASTICS

ESTIMATED REPLACEMENT OF SELECTED MATERIALS BY PLASTICS IN 1970



ESTIMATED USE OF PLASTICS IN APPLIANCES & AUTOMOBILES



"Since 1955 the average plastic has dropped in price by about 35%, whereas steel has increased in price by more than 20%....On a weight basis, plastics probably never will be as cheap as steel; but on a volume basis the price difference could all but disappear.

"....Tooling costs are lower for plastics than for metals. Also, complex shapes can be molded in a single operation, and finishing of parts is virtually eliminated. A metal part often involves the assembly of several components -- this means additional labor cost and a higher price for the finished part." --"Chemicals and the Auto Industry," Special Report, Chemical and Engineering News, October 22, 1962, p. 117.

Sources: (1) Technology Behind Investment, (New York: A. D. Little, Inc.), 1965.
(2) "Cost-Price Squeeze Tightens Materials Battle in Major Appliances," Steel, July 1966.

have touched upon aerospace, aircraft and autos. As we come to marine technologies, though this is one of the oldest sectors, its eruption into 'below surface' areas has given it a new technological dimension as rigorous in its performance demands as aerospace. Marine uses for corrosion resistant and high strength plastics now ranges through all plastic craft to cables, instrumentation housing, propellers, submersible shells and submarine parts, etc. One of the least advanced technological sectors is in building construction which typically uses less structural plastic than other major areas, e.g., its overall bulk uses of plastics represents other functions such as internal surfacing, appliances, etc.

Though, within our present review, we have devoted most space to the metals, particularly steel, this has been due to their present importance in the critical transition necessity to raise world living standards to parity as soon as possible. This critical focus may already be changing swiftly as the plastics begin to take over from the steels and other common metal alloys in increasing proportions. The pattern is partially obscured by the difference in weight/volume measures obtaining in the two areas of metals and plastics. One weight unit of plastic may replace the same weight unit of metal, but the volume displacement may be much greater due to their difference in density.[13] Analysis of cost comparisons of metals to plastic is already conducted in volumetric terms, e.g., plastics are now cheaper than steel, aluminum or magnesium for various uses on a cost per cubic inch basis.[14]

This progressive replacement of metals by swiftly developing groups of plastic may be particularly noted not only in relation to the composites discussed above, but in the range of 'structural polymers'. Using the analogy of designed rearrangements of carbon to produce man-made diamonds which duplicate the hardness and strength characteristic of natural diamond forms of carbon, one authority, referring to the "Age of Polymers", notes that:

> (polymers) . . . are becoming bona fide structural materials of real consequence. They are already replacing many metals in consumer products to such a degree that in United State's industry as a whole the volume of polymers used already exceeds the volume of steel . . . (due to) the density difference averaging about seven times in favor of polymers. But relative growth rate of usage is such that polymers will soon overtake steel, even on a weight basis, and they may have already done so . . . polymers will indeed become the basic materials of the future. We will be manufacturing the bulk of our products, and even the machines that make them from new, man-made, synthetic polymers. And, inevitably, the elements from which we will fashion these new polymers are common inexpensive ones.[15]

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[13]See accompanying tables of displacement of metals by plastic, also specific discussion of this point in "The Synthetics Age," R. Houwink, Modern Plastics, 1966.

[14]Technology Behind Investment, (A. D. Little Inc., 1966).

[15]Statement by Dr. G. Guy Suits, Vice President and Director of Research, General Electric Co., 7th Panel on Science and Technology, 89th U.S. Congress, Jan. 1966.

MATERIAL USAGE IN INDUSTRY

ALLOY STEEL

Automotive	40.1%
Marine	4.9%
Elect./Indust. Equip.	11.6%
Rail Transportation	15.9%
Consumer Prod./Export	7.9%
Const./ContractorProd	13.7%
Miscellaneous	5.9%

100%

ALUMINIUM

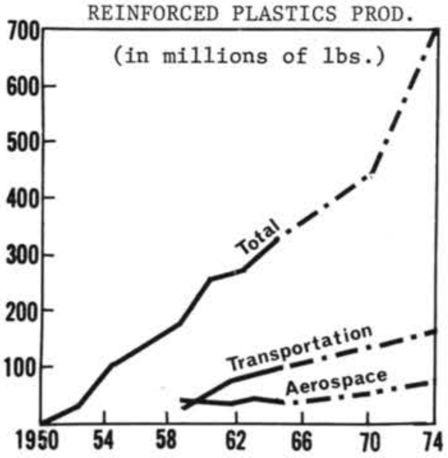
Transportation	22.0%
Packaging	8.0%
Elect. Industrial	15.0%
Household Goods	12.3%
Bldg. & Construction	19.0%
Miscellaneous	23.5%

REINFORCED PLASTICS

Transportation	19.7%
Pipes, Ducts etc.	4.7%
Marine	17.2%
Containers	4.3%
Aerospace	11.6%
Electrical	5.1%
Consumer Prod.	13.0%
Construction	20.3%
Miscellaneous	4.2%

100%

REINFORCED PLASTICS PROD.



in U.S.A. figures

Sources: (1) Trends in Applications of Structural Composite Materials, David L. Grimes, (Washington, D. C.: Advisory Group for Aerospace Research & Development), November 1965. p. 11.

(2) Metals Handbook, Eight Edition, Vol. 1, (Ohio: American Society for Metals), 1961.

When we extend discussion of plastics into the non-structural area, including synthetic rubbers, man-made fibers, etc. We may see the increased range of human activity in which these are now employed. Through packaging, clothes, all types of tools and appliances, to large scale agricultural and other uses, we engage not only with polymers but with the entire range of the electro-chemical industries, now extending into the scale incorporation of bio-electro-chemical techniques. These industries are now the forward core base of industrialization rather than the steel producing complex -- with which, of course, they are closely associated.

This brings many other issues into fresh perspective, particularly that of the use of fossil fuels. The chemicals derived from these fuels are the basic materials for most of the synthetic resins and elastomer plastics, and importantly, for the synthetic rubbers -- a further important reason to reconsider our presently prodigal energy extraction from these fuel deposits.

We have earlier referred to this third phase of industrialization with its shift from earlier dependence on steels and associated direct use of fossil fuels. By moving out of this dependence, we shift also from the capital depletion bias of our resources use till now -- to that of a more ecologically oriented 'tapping in' to the basic income sources of energies and materials.

When we begin to use the most commonly available and abundant elements in the earth crust, atmosphere and oceans, in 'designed' combinations with the rarer elements, within a pattern of comprehensive recycling and re-use, we come to an almost entirely different picture of our material resources.

Questions of resource balances, reserves, the dependence of industries and whole economies on access to this or that resource will change radically. This is demonstrated by the above examples of the newer alloys, the 'electronic' and 'nuclear' elements, and even more in the plastics and other designed and man-made materials.

We will be less and less dependent on the given configurations and properties of naturally occurring 'rare' deposits, on the ownership and control of strategic minerals, but rather more on the possession of organized knowledge, i.e., trained human beings, their requisite standards for full creative living and the material facilities for their continued pursuit of further knowledge. Unfortunately the earlier polarity established between advanced and less advanced world regions is only further intensified in this dimension during our present transition period. The accummulated industrial wealth, associated higher living and educational standards, and research facilities of the former still maintain their earlier advantage.

The actual trends in materials research and development suggest that if we are able to assist the advance of the lesser developed peoples more swiftly, and survive this period of laggard disparities, then many of the older bases for conflict over 'scarce' and inequably distributed resources will disappear. Conflict and competition will be re-oriented toward other areas of human activity. Notions of territoriality, strategic rights and control of material resource deposits will shift to the 'brain mines' of the world -- and these are, perhaps, not so amenable to the older forms of political and economic control.

Returning briefly to our central topic of the development of the world's less advantaged regions, we may note, again, that the emerging patterns of new material types and uses, discussed above, restresses new directions for such development. The old patterns of steel, heavy industry, massive centralization, etc., are no longer viable. The

POPULATION/MATERIALS: Projected Consumption

	YEAR	1966	1970	1980	1985	1990	2000
	POPULATION (billions)	3.4	3.7	4.6	5.0	5.6	7.0
Metals	IRON						
	Mil. tons	469.0	560.0	900.0	1130.0	1400.0	2250.0
	Lbs./person	304.0	332.0	431.0	497.0	550.0	706.0
	ALUMINUM						
	Mil. tons	7.7	11.3	32.0	55.0	90.0	250.0
	Lbs./person	5.0	7.0	15.0	24.0	35.0	79.0
	COPPER						
	Mil. tons	5.4	6.2	9.2	10.0	13.5	20.0
	Lbs./person	4.0	4.0	4.0	4.0	5.0	6.0
	ZINC						
	Mil. tons	4.3	5.0	7.2	8.7	10.4	15.0
	Lbs./person	3.0	3.0	4.0	4.0	4.0	4.0
	TOTAL METALS						
	Mil. tons	486.0	582.0	948.0	1204.0	1514.0	2535.0
	Lbs./person	315.0	345.0	453.0	503.0	594.0	795.0
	Mil. cu. m.	64.0	78.0	129.0	167.0	215.0	384.0
	Liters/person	19.0	21.0	28.0	33.0	38.0	55.0
Synthetics	PLASTICS						
	Mil. tons	16.0	27.0	105.0	240.0	420.0	1700.0
	Lbs./person	10.0	16.0	50.0	116.0	165.0	535.0
	SYNTHETIC RUBBERS						
	Mil. tons	3.9	5.5	11.5	16.0	23.0	44.0
	Lbs./person	2.0	3.0	6.0	7.0	9.0	14.0
	MAN-MADE FIBERS						
	Mil. tons	5.6	7.2	13.0	17.0	24.5	46.0
	Lbs./person	4.0	4.0	6.0	7.0	10.0	15.0
	TOTAL SYNTHETICS						
	Mil. tons	25.5	40.0	130.0	273.0	467.0	1790.0
	Lbs./person	17.0	24.0	62.0	121.0	183.0	563.0
	Mil. cu. m.	23.0	35.0	114.0	236.0	409.0	1564.0
	Liters/person	6.8	9.5	25.0	47.0	73.0	224.0
Natural Products	NATURAL RUBBER						
	Mil. tons	2.2	2.5	2.6	2.7	2.8	3.0
	Lbs./person	1.0	2.0	1.0	1.0	1.0	1.0
	NATURAL FIBERS						
	Mil. tons	19.0	21.5	30.2	35.0	41.5	60.0
	Lbs./person	12.0	13.0	15.0	15.0	16.0	19.0
	TOTAL NATURAL PROD.						
	Mil. tons	21.2	24.0	32.8	37.7	44.3	63.0
	Lbs./person	14.0	14.0	16.0	17.0	17.0	20.0
	Mil. cu. m.	18.4	20.7	27.7	31.9	37.5	53.2
	Liters/person	5.4	5.6	6.0	6.4	6.7	7.6
Totals	Million tons	533.0	646.0	1111.0	1515.0	2025.0	4388.0
	Lbs./person	345.0	385.0	530.0	667.0	794.0	1379.0
	Mil. cu. m.	105.0	134.0	271.0	435.0	662.0	2001.0
	Liters/person	31.0	36.0	59.0	87.0	118.0	286.0

The paper from which the preceeding table has been adapted suggests that we use volume as against weight measures, particularly in relation to the comparative use of plastics -- whose weight consumption does not reflect their increasing use volume. This is an important point. With the density differential involved, one pound of plastic may replace up to eight pounds of metal. As strength to weight ratio increases in the synthetics, weight alone may be less important than space volume per performance.

Source: "The Synthetics Age," R. Houwink, Modern Plastics, August 1966, table 1, p. 99.

developing nations would be better encouraged by, and <u>for</u>, the world community of nations to move directly into the forward phases of industrialization, into the age of polymers, light metals, nuclear power generation and the full range of automated production, transportation and communication facilities. Questions as to how, at what monetary cost, and by whom supported, are increasingly irrelevant as we begin to spend more materials, energies and human lives in our present global conflicts than have been even fractionally used on behalf of human advancement.

Ecological Re-design

Though concentrating on the more immediate and positive advantage which may be sought through increasing the efficiency of energy and materials usage in our technological systems, we have also underlined the necessary long range re-design of these so that they may be more compatible with the overall ecological system.

Until recently our technological systems were hardly considered as an 'organic' part of the ecology, hence little attention was given to this aspect of their function. Now when they begin to degrade environ usage and soil various preferred sectors of the air, earth and waters with their discarded materials and energy use by-products, we begin to examine their 'pathology' -- without, in a sense, having engaged first in some overall assessment of their physiology.

Generally, when the problem is stated simply in terms of 'technological hazards', this tends to produce various piecemeal programs of filtering industrial smoke or car exhausts, or checking the level of effluents into rivers and streams, or legislating natural conservation and 'beautification' projects. Laudable as these may be, they do not pose the problem in large enough terms. Fortunately, the various scientific bodies in different countries who have been called upon to consult on the 'pollution problem' have already reframed this within the larger context of some overall 'management' of air, water and other physical resource utilization at the various regional and national levels. They have addressed themselves not only to the quantitative aspects of such resource management, but also to the quality of the environment.

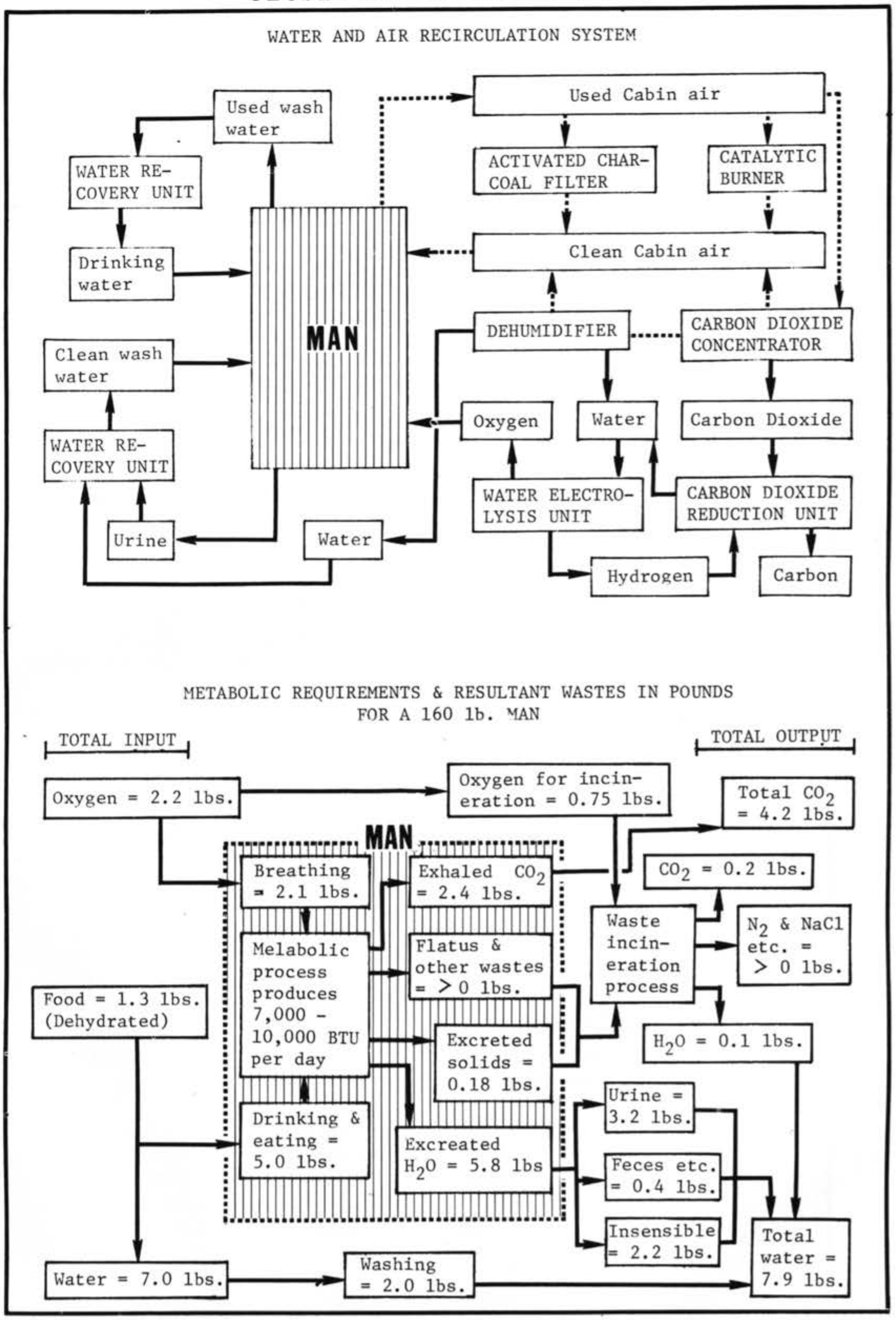
We have referred to technology as an extension of the human metabolism -- one which processes millions of tons of material each day, yet we have no very clear picture of its operation even to the extent that we have such knowledge of our own internal workings.

We need to reconceptualize our global, man-made environ facilities within more comprehensive and coherent schemes. For example, even where refined and advanced econometric models of whole regional and national economies are presently used, they concern themselves largely with the <u>inputs and outputs</u> of the industrial system almost solely from the viewpoint of its economic operation, in terms of fiscal and material balances. There is little sense of the complex ecological relationships and <u>throughputs</u> which obtain even when we consider the industrial-economic system in isolation.

A great deal is known about the overall operation and linkages of the different components of the industrial complex, so patently many of the inefficiencies, wastages and breakdowns occur not through lack of such operational knowledge, but through lack of adequate conceptuality of the whole system's operation. We need to reanalyze our industrial systems in terms of models which are not based on simplistic notions of production/consumption.

We do not 'produce' things in the sense of manufacturing them out of new raw materials only -- then 'consume' them so that they and their constituent materials no longer exist.

CLOSED ECOLOGICAL SYSTEM



Sources: (1) E. S. Mills, R. L. Butterton, Douglas Missile & space Systems Development Interplanetary Mission Life Support System, 1965.
(2) NASA: ASD Report TR 61-363.

We extract materials out of the earth in one part of the globe, transport them to another area halfway around the world, process them with other locally available materials, e.g., air/water/energy, into various 'use' configurations which are then further processed elsewhere in the system or go directly into human use.

We do not then 'consume' products in any kind of end sense. They are used in a well defined life cycle, then broken down in such use and are repaired, or discarded and replaced. Some of their material constituents are returned to the process and fabrication cycle directly or indirectly in various time lags of secondary uses, others are further decomposed, returned in part to the earth or atmosphere or 'flushed' into the oceans.

Though the above schema seems repetitive, and simplistically drawn, we generally design and use our environment as if we had no knowledge of its existence! As has been underlined, most of our currently prodigal modes of using the earth and biosphere systems are potentially dangerous. We dissipate vast quantities of capital energies which may be needed in future emergencies, and we disperse valuable concentrations of materials which we have no present means of reconstituting. Referring earlier to the concept of 'spaceship earth', we may quote another version of this:

> The closed economy of the future might similarly be called the 'spaceman' economy, in which the earth has become a single spaceship, without unlimited reservoirs of anything, either for extraction or for pollution, and in which, therefore, man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form even though it cannot escape having inputs of energy . . . [16]

This extends to our use of 'income' resources, to the use of soils, of air, water, and to our understanding of our complex interdependence on other organic life forms. We have already used up and destroyed a great many other living species with little enquiry as to their possible functional relation to our own survival.

In re-designing our environmental, and particularly our industrial, facilities as ecological subsystems, we need to determine the gainful and more efficient linkages which may be established between separately functioning processes. To this end, the various major cycle charts, and those of the closed aerospace ecologies may be usefully related and compared with industrial networks or with the systems function of a community, or with a large scale building complex. We may ask how the overall energy flows are disposed relative to each use and function in the latter systems, and how more performance may be gained through different relations. In such extended systems review we might re-design materials throughput so that the wastes and by-products, the discards and residues of one sector of the network may become the raw materials (or energy source) of another. In general, this direction has already been broached in 'systems design', but requires much larger scale investigation and application.

One convenient focus of attention lies, specifically, in the scrapping and reuse cycles of materials. We customarily design our structures and other facilities and artefacts only in terms of one cycle use -- with design calculation given to the eventual disassembly of components and their direct reuse, or their scrapping and re-entry into the

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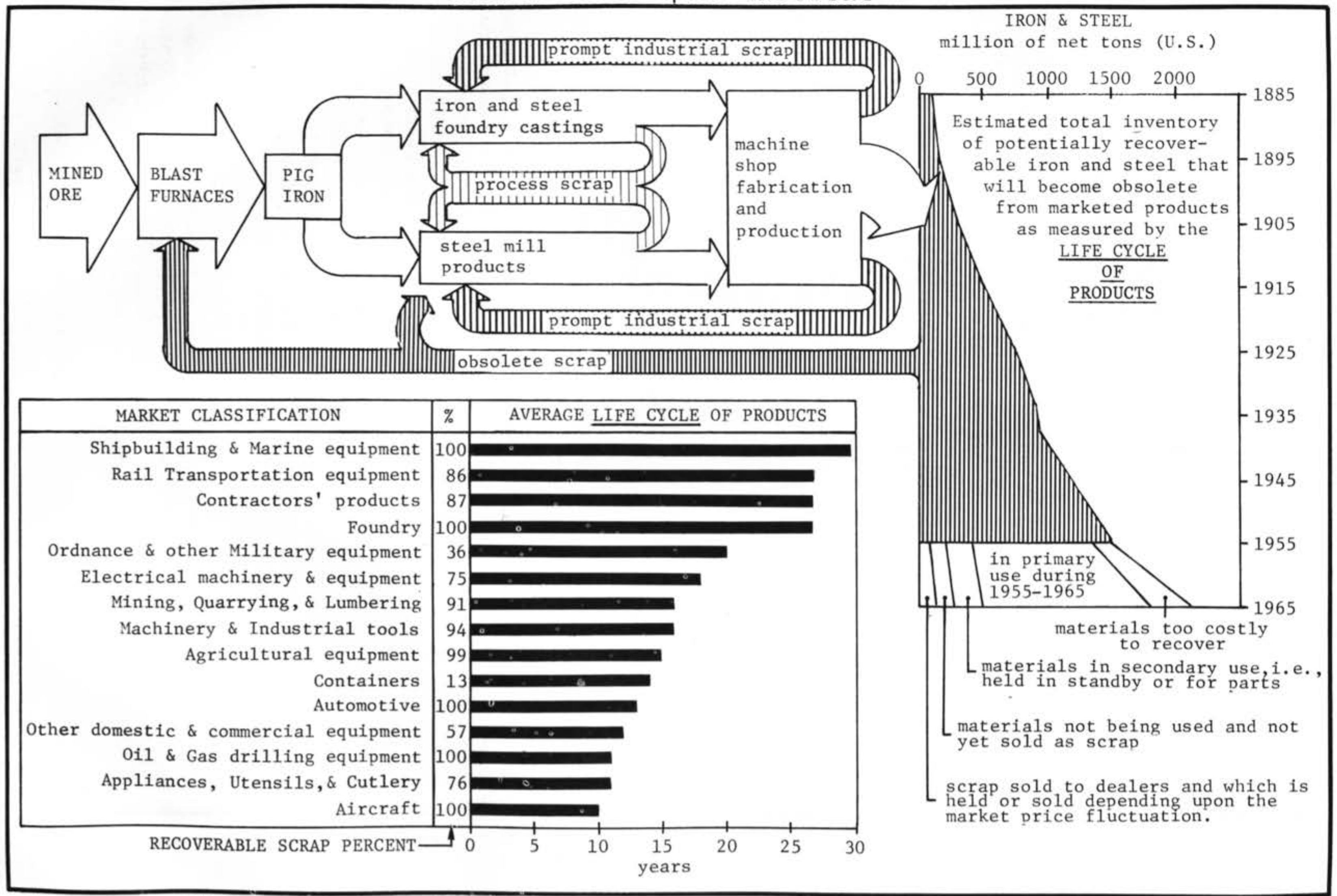
[16] K. E. Boulding, "Resources for the Future: Forum", October, 1966.

IRON & STEEL SCRAP INDUSTRY



Data: (1) Survey & Analysis of the Supply and Availability of Obsolete Iron & Steel Scrap, Revised Edition, Batelle Memorial Institute, (Ohio, Battelle Memorial Institute), 1957. (2) "Iron & Steel Scrap: Consumption Problems," U. S. Department of Commerce, U. S. Printing Office, 1966. p. 4.

processing cycle. This is not only confined to buildings, though they are a particularly obvious case, but may be extended, for example, to the myriad artefacts of metal, glass, plastics and other materials which are used daily. Unless we begin to account for each phase in this cycle, we cannot, in any real sense, design 'ecologically' or in terms of overall efficiency of performance.

The metals and metallic alloys are an example here where very little has been known about their actual reuse and discard cycles. For each billion tons of main metal ores mined, about two thirds is 'waste' rock or mine tailings discarded at the mine site. From this point on through foundry processing and fabrication there is some control of 'process' scrap, but as the finished products go into use, such control is lost and the scrap return cycle has been left to the haphazard operations of the 'salvage' market. The obscurity of this pattern leads many authorities to talk about metals being 'used up' through manufacture when, in effect, most metals are almost wholly recoverable -- or could be with adequate 'cycling' design. We may ask then:

> To what extent are they lost in use? To what extent do they follow man-made cycles like the well known carbon cycle in nature, so that the world stock is not depleted?[17]

The only cycle here which has been delineated approximately is that of the ferrous metals, as large amounts of scrap have long been reused in steel making. The detailed scrap and reuse cycles of copper, lead, aluminum, etc., are less clear, though figures of scrap generated and collected in various sectors of industry give some knowledge of the recycling of such metals. Through these we may ascertain the cycle of a given material in its 'use-life' in various products -- but we have no clear picture, for example, of the changing pattern of 'new' metal versus scrap use in specific industries, or of the various inputs of energy required at different parts of the scrap/reuse cycle, etc., and how these relate to the overall 'energy costs' of various use performances in different product cycles.

As we have earlier emphasized, were it not for such 'regenerative' cycling of industrial materials, we would not have enough metals, etc., to take care of expanding technological requirements. Some indication of the importance of the scrap cycle may be gauged from the following figures, as well as those introduced earlier in our materials discussion:

> About 957,000 tons of copper were recovered from scrap in 1963. This represented about 40 per cent of the total supply of copper in the U.S. for that year and 80 per cent of the total copper produced by domestic mines. The lead recovered from scrap amounted to about 494,000 tons -- almost double the 253,000 tons of lead produced in the U.S. during 1963. The annual volume of aluminum scrap is about 25% of the total aluminum supply.[18]

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[17] "The Recovery of Metals from Scrap", Sir Harold Hartley, Advancement of Science, Vol, II, No. 7, 1942. (N.B. Despite the date, this remains one of the classical and most informative papers in this area).

[18] "Restoring the Quality of the Environment": Report of the Environmental Pollution Panel, President's Science Advisory Committee, The White House, November 1965.

The increasing number of exotic alloys now used in advanced technologies, their high energy cost in manufacture and strategic importance in missiles and aerospace, for example, has led the military to examine the possibility of clearly identifying metal alloys in use so that they may be more easily recovered.

> In the future, any one of the jet blades, or any component part of a jet aircraft engine, will have the type of metal stamped on it ... so that regardless of use or wear the type of metal will be known and identifiable.[19]

This example of the scrapping and reuse pattern of metals may seem a narrowly specific one, at some distance from our overall ecological viewpoint. In actuality it is, however, a key 'systems model' aspect of the entire industrial pattern and its ecological function. This scrap reuse cycle is a parallel of the larger, naturally occurring cycles in the ecosystem, and will furnish the 'systems model' for the solution of many other problems in the re-design of our major environment facilities.

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[19] Proceedings: 37th Annual Convention, U.S. Institute of Scrap Iron and Steel, Jan., 1965, comments by B. J. Outman, relating to a report entitled, "Marking of Aircraft and Missile System Parts Fabricated From Critical High Temperature Alloys," Air Force and Navy Defense Procurement Department, June 29th, 1964.

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TOWARDS THE FUTURE

The technological systems which we have evolved are now global in their operation and their efficient ecological operation is now interlocked with the maintenance of the entire human family on the planet.

Our present level of technological operations already interferes substantially with the natural cycles of energy and materials in the biosphere within which all of our major life processes are sustained -- and we now probe beyond these toward outer space.

> Is it too soon to inquire if these factors, plus others, may be contributing to an upset of nature's delicate balance? Are we slowly overturning the oxygen-carbon dioxide system upon which all life is dependent? Is that cycle being disturbed by high oxygen consumption and low oxygen yield? Are we thus shifting certain basic weather patterns upon which our various civilizations have come to depend?[1]

It is patently no longer adequate to consider any such 'problems' in isolation or with sole regard to their unilateral solution at local, regional or national levels -- whether they be pollution, hunger, lack of adequate shelter, population pressures, etc.

The minimal set of basic questions we need to ask ranges far beyond those required for local solutions to our various problems. Many of the problems are only problems because of a parochial concern with this, or that, economically or politically 'convenient' set of solutions. There are no wholly local solutions any more -- as there are no major human problems which are not also global. The basic questions revolve around the overall ecological maintenance of the entire human community.

<u>What are the optimal conditions for human society on earth</u>? There is obviously no fixed answer to such a question. But there are the various physical factors of adequacy in food, shelter, health, general welfare, and the concomitant access to the individually preferred physical and social facilities which make life meaningful and enjoyable. We have gradually arrived at sets of such conditions, as in the various bills of human rights -- like that of the United Nations.

Whether such 'ground rules' may be practical or not, we do in effect approach them, however tentatively, when we try to legislate for some human welfare or environmental control measure. The time is overdue for much more than tentative or local measures. To design our way forward through our present critical transitions, we need to adopt some more positive and operational indicators of the optimal conditions for the fulfillment of human life. By this, we do not mean optimal determinants which may be valid for all time and all people, i.e., some set of absolutes. The variable and changing nature of human values make this not only undesirable, but unrealistic, in that one set of values in development may considerably modify others. But such considerations may still be flexibly accommodated and yet allow adequate definition.

We may tackle this in other ways by asking various fundamental questions about our planetary society. Which activities are most inimical to this; which more positively sustain, and forward, the human enterprise?

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[1] <u>2nd Progress Report of the Subcommittee on Science Research and Development</u>: Committee on Science and Astronautics, U.S. 89th Congress, 1966.

> What are the physical limits and constraints in the overall ecosystem, with regard to our growing technological systems?
>
> What are the relevant human limits, e.g., the biological limits; air, food, water; temperature, space, speed and noise tolerances.
>
> What are the irreplaceable resource limits, e.g., both the physical energy and material resources, and the human, individual, social, and genetic resources?

In many ways, the core of our discussion has revolved around the same enquiry, repeated in different ways:

> What are the physical operational parameters for the planet -- the ecological or housekeeping rules which govern human occupancy?

These are very large questions, but they are those to which we must now apply ourselves -- in many different ways and over a very long period. Some of the answers we already know, in part. Others are, in some senses, ultimately unanswerable -- that they may be so is the more reason to ask them -- if only to probe the limits of our knowledge.

We are now developing the technological capacity to deal with such questions, even on the global level, via the computer and its ancillary technologies. It is, perhaps, not entirely irrelevant that 'cybernetics', as used to describe this new field of human enquiry, was derived from the Greek word for 'steersman'. It is precisely such large scale 'navigational' aids which we require to help guide our planetary undertakings forward.

A New Symbiosis [2]

Implicit also within both individual and social relations to cybernetics is the emergence of a new symbiotic growth in the ecosystem of the planet. Other types of machines are merely mechanical extensions, 'there is only one organism -- man -- and the rest are there to help him'. [3]

But recently, as in his natural symbiotic relations with plants and animals, man's relationship to cybernetic systems has been subtly changing, towards a more closely woven interdependency resembling his other ecological ties.

This point has often been alluded to in terms of intelligent machines dominating man, but the possibility is more clearly that of the type of organic partnership which characterizes his other 'natural' relations.

The most pervasive aspect of the developing man/computer symbiosis, and the most immediately important in large-scale societal effects, has been the automation of production and services in the advanced economies. Man is clearly no longer required as a mechanical

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[2] Extract from "2000+", J. McHale, (special issue of Architectural Design, London, February 1967).

[3] The Rational Behaviour of Mechanically Extended Men, J. D. North, Boulton Paul Aircraft Ltd., United Kingdom, September 1954.

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energy converter, as part of an assembly line or as a routine worker. Many such tasks have been taken over by automated machine -- process and product wealth may be generated with less and less input of human energy, intervention and decision. This aspect of automation is only the more visible and easier to grasp.

The extent to which automated systems have now assumed the operation of the invisible metabolics of advanced economies is more far-reaching. Apart from completely automated factories and continentally linked automatic inventory dispatch and control operations, the whole energy conversion and transmission system of vast areas are increasingly under automated control. Over 80 per cent of the U.S.'s electrical capcity is, for example, controlled at present by automatic dispatch systems.

> The processes of control everywhere they are encountered, that is, in living organisms, social organisms, and the psyche, lead in their development to automation. Automation creates that simplification without which further development would be impossible. Their control of the activity of the inner organs is completely automated and does not require attracting the attention. In the learning process we constantly encounter the phenomenon of automation. Even when learning to walk a system of automatic control arises in our consciousness. Habits without which the successful execution of any kind of complex activity would not be possible represent the working out of automatic responses.[4]

The extension of automated control measures to the operation of national economies is being developed in many countries and is foreseeable for the planetary economy in the link-up of world airlines, energy and communication networks. This type of control design requires prior large-scale simulation. Such simulation is much the same as we do in our head when confronted with problems of decision-making under various degrees of uncertainty. We review and organize information on the problem, assign different contingencies to various possible actions and choose the optimal strategic combination of actions. These mental simulations, or models, plus the results of action based upon them, become memory/experience components in future decision-making. By organic automation, or habit, they are incorporated as patterns in our nervous systems.

The use of the computer in the simulation of processes with large numbers of interacting variables is now commonplace. In large-scale economic, business and politico-military simulations, actions which might take weeks or months to occur in real time may be run through in a few days.

Prerequisites for such simulation, for increasing the predictive capacity of the organism in its environment, are adequate information and communications. It is interesting, therefore, to observe the exponential growth of information accumulation, and the parallel expansion of information and communication systems to the global level.

The most advanced development of such systems at present is, of course, in support of military prediction, planning and control procedures. When ICBMs may be launched to

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[4] Cybernetics and Problems of Development, B. V. Akhlibininsky and N. I. Khrallenko, (Lenizdat Publishing House, 1963), U.S. Dept. of Commerce, OTS Report 64-215-17.

strike anywhere in the world in less than 30 minutes, the factors of speed in information handling of incoming data and outgoing corrections of hour by hour posture are enormous. Add to this the given figures of operational air forces of 15,000 aircraft, 1000 missiles and a quarter of a million personnel, and we have a global operation of considerable size. The facilities developed match up to the requirement. Operational data referring to the location and state of the above components, to global weather conditions, intelligence, materials inventory, transport, location, is constantly being fed into such centers, and may within seconds be flashed on screens for simultaneous viewing of its complex relationships. Aircraft in flight may be contacted swiftly anywhere in the world and direct telephone contact made immediately through one handset with more than 70 subordinate centers spread halfway around the world.[5]

Such worldwide systems are working examples of Marshall McLuhan's statement, 'Today, after more than a century of electric technology, we have extended our central nervous system itself in a global embrace, abolishing both time and space as far as our planet is concerned'.

The first recorded voice was heard from a satellite only eight years ago; four years later the first live telephone, television, data and facsimile transmission was made between Europe and the U.S. via Telstar I and II. Since then, Syncom, Echo, and the Early Bird satellite relays have transmitted between Russia, Japan, the U.S. and Europe.

The less obvious uses of such satellite repeaters, observers and relay stations is their direct scientific value. One of the latest of these, Nimbus II, specifically designed to monitor weather information, was sent aloft in May 1966 for a six-month work period. Its set of Vidicon automatic picture transmission cameras will photograph not only cloud cover and weather, but anything as small as a half a mile in length on the earth surface. Pictures will be relayed automatically to 150 ground stations in 27 countries. This example may seem much less dramatic than the TV transmission of human space walks, and moon surfaces viewed recently, but information gained by such workaday satellites may be of greater direct value to the solution of various world problems. The World Weather Watch scheme, proposed in 1965 as part of the UN International Cooperation Year, seeks the combination of such satellite reported data with global weather observation at various atmospheric levels, a fast world-wide high capacity communication system and a large size computer facility containing an adequate 'numerical model of the atmosphere'.

> With the World Weather Watch data, an adequate computer and global mathematical model, a vast array of experiments on weather and climate modification can be performed by numerical computation rather than in nature . . . full effect and potential hazard can be determined without risk to life or property. For example, a dam can be 'built' across the Bering Strait for an infinitesimal fraction of its real life cost, and we can evaluate its effect on the Kamchatka or Canada wheat growing season . . . we can model a megalopolis and its atmospheric cesspool, examine the extent to which it acts as an inadvertent weather modifier, then 'clean up' the atmosphere and see the difference. We can do this without taxes, political strife, vast engineering expense -- in a computer.[6]

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[5]Information: U.S. Strategic Air Command, 294-2544/4433.

[6]"National Center for Atmospheric Research", W. O. Roberts, Science, Vol. 152, No. 3119, April 1966.

In addition to conventional photography from satellites, multispectral sensing is also being employed with the infra-red, ultraviolet and other wavelengths such as X-rays and radar. Using infra-red, for example, it would be possible to have detailed surveys of traffic in and out of cities, of human occupancy of building through their heat patterns. Numbers of cattle on grazing range, changes in forests, fields and even animal bird migrations could be easily surveyed.

These developed capacities for swift 'planetary stocktaking are further amplified by such programs as the International Geophysical Year and others sponsored by the U.N.

In 1966 the UN Secretary-General called upon Canada, Chile, France, the Phillippines, the Soviet Union and the United States to endorse a proposed five year programme of world surveys of minerals, energy and water resources. This will be a first step towards 'an orderly systematic approach to natural resources development in the world and the developing countries in particular'. The cost of this world resources survey of non-agricultural resources is set at $10 million spread over the five-year period. The nine survey areas are:

World iron ore resources.
Important non-ferrous metals
Selected mines in developing countries with view to increasing ore reserves and production through application of modern technology.
Offshore minerals in developing areas.
Water needs and resources in potentially water short developing countries.
Potential for development in international rivers.
Potential geothermal energy resources in developing countries.
Oil shale resources.
Needs for small-scale power generation in developing countries.[7]

In developing the theme of the new symbiotic relation of man to his most advanced machines, we have emphasized those aspects of technological means, 'that have been pressing humanity so rapidly towards a closely interconnected species, a species in full possession of the world and its abundance and with an adequate capacity for control and survival, that are reaching towards more mature and stable forms in this generation.'[8] As earlier stated, where tribal man became disoriented when separated from his local tribe, and early city and local state man could barely conceptualize his immediate surrounding environment, we are now in a period when men think casually in terms of the entire planet.

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[7] UN Press Release, E. C. 2308, April 1966.

[8] The Step to Man, John R. Platt, September 1964.

Social Design

Whilst our primary concern here has been with 'physical' technologies, the more crucial aspects of future planning are now more clearly non-technological. The hardware with which to solve our main physical problems is largely given; the 'software', or social technology, through which we may apply our developed technical capacities to their fullest advantage, is still to be designed.

The idea of social design is almost always negatively conceived -- especially when paired with the application of scientific and technological means. There is the assumption that such 'design', or planning, introduced more directly into social affairs is a threat to individual freedom of action. But freedom and liberty are, in essence, the liberty to choose, the freedom to make choices! We may well reflect that such 'freedoms' only become real for the majority of men when the industrial revolution began to provide the material life means which freed man from margin survival constraint. In general, such continued technological development makes for more freedom, not less. Man today in the advanced regions of the world has more freedom and choice than ever before -- in occupation, in geographical mobility, in overall life chances.

Social design means, therefore, the re-design of both the physical and social aspects of man's environment towards the widening of 'multiple choices' for the greatest number of men -- as distinct from previous societies in which choice, in this sense, was restricted to comparatively small elites. For the majority, life in earlier, agriculturally based marginal-survival societies was largely constrained in either/or terms -- either conform or be punished, either 'marry or burn' , and so on! When we may now produce far beyond immediate necessity, most of these constraints hitherto necessary for group survival become obsolete. A vast range of material means and alternative life conditions, previously unattainable, are now freely available. When the growth of such industrial means removes dependence on the natural cycles, frees man from geographical limits, measurably extends his life expectancy, etc., the human condition may be phrased in terms of a multiplicity of both/and life choice possibilities. Life need no longer be constrained by material survival and 'economic' necessity. Ways of 'earning a living' are replaced more simply by ways of living. The ranges of choice, of life style, milieu and vocation are enormously extended.

In considering the design parameters of new societal forms, as no longer based on earlier survival needs to labor in the traditional sense, or to conform to other survival pressures historically conditioned by material limitations, many alternate modes of individual and group life styles become possible. Our traditional attitudes and ideologies are inadequate guides to the future. Faced with possible abundance for all, they tend to perpetuate old inequities and insecurities; confronted with freedom, they will often assume new forms of slavery.

The strongest attitudes still surround the nature of material wealth, value and meaning as related to their past forms. There is a refusal to accept potentially 'limitless' wealth as inherent in our technological processes. That there is no longer any intrinsic material value in physical products, resources or material 'property' has not yet reached general consciousness. Yet it is clearly demonstrable that industrial society is non-materialistic in its basic direction, as progressively less human life hours, energies or values are attached to its material means and products. Material 'possession' declines steadily as a source of economic power, and ownership is no longer a necessary use relation between people and facilities. Technological means actually trend toward using less material and being less materially evident, e.g., as either 'invisibly' operating in nonvisible portions of the spectrum, or as progressively miniaturized.

The future of society is, in this sense, less centrally dependent on the further elaboration of material technologies whose evolution may continue with less investment of human energy and attention. Our priorities lie, rather, with social invention, with the understanding and re-design of our social 'ecological' possibilities. Here, of course, we must beware of interpreting 'ecology' too literally. We do not know enough about the design of human society as an ecological process to be able to rationalize its wastes, discards and useful products! Rather, our direction may be to experiment more consciously with innovative social organizations, exploratory groups, and new modes of individual and cooperative social action and decision-making.

The design of such forms is already evident in many societies at different levels -- from the 'systems' approach to large-scale complex tasks, to the experimental life styles of various marginal groups. The problem of more consciously directed social exploration may be viewed at two related levels -- one, to encourage within local societies those new forms of social organization which may provide internally innovative directions -- experimental ecological units directed towards social, vocational and other purposes. A specific example of this form has been referred to recently by a distinguished anthropoligist:

> We have not yet created, even on a pilot experimental basis, a type of social organization capable of finding, recruiting, educating, and providing for the innovative intelligence we need. Yet there is little doubt that . . . there is a sufficient number of highly gifted individuals who, given the proper cultural conditions in which to work, could go on to make the necessary innovations . . . It is vitally necessary for us to find the means of creating the evolutionary clusters for which (our present social) problems provide a focus.[9]

Two, such 'evolutionary cluster' units are not only necessary in the local society, but even more required at the transnational, world society, level. One of our most urgent global needs is the design of such units, organizations and agencies which may mitigate and counter balance the more negative forces conducive to tension and conflict. The United Nations, though still rendered ineffective by its political format, is a useful prototype for viable forms of similar magnitude which might progressively supersede those obsolete mechanisms which perpetuate, rather than diminsh, global inequities and the danger of world warring.

In this regard, the international regulatory and professional organizations, the various formal and informal world associations and union, etc., represent a sector of the 'noosphere', the potential of whose function is as yet unrealized. Apart from the 'invisible' regulatory agencies maintaining the vital operation of the world postal, air transport, broadcasting and other ecological networks, there is the more direct action of regulatory bodies concerned with specific areas of human activity. For example, the First World Conference of United Auto Workers in 1966 announced its goal of international collective bargaining directed towards parity of wages in world terms. From such steps, of which many could be cited, we may also envisage other global effects of the emergence of world

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[9] Continuities in Cultural Evolution, Margaret Mead, (Yale University Press 1965).

man -- already beginning to control and dispose of his facilities and requirements in ways which increasingly transcend yesterday's sovereignties and their insecurities. As local royalties have moved from their historically central position in the polity to none the less socially central but symbolic functions, so many of our later political structures will be increasingly circumvented in their function at the world level. We already realize this, not only in the limited example above of setting work conditions transnationally, but in the power to resolve dangerous world conflicts through the regulatory control of airlines, telecommunications and other essential global services. The complex technological interdependence of all sovereign nations on an enormous range of such services to maintain their daily operation, in reality, now renders ineffective any attempts at unilateral action based on some imaginary sovereign autonomy. We are, of course, still hypnotised by such notions, and cling to them tenaciously, even though they are no longer operable in the real world.

As science is turned to, increasingly, for public and legislative guidance in both physical and social affairs, many scientists have begun to question the ethical accountability of their professions for the uses to which science may be put. Such uses have, hitherto, been determined almost wholly by the attitudes and circumstances of their local national societies. There is an increasing realization that the central allegiance of science to the maintenance of the larger human community must take precedence over the more transient, and often dangerous, predilections of such local sovereignties.

In a further example of transnational action, the 'Pugwash' Scientific Conference of 1966 reported on the setting up of their own inspection teams against the development of biological and other weapons, to circumvent the political deadlock on such controls. We may again envisage the future apolitical enforcement of such control measures by withdrawal of key scientific services and support from contravening nations. In the interests of larger human welfare, we already control the spread of smallpox, plague and other physical viruses by restricting intercontinental traffic, impounding cargoes and the like. We patently need to enlarge our concepts, and enforcement of human welfare to monitor and control the spread of other ecological threats to the global community.

To accomplish such tasks and to ease our presently painful transition toward a more equitable world society, we require many such global agencies, diversely organized and broadly representative of all positive transnational forces.

Our generation faces the future with globally developed physical capabilities which free man, for the first time in human history, from age-old 'fear' constraints of material scarcity, individual and group insecurity and the necessary competition for life survival through access to limited resources. This enormous capability inherent in all our developed sciences, arts and technologies was not created by us, in our period only, but results from the cumulative experience and knowledge of countless generations of men all around the earth. From this time forward our central task is to apply this accummulated advantage not only in measures of one or a few generations of men, of some preferred national or ideological group, but in terms of all men -- now -- and in the future.

APPENDIX

"THE WORLD DESIGN SCIENCE DECADE 1965 - 1975"

This program was proposed by R. Buckminster Fuller to the International Union of Architects (IUA) at their VIth World Congress in England in 1961. He suggested then that the architectural and environmental planning schools around the world be encouraged by the IUA to invest the next ten years in a continuing theme of "How to make the world work" -- how to redesign the world's prime tool networks and environment facilities so as to make the world's total resources, now serving only 44 percent of humanity, serve 100 percent through competent scientific design and anticipatory planning.

This proposal called for the initiation, by the world schools, of a continuing survey of the total chemical and energy resources now available to man on a global scale, and of human trends and needs in relation to these resources -- of how we may redesign the use of these resources to serve all humanity.

Document One (1963), "Inventory of World Resources, Human Trends and Needs," by R. Buckminster Fuller and John McHale, was presented to the world architects and students at their International Symposium in Mexico City, October, 1963. This "inventory" outlined the main aspects of man's present world resources position and provided a broad survey of his major trends and needs relative to his resources.
Document Two (1964), "World Design Initiative," by R. Buckminster Fuller, dealt specifically with the manner in which the world students might assume the initiative, and gave procedural outlines and examples for the conduct of generalized design science exploration.

During 1964 there was a considerably increased response to the program by schools and student groups around the world. Various student projects on the first phase of the program, "World Literacy re World Problems," were forwarded for exhibit at the VIIth World Congress of the IUA in Paris, July 1965. The IUA set aside exposition space for this in the Tuileries Gardens and this first exposition was given a most favorable and encouraging coverage in the world press.

Document Three (1965), "Comprehensive Thinking," by R. Buckminster Fuller and Document Four (1965), "The Ten Year Program," by John McHale were prepared for the 1965 Paris Congress. They discuss in detail the forward program.

In 1967 there will be three major events in the world students' activity.

One: Participation in the IXth IUA World Congress to be held in Prague, Czechoslovakia in July. R. Buckminster Fuller will speak in the Tribune Libre section of the Congress reporting on the WDSD program, and an exhibit of work from the program will be displayed in one of the Prague schools.

Two: World Design Science Decade Conference, London, later in July has been arranged by the United Kingdom WDSD Coordinators at the Architectural Association School of Architecture. A number of distinguished speakers will address the Conference and an exhibit of WDSD student projects will be displayed in one of the main public squares in London.

Three: World Students' Design Science Day -- EXPO 67. With the cooperation of the Canadian Corporation for the World Exhibition 1967 and the McGill University School of Architecture, a conference will be held on August 25th. An exhibit of world students' work in the program will be displayed in the EXPO International Youth Science Week.

In relation to the above meetings, and as part of the work being forwarded in the next phase of the program, two further 'guide' documents have been prepared:

Document Five (1967), "Comprehensive Design Strategy," by R. Buckminster Fuller
Document Six (1967), "The Ecological Context: Energy and Materials," by John McHale

The role of the World Resources Inventory center at Southern Illinois University is essentially that of a coordination agency and clearinghouse for information on the world students' program. This center assembles information on world resources and potentials in relation to human trends and needs. From this data collection and analysis the WDSD documents, and other publications, are prepared which serve as guide sources for work in the program.

The preparation of projects by student and school groups around the world rests with initiative of the collaborating individuals. Since the inauguration of the program many such groups have also spontaneously assumed the responsibility for coordinating work, arranging meetings, exhibits and conferences in their various countries.

The five two-year stages of the program, which follow, should be considered as overlapping and interweaving -- their given order only indicates prior emphasis for consideration.

Phase 1. World Literacy re World Problems - World Industrio-Economic Literacy and its design science solution by dramatic educational tools for realization of the world resources inventory of human trends and needs -- world's people. Together with dramatic indication of potential solution, by design science upping of the overall performance of world resource units to serve 100 percent instead of the present 44 percent of humanity.

Phase 2. Prime Movers and Prime Metals - Review and analysis of world energy resources differentiation between "income" and "capital" energies -- design of more efficient utilization. Analysis of circulation and scrap recycling of prime metals. Redesign towards comprehensive and more efficient use and reuse "assemblies" with higher extraction of performance per unit of all invested prime metals in use.

Phase 3. Tool Evolution - Differentiation and evolution of machine tools -- the integration of these tools into the industrial complex; review and analysis of generalized and specialized tools - automated processes and control systems - redesign and replanning of total world tool complexes and instrumentation systems, i.e., total buildings, jig assembled by computer within optimum environment control, air delivered, ready to use in one helilift.

Phase 4. The Service Industries - Analysis of world network of service industries, i.e., telephone, airways, communication services, hoteling, universities. General extension of dynamic network operating principles into formerly "static" areas of environment control both internal and external. Frequency modulated, - world planning of three shift, 24-hour use of facilities, i.e., most industrial facilities as yet operating under obsolete agricultural dawn to dusk, single frequency usage. Trans-sonic 1800 mph air travel transcends day-night and seasonal characteristics. Men literally jump out of night into day and out of winter into summer in minutes. Thus, local patterns of facilities employment trending swiftly into 24-hour success of users, i.e., electrically lit telephone booths by roadside.

Phase 5. The Evoluting Contact Products - Usually phrased as "end products" -- there are, in effect, no end products but only the contact instruments of industrializations human ecology services which are the plug-in or latch-on terminals of service industries, e.g., the telephone, transportation and other communication units, the motel (bathroom and bed) - and eventually the world-around environ control service unit.

The "World Design Science Decade" may be generally viewed as requiring a major shift of emphasis in the education of the architect and environment planner. It defines a much larger context of social initiative and respondibility, and charges the emergent architect and planner not only with designing the major ecological environment facilities required by man but also with designing the means whereby such full environmental advantage may be made available to all men.

John McHale
Carbondale, Illinois
June 1967