Defining Goals and Conditions for a Sustainable World

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Sustainable development is being approached component by component—socioeconomic, sustainable agriculture, transportation, forestry, energy use, cities, and the like—but, leaving a habitable planet for future generations will require the development of a widely shared paradigm. Further, the paradigm should be ecological from a scientific point of view. This development will be facilitated by a discussion of goals and those conditions necessary to meet them. The presently shared paradigm is that economic growth is the cure for all of society's problems, such as poverty, overpopulation, environmental degradation, and the increasing gap between rich and poor. A paradigm shift from growth to sustainability might result either from suffering painful consequences of continuing to follow out-moded paradigms or by discussing what sort of ecosystems will be available to future generations. The purpose of this paper is to help initiate such a discussion. *Key words:* conditions for sustainability, habitable planet, paradigm shift, sustainability goals, sustainable development.
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Economist Kenneth Boulding (*1*) once stated, "Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist." Since that time, increasing attention has been paid to possible biophysical limits to the growth of human society. There are at least two ways to respond to limits: one is to deal with the consequences of exceeding limits as they are encountered; the other is to adjust behavior now to preempt the unpleasant consequences of exceeding limits to growth. The types of adjustments that may be necessary are the focus of the concept of sustainability.

The United Nations World Commission on Environment and Development report (*2*), commonly called the Brundtland Report after the woman who chaired the commission, is generally recognized as the document most responsible for the increased attention to the concept of sustainable development. Sustainable development is defined in the report as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. More recently, Karl-Henrik Robèrt, Herman Daly, Paul Hawken, and John Holmberg (*3*) described a simple and accessible model of sustainability, which has been used by corporations and municipalities to guide choices towards those consistent with sustainability. This program, called the Natural Step Program, lists four conditions for sustainability (Table 1) that go beyond the Brundtland report. The Natural Step Program espouses "the need to re-examine the negotiable rules of our economic game so they conform to the non-negotiable rules of the biophysical world." The conditions (K-H. Robèrt, personal communication) are first-order principles for sustainability because 1) they are all necessary for sustainability, 2) they are sufficient for sustainability (i.e., cover the whole area), and 3) they do not overlap. Conditions 1–3 (Table 1) are ecological but severely economical in words, which is essential to reaching a consensus on first-order principles. The discussions will doubtless become more heated when the consequences of accepting a first-order principle are more explicitly stated. In addition, Paul G. Hawken has established a U.S. Natural Step Program, industries have taken note of sustainable development (*4*), and the George and Cynthia Mitchell International Prize for Sustainable Development has been awarded for a number of years. The prize recognizes scientific, technical, or management contributions to sustainable development by individuals in the corporate setting or by individuals who have made corporate sustainable development activities possible. This progress indicates that organizations may meet one or more conditions for sustainability, but these commendable efforts are hardly adequate for achieving sustainability at a planetary level. Not surprisingly, thinkers are often better known than doers, but the latter are now beginning to receive some public recognition. However, a list of publications on sustainability is much more easily acquired than a list of organizations or regions practicing sustainability. Only one person is required to write an article on sustainability, but an organization, tribal unit, or society is needed to practice it.

The term sustainable development implies to many people that the present kinds of resource utilization, space allocation, and the like can be continued with only minor modifications. That is, society can indefinitely continue the loss of biodiversity and the further loss of old growth forests, groundwater aquifers, and ecological habitat. This misconception is one reason why the term sustainable use of the planet may be more appropriate than sustainable development, although initially less acceptable to policymakers. This same misconception is often why many, including myself, use the term sustainability instead of sustainable development. As the UNESCO-UNEP Environmental Newsletter *Connect* (*5*) notes

> Economic growth—until recently synonymous with development—was once presented as the panacea to the ills of humanity: from poverty and disease to over-population and environmental degradation. Even today there are those who firmly believe that it is the surest cure for ailing humanity.

Human society may have existed for over a million years (arguably as long as several million years) and, at the very least, for hundreds of thousands of years. For most of this time, humans were spread rather thinly across the planet, compared to present population levels and densities, and usually existed in tribal units or small societies. One notable feature of tribal life is that, when consequences surfaced from bad situations (e.g., food shortages), the suffering of the tribe was relatively equitably distributed. In a sense, sustainable use of the planet is an attempt to achieve equitable natural resource distribution over both large temporal and spatial spans (*6*). One wonders whether compassion for individuals with little access to resources is a persuasive basis for equitable resource distribution for both present and future generations. Some suffering is inevitable, from earthquakes, hurricanes, and other climatic events, or from diverse susceptibility to cancer and other diseases that have dramatic effects on some

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Table 1. The four system conditions

System condition	This means:	Reason:	Question to ask:
1. Substances from the Earth's crust must not systematically increase in the ecosphere	Fossil fuels, metals, and other minerals must not be extracted at a faster pace than their slow redeposit and reintegration into the Earth's crust	Otherwise the concentration of substances in the ecosphere will increase and eventually reach limits—often unknown—beyond which irreversible changes occur	Does your organization systematically decrease its economic dependence on underground metals, fuels, and other minerals?
2. Substances produced by society must not systemically increase in the ecosphere	Substances must not be produced at a faster pace than they can be broken down and integrated into the cycles of nature or deposited into the Earth's crust	Otherwise the concentration of substances in the ecosphere will increase and eventually reach limits—often unknown—beyond which irreversible changes occur	Does your organization systematically decrease its economic dependence on persistent unnatural substances?
3. The physical basis for productivity and diversity of nature must not be systematically diminished	We cannot harvest or manipulate ecosystems in such a way that productive capacity and diversity systematically diminish	Our health and prosperity depend on the capacity of nature to reconcentrate and restructure wastes into new resources	Does your organization systematically decrease its economic dependence on activities that encroach on productive parts of nature, e.g., over-fishing?
4. Fair and efficient use of resources with respect to meeting human needs	Basic human needs must be met with the most resource-efficient methods possible, and their satisfaction must take precedence over provision of luxuries	Humanity must prosper with a resource metabolism meeting system conditions 1–3. This is necessary in order to get the social stability and cooperation for achieving the changes in time	Does your organization systematically decrease its economic dependence on using an unnecessarily large amount of resources in relation to added human value?

Reproduced with permission from Robèrt et al. (*3*).

individuals and not on others. In many human tribes, equitability apparently was achieved through mutual, voluntary sacrifice rather than government edicts, indicating that compassion sometimes has resulted in more equitable distribution of resources.

Illustrative Questions on Sustainability

Human society needs to ask a wide variety of questions about sustainability goals; the following is an illustrative list. Clearly, a comprehensive list is beyond the scope of this paper. Instead, it seems desirable to alert readers not familiar with sustainabilty issues to the breadth of the subject.

Are changes to assure sustainability really desirable? Most publications on sustainability assume that present lifestyles are highly successful and need only relatively modest tweaking (e.g., recycling) to be sustainable. However, what if the question of sustainability is studied in a systematic, orderly way and a dramatically different lifestyle becomes mandatory? Would society embrace sustainability and, more importantly, implement it? The sustainability initiative makes sense only if an extremely high priority is given to the well-being of future generations. Does the initiative also make sense if society does not always give as high a priority to the well-being of all humans presently alive in order to benefit future generations?

What are discussions of sustainability really trying to accomplish? Costanza (*7*) believes that discussing sustainability for infinite periods of time is inappropriate—all discussions of sustainability should have a particular time frame. Clearly, sustainability initiatives cannot exceed the life of the universe (*8*). Perhaps the indigenous North American tribes who felt that no decision should be made unless it considered the next seven generations had it right. In fact, experience with money transfer systems, such as the U.S. Social Security system, has shown that some assumptions (in this case, the ratio of citizens contributing funds to those withdrawing funds) do not hold true for even seven generations.

The Natural Step Program lists conditions, meanings, reasons, and questions that should be asked for achieving sustainability. Acceptance of these conditions could be enhanced by stating what is being attempted and what condition must be in place to be successful. Some illustrative examples of my own are covered later in this discussion.

What should the scope and emphasis of a sustainability initiative be? This question is probably one of the biggest hurdles of the whole process. Clearly, countries such as Bermuda and, arguably, even Japan could not achieve sustainability in the near future without external resources because of their population density and the ratio of arable land per capita. Thus, such countries would require somewhat different sustainability scopes and emphases than Australia or Canada, which could possibly be entirely self-sufficient with internal resources. Furthermore, sustainability initiatives should have a strong local or regional component, in addition to sustainability initiatives for larger regions, countries, and, in fact, the entire planet. The People's Republic of China and the United States clearly would, at least initially, have different sustainability emphases and different scopes for each of these components.

The significant differences among geographic regions will necessitate lengthy discussions of any implementation of a sustainability initiative. Experiencing severe consequences will undoubtedly affect attitudes toward making sustainability conditions more socially and economically acceptable; however, informed self interest might reduce suffering if action is taken in time. Becoming doers clearly requires acceptance of a major new paradigm.

What program elements should a sustainability initiative contain? Program elements might be grouped by activities such as the timber industry, fisheries, agriculture, energy production, and the like. Considerable emphasis would also have to be given to ensuring that program components did not interact negatively or that program components, each attractive in isolation, would not be incompatible in concert. Also, components at the local, state, regional, national, and international levels must be compatible and not mutually exclusive at these geographic levels and at different levels of political organization. This situation emphasizes the importance of the dictum: every specialist should be able to talk professionally with those in other professions, and representatives from various regions should be able to communicate with each other.

Tentative Goals and Conditions for Sustainability

Thinkers and doers represent a striking dichotomy: some doers are unaware of

thinkers, but are well aware of other doers; some thinkers are unaware of the degree to which implementation has occurred and the degree of correspondence to the theoretical models. Of course, this dichotomy is not absolute because some individuals are both thinkers and doers, but the dichotomy does exist to a surprising degree. Perhaps the following section, which attempts to link goals and conditions necessary to meet the goals, might bridge the gap between thinkers and doers.

The term condition is used here to follow the terminology of the Natural Step Program (*3*). It does not describe existing conditions but, rather, refers to anticipated or qualifier conditions necessary to achieve sustainability.

Goal 1. To see that the machinery of nature has sufficient energy to deliver necessary ecosystem services.

Condition. Human society shall not co-opt so much of Earth's energy that ecosystems can neither furnish services nor endure for substantial periods of time.

Ecosystem services are defined as those functions of ecosystems that are necessary for human survival and welfare. A list of ecosystem services consolidated from many sources (*9–14*) is as follows:

- Capture of solar energy and conversion into food, fuel, and other raw materials
- Decomposition of organic wastes and sequestration of other wastes that cannot be broken down, such as heavy metals
- Maintenance of a gas balance in the atmosphere favorable to humans, i.e., storage of carbon dioxide and release of oxygen
- Recycling nutrients in forms useful for plant growth
- Storage, distribution, and regulation of freshwater
- Erosion control and sediment retention
- Generation of agricultural soils
- Control of pests by birds, bats, insects, etc.
- Pollination of crops
- Provision of a genetic library for development of new foods, drugs, building materials, and waste treatment processes through both Mendelian genetics and bioengineering
- Disturbance regulation, i.e., limiting destruction and disruption of other ecosystem services after expected disturbances such as fire, flood, hurricanes, and droughts
- Control of both microclimate and macroclimate
- Recreation and cultural amenities.

The structures of natural systems (i.e., forests, rivers, wetlands, oceans, etc.) can be thought of as natural capital or machinery. The functions of natural systems (i.e., photosynthesis, decomposition, etc.) can be thought of as interest. Without natural systems to capture sunlight, provide food and fiber, break down wastes, or distribute freshwater, human society could not survive. To the extent that human society destroys these ecosystem services, either by destroying the systems that provide them (the capital) or by impairing systems so they provide them less efficiently (reducing interest), sustainability is compromised. The combined value of these ecosystem services to human society has been estimated to be >$33 trillion per year (U.S. dollars) (*14*).

Vitousek et al. (*15*) have hypothesized that human society is co-opting approximately 40% of the photosynthetic energy of Earth (i.e., that energy converted by plants from sunlight to forms such as carbohydrates that are more suitable for use by humans), which includes photosynthetic energy used for domesticated animals, gasohol, etc. At present, the percentage of the photosynthetic energy necessary for the machinery of nature to deliver the services essential for sustainability is unknown. At one time, human society used only a minuscule portion of the total; in fact, in the hunters and gatherers stage, society probably used far less than 1%. Energy is also extracted from rivers as hydroelectric power, which has a number of deleterious effects upon riverine ecosystems. The energy deprivation threshold at which the machinery of nature would break down is also unknown, but persuasive evidence indicates that some has already broken down. It would be prudent to have more robust information on various thresholds before developing a management strategy for sustainability that might give humans too large a share of Earth's energy.

Goal 2. To avoid poisoning or impairing the machinery of nature by altering both the structure and function of natural systems by means of toxicants.

Condition. Substances extracted from the Earth's crust or synthesized from raw materials must not be concentrated or dispersed in ways harmful to the biosphere (e.g., metals, oil, or pesticides). This condition is essentially identical to system condition 1 in Table 1.

Humans and other species can have their functional capabilities impaired without actually causing death. In fact, medicine has moved from merely preventing symptoms of malfunction in humans to requiring evidence of robust health. Similar thinking should apply to natural systems.

Cairns et al. (*16*) have shown that ecological toxicity testing is still evolving despite notable advances during the last four decades. Human society has not yet developed effective predictive models for determining the effects of toxicants on ecosystem services, but the field of landscape ecotoxicology, once developed, should do so (*17*). More important, more methods are being developed to improve protection and ultimately make ecosystem health a reality.

Goal 3. To ensure that ecosystem services, such as the maintenance of atmospheric gas balance, favorable to human and other life forms continue at their present or, preferably, better levels.

Condition 1. The physical and biological basis for the services provided by nature shall not be systematically diminished (e.g., overharvesting whales or fishery breeding stocks). This condition is similar to system condition 3 in Table 1.

To achieve sustainability, the life support system's integrity cannot be impaired. This requirement applies to both the technological life support system upon which human society is now dependent because of its distribution and density (urbanization) and the ecological component. The biotic impoverishment involving the loss of species in most parts of the planet will undoubtedly affect the delivery of ecosystem services, and some evidence exists that allows an estimate of the relationship between species diversity and the delivery of ecosystem services (*18–20*). Although biotic impoverishment remains a major problem when consequences are likely to be severe (i.e., partial or total loss of life support functions), caution is required about further impairing the physical and biological basis for nature's services.

Condition 2. Artifacts created by human society may not systematically increase on the planet. This condition is similar to system condition 2 in Table 1.

Arguably, physical displacement of species and the ecosystems they inhabit, which is caused by urbanization, construction of interstate highways, surface mining, shopping malls, and a variety of other physical events, is a serious problem. Physical space is taken away from natural systems and perhaps, even worse, fragments the remainder. Small tracts support far fewer species than large tracts because not all species have the same home range. Some species, for example, must live in large forests: the spotted owl/old growth forest controversy in the Pacific Northwest in the United States is a good example of how dependence on a certain type of ecosystem is common to many species.

Condition 3. A balance must exist between ecological destruction and repair.

Clearly, ecosystems cannot continue to be destroyed at the present rate with the expectation of having anything ecologically significant left by the end of the next century.

Therefore, in order to achieve sustainability at some point, a balance must exist between ecological destruction and repair. Because the present rate of ecological destruction is unique in human history, now is the time to attempt to achieve a balance, while the quality of life is still reasonably high and some relatively pristine ecosystems are available to use as models. Of course, human error will always produce such destruction as accidental oil spills and other ecological catastrophes. In some cases, natural recovery will heal the damage; however, as sources of recolonizing species diminish and are more widely separated geographically, managed recovery or ecological restoration will be essential. The National Research Council (*21*) recommends beginning this process of restoration at a modest level for aquatic ecosystems.

Cairns (*22*) describes five options for human society regarding its relationship with the environment, only two (stabilize human population and exercise no-net-loss of ecosystem services, which would then maintain a status quo on ecosystem services per capita; and stabilize human population growth and restore ecosystems at a greater rate than destruction, which would improve ecosystem services per capita) of which are likely to result in sustainability. Both of these options would presently be regarded as visionary because they involve stabilizing the human population and level of affluence (which is not necessarily closely correlated with quality of life) and repairing ecosystems at the same rate as they are damaged or an even greater rate for a certain period of time.

Condition 4. Management strategies for sustainability must allow natural processes such as succession, evolution, predator/prey relationships, and the like to continue.

The machinery of nature has adjusted over literally billions of years to continual change. Although the changes in species composition may be imperceptible within human time frames, they are often quite dramatic in geological time frames. Ecosystem function (and delivery of services) may be relatively stable with regard to turnover in species within an ecosystem if there is substantial redundancy within the ecosystem (i.e., replacement species with similar function). However, the rate of change and increasing fragmentation of ecosystems might well negate the advantages of functional redundancy. The resiliency of natural systems is sufficient to overcome these changes, which are often (no pun intended) glacially slow. However, human-initiated perturbations (such as persistent toxic chemicals with no natural counterparts, habitat fragmentation on a large scale, and a very high rate of species impoverishment) have developed with such rapidity that natural systems are unable to function as they normally would.

Goal 4. To devise a better balance in meeting short-term and long-term needs of human society.

Condition. Short-term human needs may not be met if doing so endangers the planet's ecological life support system.

The essence of sustainable use of the planet is to give a far higher priority to long-term needs than has been given in the history of human society. In essence, short-term needs might be denied or postponed if they endanger long-term needs. This is a difficult position to achieve and seems almost unthinkable in a society that insists on needs being met immediately. However, if some attention is not given to this issue, natural forces (*23,24*) will almost certainly adversely affect human society and deprive many individuals of perceived needs.

Sub-condition 1. If a world food shortage develops, grains will be shifted from domesticated animals to humans, rather than convert more natural systems to agriculture.

Converting more natural systems to agriculture is an example of placing short-term needs ahead of long-term needs. A recent article in *Scientific American* (*25*) recommended converting wasteland to agricultural use to solve China's food crisis. While not explicitly stated in the article, the impression is conveyed that wasteland is land not intensely used by human society, but clearly used by other species. Wasteland so defined is land going to waste in terms of human use, but it is not wasteland if other species and ecosystem services are valued. In short, the term wasteland would be inappropriate if this land were providing ecological services for society's life support system. For example, wetlands converted to agricultural purposes would no longer store flood waters and release them gradually into either surface waters or groundwater, thus changing both the amplitude and duration of flood peaks. This storage and release are definitely ecosystem services. However, this tyranny of small decisions—filling in a wetland here and there on a vast drainage basin—seems rational until the aggregate effect of a large number of small decisions is considered. California has eliminated approximately 91% of the wetlands that existed there in 1800 (*21*), thus having an effect on the amplitude of flood waters in that state. This reduction is, of course, not the only reason for floods since creating impervious surfaces such as roads, roofs, shopping malls with large parking lots, and the like also changes runoff patterns, as does decreasing the ability of natural systems to transpire and absorb rainwater by losing topsoil and clear-cutting forests. Small decisions considered in isolation from other decisions may have effects too minor to measure and may seem inconsequential but, when taken in the aggregate, may have effects that can be measured and are accompanied by severe consequences.

Sub-condition 2. Society must not depend on yet undeveloped technologies to save it from the problems it has created.

This condition is also a part of balancing short- and long-term needs. Unquestionably, solutions to problems, particularly those involving development of new technologies, are often brought on by crises. The development of the atom bomb during the latter stages of World War II is a good example, or the U.S. space program, which was developed at a much faster rate after the former Soviet Union launched a spacecraft into orbit. Development of new technology does not inevitably follow a crisis; the AIDS crisis is one such example. Granted, some technological or medical solution to AIDS may be found through the use of advanced technology, but it will come too late to benefit many sufferers.

Goal 5. To ensure that most of Earth's population has the opportunity for a high quality life.

Condition. Human population over the long term must be stabilized at a point where adequate per capita resources are demonstrably available.

The U.S. Bureau of Land Management (BLM) has established limits to the density of cattle that may be grazed on BLM lands. These limits are, of course, not the same for every area because some areas have a higher carrying capacity than others. Nevertheless, in practice, carrying capacity is recognized for domesticated and semidomesticated animals, elevators, bridges, and wild animals such as deer and trout. However, society is not willing to admit that biophysical laws of nature apply to *Homo sapiens* in terms of resource utilization and carrying capacity. Quality of life is not high when the carrying capacity is at or above maximum. This problem can be observed in parking areas, where people must cruise the lot in search of empty space, or when a certain number of individuals are packed into an elevator, even if the number of people and their aggregate weight is within legal limits.

Sub-condition 1. When defining sustainable use of the planet, society can use quality of life as the primary criterion.

Alternatively, estimates can be made of how many people can be crammed on Earth at a subsistence level at any one period of time. Theoretically, sustainable use of the planet would be possible using either criterion, but the quality of life for an individual would be vastly different for each choice. Will quality or quantity be a primary condition for sustainable use of the planet?

Sub-condition 2. Human rights may not be met if the ecological life support system is endangered by doing so.

This condition is, again, part of the balancing act, that is, ignoring the needs of future generations by damaging their life support system in order to meet the needs of presently living persons. For example, destroying a unique ecological system to provide a power line right of way or yet another major highway will clearly be affirming that the need to reduce travel time for humans now living is more important than the need of future generations to have a robust ecological life support system and to enjoy its amenities and pleasures.

Sub-condition 3. The majority of people and countries on the planet must accept a single paradigm on sustainable use of the planet.

Getting most of the world, both countries and people, to accept a single paradigm seems an unachievable goal. However, this condition has already been met by the common acceptance of the economic growth paradigm. Arguably, the reluctance to relinquish the growth paradigm is the reason the term sustainable development has been used instead of the term sustainable use of the planet. At any rate, since a large portion of the planet, including all developed countries and most developing countries, at one time accepted the growth paradigm, and most still do, it is at least conceivable that an alternative paradigm could have comparable acceptance. Since the free market paradigm is still painfully under way in Russia and a number of other countries, this situation is an illustrative example of an occurring paradigm shift. Diamond (*26*) provides a plausible hypothesis [i.e., under certain conditions, a wide variety of cultural entities (in China) merged to a remarkable degree as a result of a shared paradigm] for achieving a shared paradigm from a sizable array of culturally different groups. As always, this change was achieved at a cost to a number of generations and cultures.

Sustainable use of the planet probably cannot be achieved with a mixture of traditional economic or ecological paradigms. The coexistence of a limits-to-growth paradigm and an unlimited growth paradigm does not seem viable. Further, environmental refugees are likely to increase as resources are overutilized or severely damaged (or both) in particular countries. Stemming the flow of environmental refugees (not to mention political and economic refugees) is likely to consume so much time and energy and be such a long-term management concern that the energy necessary for transition to sustainable use simply will not be available in time. It is disturbing that so much energy and resources are devoted to placing the blame rather than solving the environmental problem (*27*). Instead of repairing environmental damage that occurred many years ago, society is engaged in endless legal battles to see if present property owners can be held accountable.

Goal 6. To avoid a human-induced episodic environmental catastrophe that would cause much human suffering.

Condition. When employing environmental management strategies about which the precise consequences are still somewhat uncertain, large protective safety margins (i.e., either slowing development or carrying it out extremely cautiously) are essential until the outcome has been better defined and the consequences have been determined to be acceptable and not of long-term sustainability significance.

The sun has a finite life span, even though it is probably in excess of a billion years, and the universe will not last forever (*8*). Consequently, no sustainability initiative should be designed for an infinite period of time. In fact, glacial and interglacial cycles of approximately 100 thousand years are well documented, and management strategies for sustainable use of the planet would definitely have to be altered as a consequence of these events. A possibility also exists that the Earth could be struck by objects from outer space that would cause dust clouds to change the Earth's climate and a variety of other events will occur over which human society has no control. However, society can control many events. For example, greater protection can be given to the other species with which humans share the planet. At the very least, the rate of biotic impoverishment (i.e., extinction of species) could be substantially reduced. Development of sustainable management strategies is also complicated by not knowing when the rapid rate of extinction of species will stop. Some species may have enormous value to human society, but these values may not yet be known, or the species themselves may be unknown because inventories of much of the Earth's biota are still inadequate. The problem is, of course, that short-term benefits accrue to those now living, who take risks with the planetary life support system, but the consequences of unwise decisions are likely to be endured mostly by future generations. Therefore, the type of development based on a frontier land use ethic, which is still all too present in human society globally, should be replaced by a maintenance ethic that would benefit both present and future generations.

Goal 7. To diminish the conflict between generations caused by U.S. Social Security and Medicare and elsewhere caused by the perception that future generations will lead impoverished lives because of present greed. (This goal is not identical to Goal 4 because long- and short-term goals may shift significantly as one ages.)

Condition. Older people must become deeply involved in sustainable use of the planet to demonstrate by deeds, not words, the older generation's concern for generations to follow.

As the number of workers decreases and retirees increase and Social Security and Medicare costs rise, the perception is that older people are maintaining their lifestyle at the expense of younger people. Developing a sustainable use policy is the best way to demonstrate with deeds, not words, a commitment to the future or succeeding generations. This development is a shared undertaking from which younger people will be the primary beneficiaries, even though the older people should take pride in this joint effort.

Goal 8. To reincorporate all waste from human society into natural systems without damaging their integrity.

Everything used by human society comes from natural systems. Although, in one view, human society is a part of all natural systems, in some ways it is apart from them. Society cannot afford to extract materials such as metals from the Earth, use them, and then place them in long-term storage such as landfills and the like. Dangerous radioactive wastes and highly toxic chemicals cannot be accumulated in situations isolated from the web of life without further depriving both humans and other species of the use of this area of the planet.

Condition 1. Materials that cannot be safely reintroduced into natural systems should not be produced.

A substantial difference exists between artifacts created by human society, such as shopping malls, and radioactive wastes that require long-term storage. Difficulties in the United States in cleaning up hazardous waste sites highlight this dilemma. The uncertainties associated with effective long-term storage of hazardous wastes are daunting and not likely to be quickly resolved. The essence of sustainability is the benign, even beneficial, reincorporation of materials extracted from natural systems back into them. If this cannot be done with present methodology, such activities are incompatible with long-term sustainable use of the planet. This issue is not an unimportant detail in the quest for sustainability.

Condition 2. Assimilative capacity of natural systems shall not be exceeded.

Cairns (*28*) has defined assimilative capacity as the ability of an ecosystem to assimilate a substance without degrading the ecosystem or damaging its ecological

integrity. Cairns (*29*) has defined ecological integrity as the maintenance of the structure and function characteristic of a locale. Meeting this condition requires that assimilative capacity be quantified and that human society adjust its waste disposal into natural systems so that they remain healthy and suitable for sustained use.

Condition 3. To develop robust predictive models regarding assimilative capacity, validate these models, and continually monitor them to ensure that previously established quality control conditions based on these two prior activities are being met at all times.

Natural systems are made up of both living and nonliving material, and it is a *sine qua non* that all living material varies. Therefore, assimilative capacity will vary within limits, and using it effectively requires attention to this characteristic. All living systems respond to the aggregate of the potentially stressing materials to which they are exposed, not to individual components in isolation from the others, although this can, at times, happen. Therefore, the monitoring and other activities must be at the system level in order to be congruent with decisions made at the system level.

Goal 9. To develop equity and fairness in resource distribution within human society and with other species with which it shares the planet.

Condition 1. A sufficient majority of humans must acknowledge the reality of equity and fairness so that there is an incentive to preserve the ecological life support system for sustainability.

This equity and fairness are best achieved at the grass roots level rather than by government coercion. Government may sometimes prevent gross damage, but fine tuning ecosystem health must be the mission of all society. As Pericles said, "All honor to him who does more than the law requires."

Condition 2. Ethnic and racial strife, holy wars, wars over resources, and other extremely diverse political issues must be eliminated or restrained so that destructive energy can be rechanneled into constructive activities.

As Diamond (*30*) notes, humans genes are more than 98% identical to those of chimpanzees. The genetic differences between ethnic groups are less. Sustainable use of the planet will be best achieved if humans stop warring on their own and other species.

Goal 10. To develop a holistic sustainability initiative.

Condition. Each specific or targeted sustainability initiative (e.g., agriculture, transportation, energy, cities, fisheries, etc.) must not act as if it is the only "flower facing the sun." It will be difficult to orchestrate these special interests but, otherwise, holistic sustainability will fail.

Ethics in Action or Inaction?

A substantial environmental ethic must be involved in any sustainability initiative. For example, Anglican Archbishop John Taylor (*31*) asked, "Is it immoral that the United States has to import over one half of its energy supply?" Similarly, he asks, "Is it reasonable that a child born in the United States or immigrating to it at an early age will probably consume 30 to 40 times the energy and natural resources per capita compared to the rest of the world, and possibly 200 times as much as some of the poorest underdeveloped countries?" One common belief among those few members of the general public who have given some casual thought to sustainable use of the planet is that, by minor changes in present practices, sustainability can be achieved without substantive behavioral change. However, much of the early literature on sustainable use of the planet indicates that a major paradigm shift and fundamental changes in human behavior, ethics, and lifestyles will be necessary. Stivers (*32*) espoused a new world that involved a radical change of attitudes and values. Birch and Rasmussen (*33*) argued that the most far-reaching change comes only with the combination of strong pressures and a compelling alternative vision.

Making no decisions that would compromise options for the next seven generations seems a sensible approach to formulating conditions for sustainable use of the planet. However, if a generation is 35 years, this span would cover 245 years, which is a long time for most human political groups. However, if each new generation were planning for the next seven, then it could adjust to climate changes, altered rainfall patterns, and other events not foreseen in the original plan. This plan might work equally effectively for a shorter number of generations, but seven seems an ideal number because it means that old growth forests, slow recharge rate groundwater aquifers, and other slowly renewing resources would get the protection they badly need for true sustainable use. The United Nations World Commission on Environment and Development (*2*) puts it more tactfully by stating that "sustainable development requires a change in the content of growth, to make it less material and energy-intensive and more equitable in its impact." Possibly this reasonable and moderate view was necessary so that the Commission would not be thought of as a group of environmental extremists. The *World Scientists Warning to Humanity*, signed by over 1,600 of the world's leading scientists, was much more blunt, as the title indicates (*34*). Since this document was also signed by a number of the world's living Nobel laureates, one would have thought that this message would have received major front page attention in the world's newspapers, but it received very little attention and discussion in the news media as a whole. A similar statement by the officers of the Royal Society of London and the U.S. National Academy of Sciences (*35*) went virtually unnoticed. Orr and Ehrenfeld (*36*) feel that willful blindness has reached epidemic proportions and that nowhere is it more evident than in the U.S. Congress, which is denying outright the still-growing mass of scientific evidence about the deterioration of the Earth's vital signs while simultaneously attempting, often successfully, to dismantle environmental laws and regulations. However, there is a failure to distinguish denial from honest disagreement about matters of fact, logic, data, and evidence that is a routine and customary part of the scientific process. Orr and Ehrenfeld (*36*) feel that denial is the willful dismissal or distortion of fact, logic, and data in the service of ideology and self-interest. Although Ehrlich and Ehrlich (*37*) do not use the word denial, they do use the word betrayal and, unlike the comparatively short Orr and Ehrenfeld article (*36*), have substantive illustrative examples to document their position.

These issues become extremely important because if denial and betrayal are the problems then more scientific evidence will not help. Kuhn (*38*) recognizes these issues when he states that "a paradigm is a belief so strongly held that when contrary evidence appears the evidence is rejected." Even earlier, Dobzhansky (*39*) stated,

> We like to believe that if we secure adequate data bearing on any scientific problem, then anybody with normal intelligence who takes the trouble to become acquainted with these data will necessarily arrive at the same conclusion regarding the problem in question. We like to speak of conclusions demonstrated, settled, proved and established. It appears, however, that no evidence is powerful enough to force acceptance of a conclusion that is emotionally distasteful.

One wonders what catastrophes human society must suffer before the major paradigm shift necessary to achieve sustainable use of the planet occurs. If the reasoned approach found in the publications of Robèrt and colleagues (*3,40*) is used, human society may be able to accomplish the transition gracefully.

References

1. Boulding K. The economics of the coming spaceship earth. In: Environmental Quality in a Growing Economy. New York:Harper and Row, 1966;3–15.
2. United Nations World Commission on Environment and Development. Our Common Future. Oxford:Oxford University Press, 1987.
3. Robèrt K-H, Daly H, Hawken P, Holmberg J. A Compass for Sustainable Development. Stockholm:The Natural Step Environmental Institute Ltd.
4. Weston RF. The Weston Way. West Chester, PA:Roy F. Weston, Inc., 1995.
5. UNESCO-UNEP Environmental Education Newsletter Connect. Humanize the urban environment. XXI(3):1–3 (1996).
6. Cairns J Jr, Dickson KL. Individual rights versus the rights of future generations: ecological resource distribution over large temporal and spatial scales. In: An Aging Population, An Aging Planet, and a Sustainable Future (Ingman SR, Pei X, Ekstrom CD, Friedsam HJ, Bartlett KR, eds). Denton, TX:Texas Institute for Research and Education on Aging, 1995;175–187.
7. Costanza R. Designing sustainable ecological economic systems. In: Engineering Within Ecological Constraints (Schulze PC, ed). Washington, DC:National Academy Press, 1996;79–95.
8. Winters J. The answer in the voids. Discover 17(1):27 (1996).
9. Holdren JP, Ehrlich PR. Human population and the global environment. Am Sci 62:282–292 (1974).
10. Westman WE. How much are nature's services worth? BioScience 197:960–964 (1978).
11. Cairns J Jr. Determining the balance between technological and ecosystem services. In: Engineering within Ecological Constraints (Schulze PC, ed). Washington, DC:National Academy Press, 1996;13–30.
12. Daily G, ed. Nature's Services: Societal Dependence on Natural Ecosystems. Washington, DC: Island Press, 1997.
13. Ecological Society of America (ESA). Ecosystem Services: Benefits Supplied to Human Society by Natural Ecosystems. Washington DC:Issues in Ecology No 2, 1997.
14. Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J. The value of the world's ecosystem services and natural capital. Nature 387:253–260 (1997).
15. Vitousek P, Ehrlich PR, Ehrlich AH, Matson P. Human appropriation of the products of photosynthesis. BioScience 36:368–373 (1986).
16. Cairns J Jr, Bidwell JR, Arnegard M. Toxicity testing with communities: microcosms, mesocosms, and whole-system manipulations. Rev Environ Contam Toxicol 147:45–69 (1996).
17. Cairns J Jr, Niederlehner BR. Developing a field of landscape ecotoxicology. Ecol Appl 6(3): 790–796 (1996).
18. Ehrlich PR, Mooney HA. Extinction, substitution, and ecosystem services. BioScience 33:248–254 (1983).
19. Naeem S, Thompson LF, Lawton SP, Lawton JH, Woodfin RM. Declining biodiversity can alter the performance of ecosystems. Nature 368:734–737 (1994).
20. Naeem S, Thompson LF, Lawton SP, Lawton JH, Woodfin RM. Empirical evidence that declining species diversity may alter the performance of terrestrial ecosystems. Philos Trans Royal Soc London B 347:249–262 (1995).
21. National Research Council. Restoration of Aquatic Ecosystems: Science, Technology and Public Policy. Washington, DC:National Academy Press, 1992.
22. Cairns J Jr. The study of ecology and environmental management: reflections on the implication of ecological history. Environ Manage Health 5(4):7–15 (1994).
23. Cairns J Jr, Bidwell JR. Discontinuities in technological and natural systems caused by exotic species. Biodivers Conserv 5:1085–1094 (1996).
24. Cairns J Jr, Bidwell JR. The modification of human society by natural systems: discontinuities caused by the exploitation of endemic species and the introduction of exotics. Environ Health Perspect 104:1142–1145 (1996).
25. Prosterman RL, Hanstad T, Ping L. Can China feed itself? Sci Am November:90–96 (1996).
26. Diamond J. Empire of uniformity. Discover 17(1):78–85 (1996).
27. Farney D. Toxic tailings: Idaho's Silver Valley polluted by mining sparks a legal fracas. The Wall Street Journal CCXXIX:1,8 (1997).
28. Cairns J Jr. Aquatic ecosystem assimilative capacity. Fisheries 2(2):5–7,24 (1977).
29. Cairns J Jr. Quantification of biological integrity. In: Integrity of Water (Ballentine RK, Guarria LJ, eds). Washington, DC:Office of Water and Hazardous Materials, U.S. Environmental Protection Agency, 1977;171–187.
30. Diamond J. The Third Chimpanzee. New York:Harper Collins Publishers, 1992.
31. Taylor JL. Enough is Enough. Minneapolis, MN:Augsburg Publishing House, 1977.
32. Stivers RL. The Sustainable Society: Ethics and Economic Growth. Philadelphia, PA:The Westminster Press, 1976.
33. Birch BC, Rasmussen LL. The Predicament of the Prosperous. Philadelphia, PA:The Westminster Press, 1978.
34. Union of Concerned Scientists. World Scientists Warning to Humanity. Cambridge, MA:Union of Concerned Scientists, 1992.
35. Joint Statement of the Royal Society of London and the U.S. National Academy of Sciences. Population Growth, Resource Consumption, and a Sustainable World. Washington, DC:National Academy Press, 1992.
36. Orr DW, Ehrenfeld D. None so blind: the problem of ecological denial. Conserv Biol 9(5):985–987 (1995).
37. Ehrlich PR, Ehrlich AH. Betrayal of Science and Reason. Covelo, CA:Island Press/Shearwater Books, 1996.
38. Kuhn TS. The Structure of Scientific Revolutions. 2nd ed. Chicago:University of Chicago Press, 1970.
39. Dobzhansky TH. Review of "Evolution, Creation, and Science" by Frank Lewis March. Am Nat 79:73–75 (1945).
40. Robèrt K-H, Holmberg J, Eriksson K-E. Socio-ecological Principles for a Sustainable Society. Stockholm:The Natural Step Environmental Institute Ltd., 1994.

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