Principles of Sustainable Development

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1 AN INTEGRATED APPROACH TO SUSTAINABLE DEVELOPMENT

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As a paradigm and important environmental theme, "sustainable development" is puzzling. On the one hand, the term means what it says; sustainable development means economic development and a standard of living which do not impair the future ability of the environment to provide sustenance and life support for the population. On the other hand, it is more difficult to envision all of the forms and implications of "sustainable development" to relate one's professional career or personal lifestyle to its pursuit.

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Perhaps part of the difficulty comes from the fact that "sustainable development," and the world in which we seek to practice it, cuts across and integrates many diverse disciplines. As humans inhabit and use the natural environment to improve a standard of living, they utilize a large variety of technologies and act, within the constraints of their culture, to transform the environment around them. However, in the twentieth century age of what I call "microspecialization," it is often difficult to see the whole system and how the parts are related to the whole. Therefore, much of what follows in this chapter underscores the importance of an interdisciplinary, "systems" approach in order to treat both fundamental problems and special situations.

In a very real sense, my goal of trying to relate what constitutes sustainable development is very humbling. We recognize that the objectives of sustainable development are to provide for the economic well-being of present and future generations and to maintain a healthy environment and life support system. However, no one truly knows what sustainable development is because we really cannot point to any examples where it has occurred. The wealthier industrial countries do not know about the "sustainable" part and most of the rest of the world does not know about the "development" part. Unfortunately, as we note below with some historical examples of the decline of civilizations, it is easier to cite where it has *not* occurred.

Moreover, it is impossible to lose sight of the fact that sustainable development is not strictly a problem of science or engineering or economics or proper management. The roots are found in values, ethics and culture of both developed countries and developing countries.

This chapter strives to articulate a better, integrated understanding of the imperative for and the many elements of sustainable development. At the same time, although I have attempted to be suggestive about some of the changes and approaches which will be needed, it is not an "action plan" for how to achieve sustainable development.

HISTORICAL PERSPECTIVES ON SUSTAINABLE DEVELOPMENT

Undoubtedly, prior to the highly publicized June 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, relatively few people had heard of the term "sustainable development." Since that time, although it is not exactly a household word, there has been rapidly growing interest among international organizations, the research community, environmental groups and professionals, and business to learn about "sustainable development," to promote it and, in some cases, to get in on the "next wave" of environmental concern.

Lessons from Other Civilizations and Societies

Although the term may be new, sustainable development is not a new phenomenon or concern. On the contrary, the impetus for our present concern dates back thousands of years, as so well illustrated by Dale and Carter in their compelling book, *Topsoil and Civilization.*[1] Two rather dramatic and insightful examples are the civilizations of North Africa, in the vicinity of ancient Carthage (now Tunisia) and Egypt, barely one thousand miles to the east.

At the height of its civilization and power, Carthage had over one million inhabitants and had an abundant food supply from the cultivation and grazing in the fertile lowlands between the coast and Atlas Mountains. Once Rome conquered Carthage and decided to make Carthage a colonial food supplier for the Roman Empire, a cycle of irreversible land degradation began, which impoverished people through history to the present. Rome opted for intensive cultivation with maximum yield per acre and when the fertility began to decline planted even more intensively to "make up" the declining yield. As productivity naturally declined even more, Rome spread cultivation and grazing into marginal and upland areas, triggering a cycle of erosion and declining productivity which ultimately ruined the land forever.

In contrast, civilization in Egypt persisted from the time of Cleopatra until the twentieth century on a "sustainable" basis; the annual spring flooding of the Nile provided both water and a replenishment of soil nutrients. Ironically, now, in the twentieth century, with the construction of the Aswan Dam, this stable system is in decline. In addition to a decline in soil fertility, which had to be supplemented by artificial soil fertilizers, there have also been many other well-documented, severe impacts upon health, sustenance and ecology from the altered hydrology and saltwater intrusion into the delta region.

Similar examples abound on virtually every continent, from the time of ancient civilizations through the Middle Ages and Renaissance periods and to the time of the Industrial Revolution. European countries, ranging from Ireland to Switzerland and Spain, among others, suffered ravages of deforestation, overgrazing and resulting flooding and loss of fertility. Watt presents an interesting theory on the decline of Spain as a naval and world power due to the inability of its limited forest resources to sustain the demands for shipbuilding.[2] Moreover, powerful landlords ("meseta") ruined a vast portion of the central and southern plain through the massive annual "sheepwalks," which denuded the land, changed the soil structure and damaged soil fertility.

Recent Roots of Sustainable Development

In the United States, we have only to think of whaling, the buffalo and the Dust Bowl as historical examples of "*non*sustainable development." It is not widely recognized that the seeds of our present concern with sustainable development were first sowed around the beginning of the twentieth century during the first wave of environmental concern in the United States, as described by Stewart Udall in his classic book, *The Quiet Crisis*.[3] The nation's first forester, Gifford Pinchot, promoted "conservation" as a field of inquiry to determine how the national forests could best serve the nation's many competing

economic interests without depleting the forests over the longer term. At the time, he was vehemently opposed by John Muir, a "preservationist," who, in response to widespread destruction of natural resources during the settlement of the nation, fought to establish forests and wilderness as refuges to preserve the physical stock of nature and the spirit of humans.

As part of the wave of environmental concern in the United States following Earth Day in 1970, air quality became a primary concern and air quality policy began to address "sustainable development"—although, of course, that term had not yet been used—through questions of how to balance air quality and economic development. There were at least three contexts. One was the (continuing) question of how to enable continuing economic growth and development in areas which do not meet ambient air quality standards. A second concern was to ensure that continuing growth and development do not cause unsatisfactory air quality at a future time (air quality maintenance). A third, still important, context was the "prevention of significant deterioration" in wilderness regions which had pristine air. Generally, these approaches prescribed "technological retrofits" to specific polluters by rationing small increments of clean air at a time.[4]

More fundamental and controversial questions about the roles of population, resource consumption, environmental pollution and technology surfaced in the early 1970s during the so-called "Limits to Growth" debate. Under sponsorship of the prestigious Club of Rome, research by a group of scholars projected dire future global environmental consequences from some simplifying assumptions and extrapolations about population and resource growth rates.[5] Much furor and controversy resulted when these *projections* became widely interpreted in the media as *predictions*. Because, too, these projections neglected the capacity of humans and technology to adapt—about the same time as the "Green Revolution" demonstrated a capacity to greatly increase food production—the work became discredited for a while.

At the same time, it is important to note that on the twentieth anniversary of their original study, the authors updated the results in a new book, *Beyond the Limits*.[6] Using recent data and trends, the authors reached the same conclusions but underscore that environmental decay and economic decline are not inevitable provided that growth in population and material consumption is not perpetuated and provided that there is a drastic increase in the efficiency of use of materials and energy through technological improvements.

Aside from these projections of the future, contemporary issues and experience—ranging from tropical rain forests and global climate change to the Gulf War to the rapid economic and population growth in some developing nations—point out the necessity to live within the carrying capacity of the earth's ecosphere, to make the global economies more efficient in the use of natural resources and to reduce population pressures. There are, in fact, "limits to growth," and it is vital to ask (1) what kind of growth is desirable, (2) what kind is not and (3) how to develop economic policy and environmental policy accordingly while maintaining consumer choices and a sense of equity within a market economy.

DEFINING AND UNDERSTANDING SUSTAINABLE DEVELOPMENT

At the 1992 U.N. Conference on Environment and Development in Rio, UNCED Principle #3 characterized sustainable development as "the right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations." UNCED Principle #4 further states: "in order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it." These two principles, stated as part of the U.N. Conference Agenda 21, have

some very profound implications for use and stewardship of natural resources, ecology and environment, as I discuss later in considerable detail.[7]

For present purposes, it is important to ask: What does it mean to "equitably meet developmental and environmental needs of present and future generations"? I suspect that international dissension within the United Nations over Agenda 21 indicates that the answer is far from complete. Nonetheless, the "spirit" of Principle #3 would seem to indicate a "fairness" in meeting the needs of all peoples in the present generation, a "fairness" in meeting the needs of future generations as well as the present generation and a "balance" between development and environmental preservation.

There is a tendency in official gatherings and communiqués and agency programs to focus upon areas of consensus and very specific "missions." Issues of controversy are swept aside, and the operating principle is that continued economic growth and new technology will solve problems of poverty and environment for all peoples. Notions of "social change" or "zero-sum" economics" and "sacrifice" are politically incorrect. Yet, as noted in the following section, there is a considerable body of scholarly thought and research which indicates that sustainable development must include a major transformation of society. Consequently, in listing elements of sustainable development (Table 1.1), I have included some of the more fundamental, root causes, as well as economic, environmental and technology dimensions which are more frequently mentioned.

Indeed, we cannot attain sustainable development without better technologies which will enable us to "stretch out" scarcer nonrenewable resources and to utilize renewable resources. Nonetheless, although the focus of this chapter and book is not on social change, it is important for environmental professionals, economists and ordinary citizens alike to recognize that there are limits to what can be accomplished by technology.

TABLE 1.1 Elements of Sustainable Development

- Population stabilization
- New technologies/technology transfer
- Efficient use of natural resources
- Waste reduction and pollution prevention
- "Win–win" situations
- Integrated environmental systems management
- Determining environmental limits
- Refining market economy
- Education
- Perception and attitude changes (paradigm shift)
- Social and cultural changes

Ethics and Culture

It would be impossible to try to define sustainable development without discussing the importance of ethics and culture. The subjects of ethics and culture tend to make many individuals, including scientists, engineers and politicians, very uncomfortable. After all, isn't every person entitled to his or her "pursuit of happiness"? What "right" do any of us have to tell another person how to live (unless, of course, that person happens to be a relative or close friend, in which case it is our inalienable right!)? And, anyway, isn't there a certain inevitability to progress and new technology, and isn't the "free market" the best judge?

These questions have been debated, of course, with respect to every social issue imaginable, but the point here is to emphasize that ethics and culture are no less important with respect to sustainable development than with respect to other issues such as birth control, gun control, redistribution of wealth, etc. Furthermore, upon a minimal amount of reflection, it becomes obvious that many other social issues are closely linked to "sustainable development."

The ethical dimensions of sustainable development are twofold: (1) our relationship to fellow inhabitants of our country and planet and (2) our relationship to the land and plant and animal inhabitants of the world. If many environmental professionals are shy, there is no shortage of ethicists, theologians and environmentalists willing to address these questions.

Is it immoral that the United States has to import over one-half of its energy supply? Or that a child born into the culture of the United States will consume 30 to 40 times per capita the energy and natural resources of the "average" of the rest of the world and 200 times as much as several undeveloped countries? Anglican Archbishop John Taylor believes so. In his provocative book *Enough Is Enough,* Taylor discusses environmental theology; based upon Judeo-Christian theology, he offers practical guidelines for a more responsible consumerism which promotes personal fulfillment and sharing but also reduces unfulfilling, unnecessary consumption.[8]

When so much of the fossil fuels and critical mineral resources have to be imported by the United States and other Western countries, there is much that has to be reformed within our cultures to set us on a path towards sustainable development. Notwithstanding the importance and role of technology, economics and better management strategies, many scholars are convinced that the only real hope for sustainable development is a radical shift in society.

Calculations by Adler-Karlsson demonstrated that a doubling of the population of the poor countries increases the consumption of world resources by one-sixth as much as doubling of the population in rich countries.[9] Carol and John Steinhart have observed that "the best energy technology can do is make things tidier while we struggle to change our habits." Stivers argued for "a new world view involving a radical change of attitudes and values."[10] Birch and Rasmussen note that "history's testimony is that the most far-reaching change comes only with the combination of strong pressures, from within and without, and a compelling alternative vision."[11]

These statements were written during the 1970s. Perhaps the reader can ponder whether the United States is beginning to see strong external pressures in the form of situations involving the Gulf War, Haiti, Cuba, Mexico and Somalia and strong internal pressures stemming from structural economic changes and social alienation and decay. No one knows what the "compelling vision" will be, but many scholars have suggested that it will have to be something of religious proportions. Both Taylor and Birch and Rasmussen have suggested the (Old Testament) concept of "shalom," or wholeness and harmony in relationships with neighbor and creation.

From the perspective of developing countries, the essence of sustainable development is to promote development which (1) reduces the disparities in lifestyles and global consumption and (2) improves and maintains a healthful local environment and (3) then, *and only then,* contributes towards solving critical global environmental management of the global "commons"—such as global climate change, oceans and fisheries, and forests.

There tends to be a wide spectrum of environmental ethics ranging from a belief that all plants and animals are on earth to serve humans to a belief that all life is part of creation and must be respected and protected. These two polar views, held respectively by "conservationist" forester Gifford Pinchot and "preservationist" John Muir, were the source of much acrimony during the spread of the first environmental movement within the United States towards the end of the nineteenth century. It should be pointed out, however, that mainstream religious denominations and theologians generally proclaim an intermediate view that plant and animal life and natural resources are on earth to serve

humans, but that we also have a "stewardship" responsibility to care for the earth and its life.

Many economists take the "utilitarian" point of view that other species do not have an intrinsic worth and that, therefore, ecological protection should be based upon whether the species or habitat provides a direct economic benefit or indirect benefit through maintaining an ecological system.[12] In reality, human civilization and its diverse cultures, from traditional hunters and gatherers to sedentary agriculture to manufacturing to high technology, have already caused the extinction of many species and are encroaching upon the habitat and threatening the survival of thousands of others. To help resolve future conflicts between land use and economic activities and the survival of habitat and species, I believe that it is important to further develop and implement a set of criteria for setting priorities in the protection of plant and animal species and habitat.[13]

The Interaction of Whole Economic and Natural Systems

Note, too, in Principle #4 that making environmental protection an "integral part of the development process" is much *different from* the traditional pattern of making economic decisions and then correcting the environmental impacts which may result. It is a critical aspect of sustainable development that the *interaction* and *feedback* between the economic system and the environmental system be evaluated so that development can proceed in ways which will *prevent* and *reduce* environmental impacts.

Let us illustrate by examining the conceptual model in Figure 1.1. The interaction of the natural system and economic system and the flows of materials and energy are illustrated. It is important to note that as the term is being used here, the "natural system" includes the ambient physical environment, ecosystems and natural resources. The "economic system" refers to the fac-

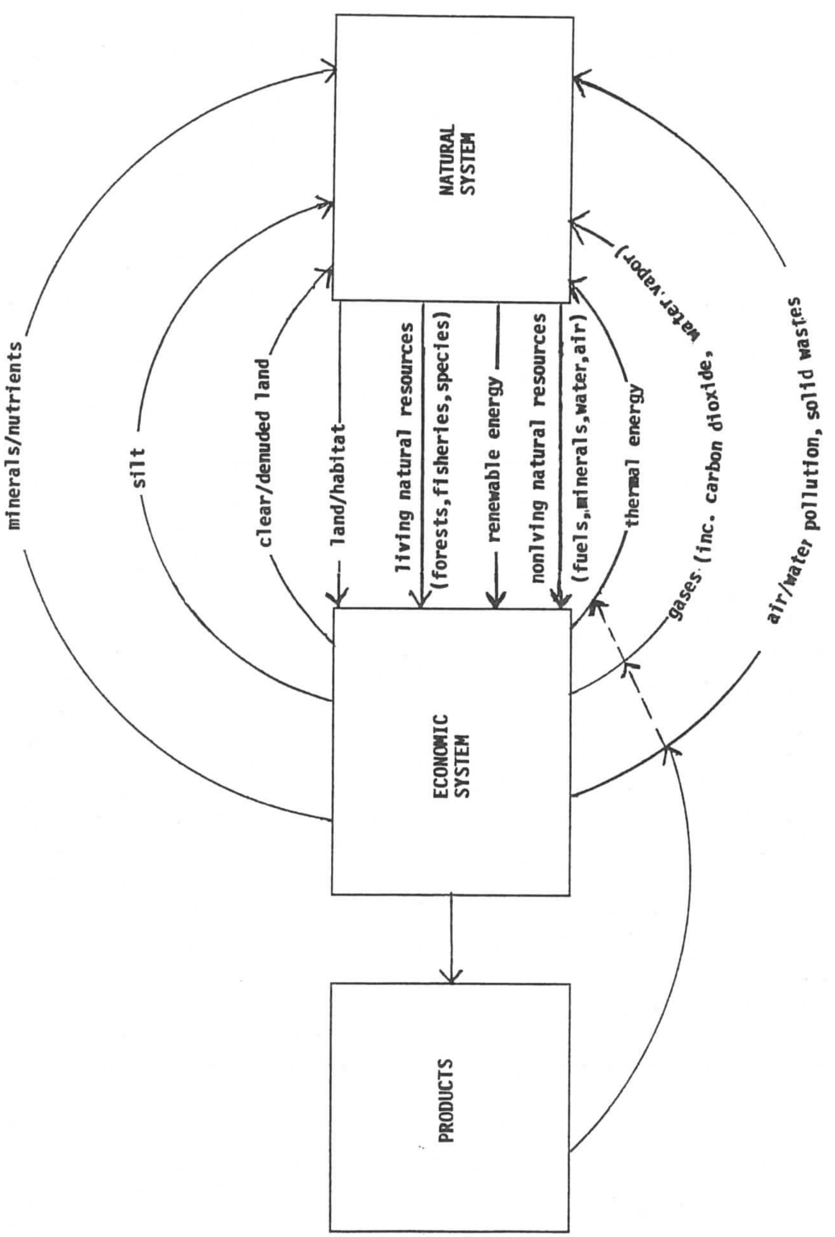

FIGURE 1.1 Conceptual interaction of economic and natural system.

tors of production for goods and services.[14] For purposes of conceptualization and discussion, the systems are generalized, but, as will be noted later, these "boxes" can be applied to specific economic sectors and products.

The purpose of Figure 1.1 is to illustrate the interactions in terms of (1) the kinds of input demands and stresses that the economic system places upon the natural system and (2) the waste outputs and stresses which the economic system places upon the natural system. With respect to the input demands posed by agricultural, industrial, commercial and residential economic sectors comprising the whole economic system, there are a few broad categories of stresses including: (1) the conversion of land and habitat to other uses; (2) ecological depletion and possible extinction of living species through harvesting, hunting, fishing and habitat conversion and (3) consumption of nonliving mineral and fossil fuel resources.

In terms of the outputs and stresses which the economic system places upon the natural system, again some broad categories are noted, including (1) air and water pollutants and solid wastes; (2) greenhouse gases, such as carbon dioxide, water vapor and other "trace" gases, and thermal energy; (3) "altered" land, which may have been cleared, denuded or paved and (4) silt, minerals and nutrients, resulting from erosion, runoff and decay products from both organisms and solid wastes.

From the standpoint of sustainable development, it should be observed that the importance of these impacts upon the natural system varies greatly geographically, dependent upon the existing states of both the natural environment and the economy. The United States has been slow to come to grips with its high per capita demands for natural resources. Although the high per capita consumption of energy and mineral resources is well documented, little attention has been given to the continuing loss of prime farmland. According to the U.S. Department of Agriculture, the United States lost 4 million acres of prime farmland to development during the period 1982–92, an increase of 18% in developed land compared to a 9% increase in population.

The loss of prime farmland, together with widespread soil erosion and soil profile changes, are examples of what can be considered an "*environmental deficit*." That is, analogous to an economic budget deficit which is repaid by and at the expense of future generations, environmental systems and natural resources are frequently consumed at the expense of future generations. In some cases, such as in the change of soil structure, the damage may be permanent. Similarly, with respect to soil erosion and certain nuclear wastes, damages cannot be reversed over many thousands of years. In other cases, such as toxic pollution of lake sediment and aquifers, the time frame may be almost as bad. On the other hand, in some instances, such as with certain forest regeneration and wetland regeneration, the restoration can be more timely.

Perhaps the first constructive step towards dealing with this "deficit" problem is the recognition that it exists. Towards this end, the U.S. Department of Commerce has recently developed a new indicator of Gross Domestic Product (GDP), which subtracts the consumption of natural resources and the costs of pollution and adds the benefits from improvements in environmental quality.

Fixing the Economic System Relations

There are several basic, underlying reforms needed throughout the whole economic system to reduce both the natural system inputs and the pollutant and waste outputs. First, with respect to the manufacturing sector, there must be more efficient product design and more efficient manufacturing processes and quality control (more on this later). There is a tendency to associate such modifications solely with the manufacturing sector. However, other reforms are also needed within the agricultural and commercial sectors as well. Careful farming methods, land use planning and proper construction practices can all reduce soil erosion. Better land use and transportation planning are necessary to reduce pollutant emissions and impacts. And new communications technology will likely reduce the amount of business travel, commuting and transportation pollution.

Another basic reform required to better integrate protection of the natural system within the macroeconomy is a shift or economic substitution for the inputs. For example, economic substitutions include a shift from fossil energy inputs to energy efficiency and renewable energy, a shift from a virgin resource to a recycled input and a shift from prime agricultural land development towards other lands. Achieving sustainable development in developing countries may even require some surprising shifts, such as from one form of renewable energy (wood biomass) to another form of renewable energy, or even a shift from wood to a fossil fuel (coupled with efficient energy use).

Economic Incentives

"The market" focuses upon profit and tends to allocate and reward investments with short-term paybacks. Some desirable policy outcomes, such as protection of the environment and conservation of natural resources, traditionally have not been achievable through reliance upon the market. Hence various programs of government regulation have evolved. Although government regulation has generally succeeded in meeting other, "noneconomic" goals, there has been increasing dissatisfaction from all sides. Slow response, slow adaptability to changing conditions, lack of innovation, excessive adjudication and expensive solutions—these have all been undesirable effects of government regulation.

The question becomes how to effect these kinds of more efficient product designs, manufacturing processes and economic substitutions of inputs. Invariably, as the world shifts more and more towards a global, free-market economy, these shifts and economic substitutions will have to be guided by economic incentives of various types. Closely related to the use of economic incentives, however, is manufacturer awareness of alternatives, consumer awareness and concern, changes in corporate culture and a concern for life cycle costs of processes and products. Many such "barriers" must be overcome before economic incentives can be fully effective.

Historically, within the field of environmental economics, economic incentives have been frequently viewed as either a form of payment or subsidy (incentive) or a form of tax (disincentive) or a combination of both, which is sometimes referred to as "push–pull." In a broader sense, however, more basic tools such as targeted investment tax credits can be important incentives to stimulate investment in more efficient manufacturing processes and to adopt the life cycle costing approach discussed below.

Other Western countries, more than the United States, have relied upon tax policy to reduce resource consumption and environmental impacts. Increasingly, though, environmental laws call for emission charges and fees as a disincentive for polluters. The present effort to revise tax policy to replace tobacco subsidies with tobacco taxes to pay for health care demonstrates a kind of "push–pull" tax policy; similar policies could eventually become more widespread as "sustainable development" issues such as global climate change, land use and prime farmland protection become more prominent.

However, it should be recognized that there are also various other powerful kinds of economic incentives beyond those defined by government economic policies. Undoubtedly, the strongest kind of incentive is a "bottom-line" cost saving through efficient operation, which means minimizing the input of energy and raw materials for operations and reducing waste. Related to this must be an increasing awareness and adoption of "life cycle costing" of products so that performance, durability and operation costs are taken into account for the lifetime of the product.

This neglect has generally hampered the adoption of state-of-the-art energy efficiency for homes and offices and factories. At least in Western countries, another important kind of economic incentive is the marketing and promotional value derived from consumer preference of "green" products.[15]

In the case of developing countries, there is *potentially* a particularly powerful economic incentive which could be used to promote sustainable economic development: international bank and lending policies. Unfortunately, this leverage is frequently not used in practice. Moreover, the increasing trend towards "privatization" with creative, private financing of projects in developing countries means that private profit interests can supersede public interests in sustainable development. For example, repeating the pattern of development in the United States, one of the more disturbing global trends in developing countries is the avalanche of electrical power plant construction, *without* strong accompanying energy efficiency programs, life cycle costing and full-cost accounting.

In fact, the preceding underscores the fact that there will always be a need for some regulation to promote public interests which would otherwise be overwhelmed by private interests. However, to the extent that incentives can be incorporated successfully within the economic system, environmentally sustainable development will be obtainable more quickly and at a generally lower cost than by regulation.

A NEW KIND OF ECONOMIC GROWTH

The U.N. World Commission on Environment and Development (WCED) observes, "Sustainable development requires a change in the content of growth, to make it less material and energy-intensive and more equitable in its impact."[16] In a global, "open" economy, the interactions between the economic and natural systems affect transfers at regional levels from one region to another. Thus, a related feature is that the economic demands from one region can cause problems of economic equity and human welfare and stresses upon the natural system in another region. For example, in developing countries, exports of cash crops and natural resources may reduce the land and natural resources available to sustain the local population and concentrate the wealth from exports among a relative few.

The above statement by the WCED raises issues which, in fact, are not new. Around the time of Earth Day 1970, both economists and environmentalists were discussing the question of changing the content of economic growth "to make it less material and energy intensive" and more equitable in its impact. In contrast to the traditional "cowboy" economy which fostered independence, recklessness and waste, economist Kenneth Boulding introduced the concept of a "spaceship economy." As the finite spaceship required the interdependency of the people and systems, a finite world requires people to work together within the limits set by the natural system and requires efficiency in our use of resources and care in our use of the environment.[17]

During a long career, economist E.F. Schumaker was concerned with economic development and equity—promoting the "right kind" of economic growth and factors of production which improve *local* employment and well-being. Although Schumaker was definitely out of the mainstream of a world which is concerned with maximizing growth rates, many of his tenets about culture, technology transfer and sustainable development projects are—finally, after his death—beginning to receive serious attention.[18]

Commoner's Simple Model

In a previous section, the interaction of the whole economic system and environmental system at a fundamental, highly aggregated level was discussed. However, let us suppose that the

"economic system" box in Figure 1.1 now represents a specific product category such as electric power, automotive horsepower, plastics, wood pulp, etc. Then Figure 1.1 represents the stresses upon the natural system resulting from (1) the inputs demanded by the product category from the natural system and (2) the waste and pollutant outputs from the product category.

Commoner was concerned with the latter in an analysis of the origins of environmental impacts in the post-war U.S. economy.[19] For a large variety of economic goods (products), Commoner defined an "index of environmental impact" (which is really pollutant emissions) through the following relationships:

$$\begin{aligned} \text{Pollutants per Product} = \; & \text{Population} && \text{(population)} \\ & \times \frac{\text{Product Output}}{\text{Population}} && \text{(affluence)} \\ & \times \frac{\text{Pollutants}}{\text{Product Output}} && \text{(technology)} \end{aligned} \tag{1.1}$$

AN INTEGRATED APPROACH

Two examples of the kind of analysis performed by Commoner are given in Table 1.2. It is important to note in the above parentheses the interpretations of the three terms as given by Commoner. These interpretations are however, I believe, a bit simplistic. The second factor relating to per capita consumption of a good is indeed related to economic affluence, but consumer decisions are also related to culture and awareness. Similarly, the third factor which relates pollution to the amount of product produced is indeed related to technology and technological changes, but is also related to economics, regulation and corporate culture. Notwithstanding these criticisms, Commoner was

TABLE 1.2 Applications of Commoner's Model for Environmental Degradation

Synthetic Organic Pesticides: Environmental Impact Index

	Index factors (a) Population (1,000)	(b) Crop production[a] / Population (crop production units/cap.)	(c) Pesticide consumption / Crop production (1,000 lb/prod. unit)	Total impact index (a × b × c) Synthetic organic pesticides (million lb.)
1950	151,868	5.66×10^{-7}	3,326	286
1967	197,859	5.96×10^{-7}	8,898	1,050
1967 : 1950	1.30	1.05	2.68	3.67
Percentage increase, 1950–1967	30	5	168	267

[a] The crop output index is an indicator of agricultural production; 1957–59 average = 100.

Nitrogen Oxides from Passenger Vehicles: Environmental Impact Index

	Index factors (a) Population (1,000)	(b) Vehicle-miles / Population	(c) Nitrogen oxides[a] / Vehicle-miles	Total impact index (a × b × c) Nitrogen oxides
1946	140,686	1,982	33.5	10.6
1967	197,849	3,962	86.4	77.5
1967 : 1946	1.41	2.00	2.58	7.3
Percentage increase, 1946–1967	41	100	158	630

[a] Dimension = NO_x (ppm) × gasoline consumption (gal. × 10^{-6}). Estimated from product of passenger vehicle gasoline consumption and ppm of NO_x emitted by engines of average compression ratio 5.9 (1946) and 9.5 (1967) under running conditions, at 15 in. manifold pressure: 1946, 500 ppm NO_x; 1967, 1,200 ppm NO_x.

Source: Originally published as Tables 3 and 7 on pages 46 and 57, respectively, in Reference 17.

able to present a rather convincing case, as in the examples in Table 1.2, for the relative importance in the changes in population, economic demand and technology as they affected the dramatic growth of pollution from different economic activities in the post-war period.

Aside from the specific sectoral analysis, part of the appeal of Commoner's work is that he attempted to analyze some fundamental causes for the dominant environmental problem of the time. It is perhaps interesting to also note that, in a far less technical fashion, an environmental theologian, Charles Birch, also developed a similar conceptual approach for analyzing root causes of environmental decay.[20]

Applying the Model to Sustainable Development

With respect to sustainable development, Commoner's simple approach can be adapted to provide some insights into how to "change the content of economic growth, to make it less material and energy-intensive." Although he was concerned with waste and pollutant outputs, a similar formulation can be used to examine *inputs* demanded by a specific product or economic sector from the natural system, as follows:

$$\text{Natural Resources Input per Product} = \text{Population} \times \frac{\text{Product Output}}{\text{Population}} \times \frac{\text{Resource Input}}{\text{Product Output}} \qquad (1.2)$$

Any resource of interest (e.g., energy, metals, wood, land, etc.) could be analyzed in this fashion to determine the relative importance of fundamental factors in the demand for inputs. For example, two such formulations could be:

$$\text{Fossil Fuel Energy Input to Steel} = \text{Population} \times \frac{\text{Steel Output}}{\text{Population}} \times \frac{\text{Energy Input}}{\text{Steel Output}} \qquad (1.3)$$

or

$$\text{Land Input to Housing} = \text{Population} \times \frac{\text{Housing Output}}{\text{Population}} \times \frac{\text{Land Input}}{\text{Housing Output}} \qquad (1.4)$$

Viewed in this manner, from the general formulation (Equation 1.2) above, any measure which serves to reduce the factors on the right-hand side will reduce proportionately the natural resource inputs required for a given economic product. The first observation is the direct importance of population in sustainable development. The coupling of the substantial populations in developing nations and their desire to become economic consumers like the Western nations is an emerging cause for global environmental concerns and a major driving force for sustainable development.

Therefore, it is essential for the Western countries, for reasons of both "fairness" and their own self-interest, to become "better mentors" in their consumption of natural resources. We can begin by using the above scheme to ask the following questions:

(1) Is it desirable or feasible to effect behavioral changes to reduce the per capita consumption of the product (second term)?

(2) What technical means are available to reduce the resource input per unit of product output (third term)?

Per Capita Consumption

Occasionally, in specific instances which are regarded as being important to the general health and well-being, there are efforts by the government or public interest groups to intervene to change consumer habits (e.g., smoking, energy conservation education, safe driving, eating habits or products from endangered species). In the short term, there are already many individual examples whereby an informed, aware consumer may wish to shift consumption from one product to another for reasons of health, economics or consumer satisfaction—and at the same time promote "sustainability"—a "win–win" situation.

For example, by reducing electric power consumption, the consumer saves money and reduces fossil fuel inputs. By reducing consumption of corn-fed beef for health reasons, a reduction in energy and agricultural chemicals is also brought about. By purchasing a smaller house, the consumer can save money, reduce maintenance and increase leisure time, and reduce natural resource consumption.

In a free society, any large shifts in consumerism, such as becoming a less materialistic and consumptive society, are necessarily dependent upon values and major social and cultural changes over long periods of time. Such changes must overcome a lot of skepticism among both economists and consumers about the nature of economic growth and what would happen to the consumer-based economy if there were a decided longer term shift towards a less materialistic society. For a long time, environmental quality—clean air and clean water, for example—was thought to be a "drag" on the economy and jobs. It was just not perceived that consumers could choose to demand more clean air and more clean water in the sense that they could demand

other economic goods. Now, however, it is widely recognized that the demand for environmental protection creates jobs.

In the same way, in the long term, possible future shifts in consumer demand towards fewer but more durable goods and more services (e.g., "online," arts, recreation, etc.) are compatible with a healthy economy. This is not to imply that there is no concern about dislocations of products and jobs; for example, the U.S. automobile industry requires time for planning and adaptation. However, there is no reason to fear cultural changes and related changes in the economy over time. Historically, in fact, the interaction of culture, technology and the market economy has demonstrated that every product and service in the marketplace has its so-called "S" curve, featuring stages of rapid growth, slower growth, stability and decline.

Reducing the Inputs

It is important to note that the extent to which we are able to reduce the ratio of "material inputs to product outputs" over time, either by efficiency or substitution methods discussed below, is an important indicator of technological progress towards sustainability. Thus, in conjunction with the kind of product life cycle analysis discussed earlier, it is important to evaluate trends in this ratio.

More Efficient Use of Inputs

During the past decade, "bottom-line" priorities and competitive pressures have shaped an emphasis upon more efficient manufacturing processes which (1) use inputs more efficiently and produce less waste per unit of output and (2) have better quality control and produce less waste. More recently, the design of the product itself, size and packaging are becoming recognized as important means of reducing resource inputs. An emerging field of product "life cycle design" is studying ways to promote sustainability, including the use of component parts which can be recycled.[21]

Substitution of Inputs

Somewhat related to the previous concept of product design is another method of reducing resource inputs: a substitution of inputs. The idea is to substitute a more plentiful resource for a critical or less plentiful resource. There are several kinds of substitutions which are possible for manufacturing. Substitutions can include one nonrenewable resource for another (steel instead of tin), a renewable resource for a nonrenewable resource (wood or biomass-derived chemicals instead of petrochemicals), one renewable resource (maple wood) for another renewable resource (mahogany) or, as in the production of music keyboards, a renewable resource (wood) or even a nonrenewable resource (plastic) for an endangered resource (ivory).

Such substitutions are also critical for the economies in developing countries. In most cases, countries must utilize abundant local natural resources such as sand, stone, wood and fossil fuels for housing and fuel, respectively. However in other cases, they must try to protect diminishing natural resources, such as forests, from population pressures.

Despite the above examples as to how a substitution of inputs can promote sustainable development, the opposite is often true in practice. That is, for reasons of product economics, performance and consumer preference, there are frequently substitutions which utilize more critical resources and nonrenewable resources. For example, over the past two decades automobile construction has shifted away from steel towards aluminum and now plastic. Rubber tires are no longer made from natural rubber. Containers have shifted towards plastics.

This situation makes one particular kind of substitution increasingly important for sustainable development: a recycled input. As part of the emerging "life cycle design" noted above, products are being designed so that the components can use recycled materials and so that the components themselves can eventually be recycled. Economist Herman Daly suggested the ultimate, idealized goal of a "stationary state" economy which minimizes what he referred to as the "throughput" by reusing and recycling.[22]

A few products in which the United States is the world leader but which would never come to mind are iron and steel scrap metals and waste paper. These waste products have economic value in large measure due to the energy saved in using the waste scraps versus processing raw materials. So, the United States exports the waste products, and many countries, particularly the Asian countries, in turn produce finished products like steel, paper, autos and appliances. This is not to suggest that U.S. manufacturers are stupid or unaware; there are many complicated factors and domestic "barriers" to the use of recycled materials which led to this situation.

Increasing the Value-Added of the Resource

Computers and software, communications technology, aerospace, agricultural products, perhaps even environmental control technology—these are products in which the United States is a world leader. In most cases, these products share the fortunate economic trait of having a high "value-added." That is, above and beyond the economic value of the natural resources in the product—the cost of the silicon and metal comprising computer components is rather minimal—there is considerable value added to the product by the sophisticated technology, professional engineering and design, and worker skills.

In the context of sustainable development, one way of reducing the natural resource input per unit of product is to improve the quality and durability of the product; that is, to manufacture a "better," more expensive product. A second way, as we have noted above, is to develop technology and economic incentives which will facilitate greater use of scrap materials. A third way to increase the economic output from the resource is to shift the product itself to another product. For example, if there are limitations upon the amount of forest that can be sustainably harvested, instead of exporting timber or lumber (the next higher valued product above timber), it may be desirable to produce furniture or doors or cabinets or prefabricated housing.

Pollution Prevention and Waste Minimization

Before concluding this section, recall that I began with an observation from the U.N. World Commission on Environment and Development 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. Therefore, I discussed some approaches towards reducing the inputs of natural resources required for individual economic products. However, as we have noted previously, actions taken to reduce the economic inputs will also reduce the wastes and pollutants produced by the economic system.

Thus there is a close relation between the above approaches and the concepts of "pollution prevention" and "waste minimization" discussed in other chapters. Pollution prevention emerged during the 1980s as perhaps the most important environmental paradigm of the decade; it was originally developed by a handful of corporate giants acting in their enlightened self-interest to save money on the costs of production and the costs of air and water pollution control.[23] Methods of pollution prevention include changing industrial processes, changing the inputs to industrial processes, reusing industrial wastes, using industrial energy more efficiently and changing product design. Subsequently, the concept expanded to embrace waste minimization for analogous methods of reducing solid and hazardous wastes.

One specific related issue deserves mention, however. Since considerable pioneering research undertaken during the 1970s at Resources for the Future in Washington, D.C., it has been recognized that beneficial, economically efficient trade-offs among the components of the environmental media can be obtained with certain changes in manufacturing processes. For example, a decrease of 50% in water organic emissions might be achieved with a process that increases air sulfur dioxide emissions by 10%.

Because the evolution of regulatory policy in the United States has been towards singular pursuit of specific air and water pollutants, an efficient, integrated "multimedia" presents formidable legal obstacles. Despite some recent attempts towards "multimedia" management concerns, there is still a long way to go. Hopefully, other countries can develop more flexible approaches in their emerging environmental management programs.

Win–Win Strategies in Sustainable Development

In the course of other discussions I have alluded to the fact that there exist possible "win–win" situations; that is, taking actions which will meet more than one objective at the same time. I believe that an important component of sustainable development in the near term should and will be efforts to identify and promote "win–win" development strategies and policies which can simultaneously help meet both development objectives and environmental objectives. Certainly, these "win–win" types of policies are more capable of generating public, private and political support than policies which are perceived to simply restrain development. And some of these policies can also be helpful immediately while we grapple with changes in our technology, economic system, thinking and behavior.

There are a few specific categories of "win–win" situations which deserve more explicit mention than previously given. One category is agriculture, a form of renewable resource. In some developing countries, land is used almost exclusively for the production of so-called "cash crops." Another possibility, which promotes both renewable resources and economic development, as Brazil has shown, is to produce biomass-derived chemicals and fuels.

However, there are also important benefits from shifting some land use from cash crops, generally owned by large landowners, to more food production with individual land ownership. The population will be better fed, and better land stewardship is generally possible. Of course, "cash crops" are an important economic base which serves to pay for imports and taxes; however, the wealth tends to be concentrated and much of it flows for purchase abroad rather than stimulating the local economy. Often it will also be necessary to effect a degree of land reform and transfer of power and wealth.

From a U.S. perspective, our present agricultural system can be characterized as an amazing success story in agricultural output, but one which is completely nonsustainable with present methods. The vast increases in agricultural output and consumer choice have come at the expense of methods which have cost approximately one-half of the topsoil and have required a "subsidy" of about ten calories of fossil-fuel input for farming, processing, distribution and preparation for each calorie of food output. In the long run, it is also desirable that agricultural policy help effect a return of the farming occupation and the "family farm." This will help to provide economic opportunities and improve rural economies and also likely will promote better care of the land (a family tends to be interested in maintaining and not "depreciating" the land).

A second kind of "win–win" situation for sustainable development, an extension of a prior discussion, is to manufacture new products from recovered waste products—solid wastes (rubber, plastics, scrap metals, papers), agricultural and organic wastes (in excess of those needed to maintain soil fertility) and animal and human wastes. Many states, such as New York, now have considerable departments within their respective economic development agencies which are dedicated towards promoting and providing incentives towards these goals and overcoming some of

the traditional market barriers. Many successes are *beginning* to occur, such as the recovery and remanufacture of plastic products like packaging materials.

Energy Efficiency and Renewable Energy: The Ultimate Win–Win Situation

Clearly, energy is a critical factor in sustainable development. On the one hand, the high per capita consumption of fossil fuels by the United States and other Western nations is nonsustainable, and on the other, the developing countries are seeking to become more like the West in lifestyle and technology. Energy costs are an important component of industry competitiveness and consumer expenditures, and the environmental impacts of fossil-fuel energy are far-reaching.

With respect to renewable energy, although many technologies of the future, such as solar photovoltaic power, are not generally economically competitive now, there are a variety of niche applications which are. Wind power is particularly well suited to powering small communities and irrigation, and solar photovoltaics is well suited for remote areas away from a transmission grid. Some forms of biomass wastes, ranging from agricultural to manures, are also a renewable form of energy, undoubtedly more widely used in the developing countries than the developed countries. The "piggybacking" of certain alternate sources of energy is also possible.[24]

Several years ago at a conference, I made the comment that energy conservation is an important strategy to combat air pollution; in response, I well remember receiving a number of blank stares of bewilderment. Thus, despite the fact that the major source of conventional air pollution, photochemical smog and acid precipitation alike is fuel combustion, these issues have been widely perceived as pollution issues, not as energy issues. Consequently, environmental management strategies have successively focused upon these issues as separate problems requiring separate programs and technologies to clean up pollution from fuel combustion. However, simultaneous "win–win" situations exist by preventing pollution through more efficient use of energy.

Fortunately, perception of the emerging greenhouse issue of global warming is different, although its major cause, energy consumption, remains the same. This situation provides an important environmental "win–win" opportunity; energy efficiency measures taken to reduce the consumption of fossil fuels will not only reduce the emission of carbon dioxide, a major greenhouse gas, but will simultaneously reduce the emissions related to several other atmospheric pollution problems as well.

Energy efficiency has several economic benefits as well. Because energy efficiency reduces the costs of energy, the local and national economies are helped in several ways: (1) domestic manufacturers can be more competitive, (2) corporate and consumer disposable income is increased, (3) more of the latter is spent in the domestic economy, (4) the vulnerability of the domestic economy to international oil prices is reduced and (5) new jobs are created in energy efficiency. New technology for lighting, industrial motors and household appliances allows truly amazing energy savings of 30 to 60% now.[25]

Because the other resource conservation, environmental and economic reasons for energy efficiency are compelling in their own right, it is not necessary to wait until all the facts are in to begin to take action against global warming. Moreover, a widely touted U.S. Environmental Protection Agency report concluded that delaying by a few decades could increase the global warming commitment by 30%.[26] In response to the 1992 United Nations Conference on Environment and Development in Rio, the United States is taking a leadership position by adopting a voluntary program, the President's Climate Change Action Plan.[27]

Although this program is relatively modest, it is a beginning. A compelling goal for sustainable development and global climate policy alike will be to further integrate environmental, energy and economic policy to provide "win–win" situations. As I have written elsewhere, there are three components which are essential towards this goal:[28]

(1) Adopting a holistic environmental management framework for related environmental problems and solutions

(2) Fostering a creative combination of regulation, incentives and penalties to guide consumer, industry and the marketplace

(3) Research and development initiatives that emphasize the *utilization,* as well as the development, of energy efficiency and renewable energy technology

SUSTAINABLE DEVELOPMENT AND THE AMBIENT ENVIRONMENT

The Role of Assimilative Capacity in Environmental Management

In the previous section, I discussed sustainable development from the perspective of trying to change the content of economic growth to become "less material and energy intensive and more equitable." As necessary as this objective is towards the goal of achieving sustainable development, it is not sufficient. If the broad objectives of reducing resource consumption inputs and reducing pollutant outputs are achieved, neither will be achieved absolutely. Nor will population growth be stabilized in the foreseeable future. Hence, there will always be stress upon the ecology and ambient physical environment.

Originally, the concept of a "sustainable yield" was applied to enable the harvest of ecological renewable resources, such as forests and fisheries, at the same rate as nature (assisted by human management) was able to replenish.[29] There are limits as to what nature will permit without damaging the ecological system and resource base. Similarly, environmental scientists have come to recognize that the physical, chemical and biological characteristics of the ambient environment determine the ability to accept, dilute, diffuse and transform pollutants; this "assimilative capacity" limits the amount of pollution tolerable without causing damages.

This principle holds whether one is considering a very localized thermal pollution plume in a river, a regional air pollution problem or a global climate change. In general, as the geographical scale increases, however, the complexities and interactions of natural scientific processes also increase. Thus, to achieve sustainable development, in all cases we must be concerned with the "assimilative capacity" of the environmental system, which in turn determines the "carrying capacity" for supporting population and economic activity and resulting pollutant emissions.

The general framework for environmental quality management, shown in Figure 1.2, has been well established in the United States and Western countries for air and water quality management. There is often an "iterative" process which examines different strategies, the resulting spatial patterns of emissions and the modeled ambient concentrations which would theoretically result as a result of the assimilative capacity. Ultimately, one or more environmental strategies are selected and implemented. This general framework is useful not only in the United States and Western countries, but also in developing regions around the world. However, as noted below, a more creative mix of environmental management strategies will be required than has generally been adopted in the United States.

Air Quality Management and Sustainable Development

Engineering control strategies have generally been highly effective in reducing air pollutant emissions, often in excess of 95 to

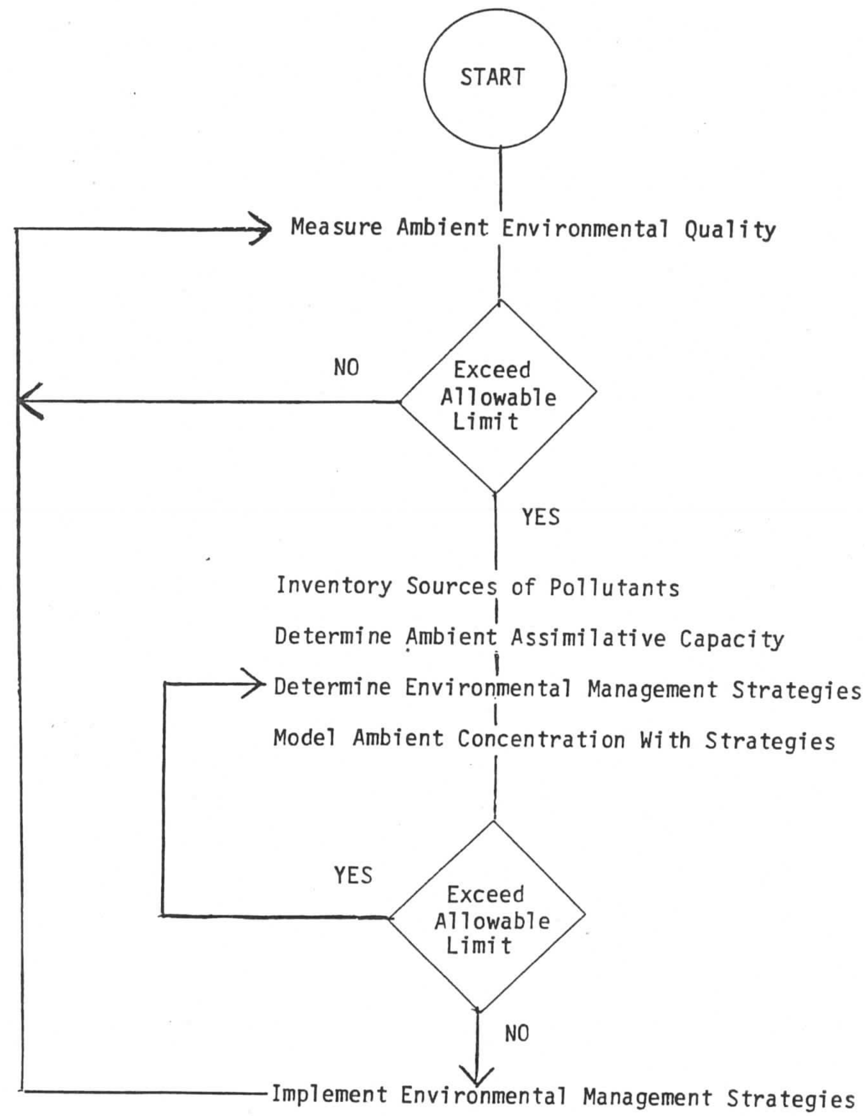

FIGURE 1.2 General framework for air and water quality management.

99%, and in meeting standards for air quality. Although engineering control strategies will continue to be widely used, many are more costly than pollution prevention and other strategies; many countries will face difficult choices among expenditures for social well-being and must pursue other strategies as well.

There are also some situations in which the combination of a high density of population and economic activity, together with a poor ambient air quality assimilative capacity, defy a solution based strictly upon engineering controls of pollutants. Over a decade ago, as part of a course I taught in environmental management, we were able to demonstrate using unsophisticated, "back of the envelope" calculations that there was not a conventional technological solution to the smog problem in Los Angeles. The population increase, coupled with more automobiles traveling more miles, simply overwhelmed the rate at which air quality improvements were made from the "turnover" of new vehicles with better technology replacing older vehicles.

Other important air quality management strategies include (1) land use planning strategies, (2) transportation planning and (3) energy management strategies. There are several types of land use planning strategies which, incidentally, *do not* mean that Big Brother is dictating exactly how a land owner is able to use the land.[30]

Infrastructure strategies, including the placement of natural gas pipelines, major highways, high-speed rail and sewage treatment facilities, are highly effective on both regional and local scales in influencing where economic growth and development take place. Locational strategies and incentives can be used to influence where industrial development or residential development takes place; these strategies are currently being used in locations such as Mexico City and Beijing to both reduce the density of pollutant emissions and reduce the exposure of the population. In smaller cities, green space and open-space strategies can be used at local geographic scales to improve the assimilative capacity for air pollutants.

Transportation strategies to reduce automobile emissions have been widely used within many major urban areas of the United States, with varying degrees of success. Strategies include carpooling, limiting highway access, mass transit, light rail, parking fees, road tolls, bicycle paths and flexible work scheduling. Many European countries have been more effective in reducing their dependence upon the automobile for transportation than has the United States (another example of the importance of culture in sustainable development). In Europe, however, the high population densities and congestion in cities, and relatively short distances for intercity travel, tend to reduce the attractiveness of automobile commuting and to enhance alternative modes of transit. (Some very provocative ideas on land use and transportation planning are presented in Chapter 6.)

Energy management strategies include "fuel-switching" to cleaner fuels, adoption of energy-efficiency strategies to reduce the demand for energy, cogeneration of electricity along with industrial process heat and the development of alternative and renewable sources of energy, including biomass and agricultural wastes, geothermal, wind and solar photovoltaic energy.[31] Oddly, whereas "fuel-switching" was widely recognized as a major pollution control strategy during the 1970s, energy efficiency and energy conservation still are not.

Water Quality Management and Sustainable Development

It must be emphasized that much, if not most, of the preceding discussion related to air quality also applies to water quality. That is, bodies of water—rivers, lakes, estuaries—have an (highly variable) assimilative capacity which is dependent upon the physical and biochemical processes which dilute, mix and transform pollutants. (Groundwater, such as aquifers, is a special case with very limited assimilative capacity because of limited water flows and turnover.)

Dependent upon the amount of pollutant discharge into the water and the assimilative capacity, the resulting concentrations of pollutants in the water and in the tissues of aquatic organisms will determine whether the body of water is fit or unfit for human consumption, aquatic life, commercial fishing, recreational purposes or industrial use.

Moreover, there are two notable constraints that the environmental system poses in relation to water quality. First, river flows tend to be extremely variable from season to season, and coupled with withdrawals for human use, there is a severe upper limit on assimilative capacity. Second, the increasing "bioaccumulation" of pollutants in successively higher levels of the food chain also severely limits the allowable concentration of pollutants in the water.

The combination of these limiting ambient conditions, together with a high density of population and economic activity, can make sustainable development very difficult to achieve. Many developing nations suffer widespread poor water quality due to a combination of high population density, widespread pollutant discharge from natural resource extraction and processing, increasing industrialization and inadequate assimilative capacity.

Since the age of industrialization began, most countries of continental Europe have experienced widespread poor water quality in surface rivers. Within the five river basins comprising the Ruhr district in Germany, a unique and fairly complex system of water quality planning and "stream specialization" had evolved by the 1960s. For example, the Ruhr River was maintained in a state of water treatment and ambient water quality suitable for water supply and recreation, whereas a parallel river, the Emscher, had been designated for untreated pollutant discharges and the dilution of pollutant wastes carried downstream.

Although the Ruhr district, one of the most concentrated industrial and population centers of the world, is hardly an example of sustainable development, this example does serve to underscore the importance of combining engineering and technology strategies and land use planning to achieve sustainable development. In some cases, it will also be possible to implement "win–win" situations; that is, infrastructure and locational strategies can be devised that will protect both air quality and water quality. Perhaps the case was best stated by landscape architect Ian McHarg in the title of his book *Design with Nature*.

Ecological and Life Support Issues

The preceding principles and discussions of this chapter are offered with the goal of nurturing some general, integrated approaches which can be used within the market economy and public policy to begin to achieve sustainable development as previously defined. Yet, there are special, critical problems which will require special, intricate responses, very possibly with much trial and error and disappointment along the way. Some of these critical problems include:

(1) Species and habitat protection, as previously discussed

(2) Global agriculture—emphasis upon feeding the population (not just raising cash crops) and agricultural methods which use indigenous and renewable resources and maintain soil structure and fertility

(3) Tropical rain forests—forest management for suitable economic uses, such as harvesting of fruits, nuts, hides, plants and lumber (subject to proper management of tree species, density and location)

(4) Global climate change—as previously discussed, identifying a continuum of possible environmental management responses to reduce emissions of greenhouse gases and implementing programs which make sense to do now for other reasons (e.g., "win–win" situations such as methane gas

recovery for fuel, composting and energy management)

These problems are well established and of sufficient complexity to be beyond the scope of a detailed analysis here. However, in the spirit of sustainable development and UNCED Principle #4 (discussed above), it is important to emphasize that the "integration of development and environmental protection" will again require an interdisciplinary approach. The close working cooperation of scientists, natural resource specialists, economists, geographers and planners will be needed to formulate, evaluate and implement development and protection strategies within a given culture which either do not diminish the life support systems or can provide reasonable trade-offs.

Holistic skills and perspectives are needed to "ask the right questions" to "obtain the right answers." Creativity is required for development strategies which meet the needs of the local population and utilize local resources without exceeding environmental limits.

CONCLUDING REMARKS

In this chapter, I have presented an overview of sustainable development and the relationship between the natural systems and the economic system. It is important to realize that "sustainability" from the standpoint of either the availability of natural resources to meet the needs of the world's population in an equitable manner or from the standpoint of environmental protection is really two sides of the same coin. That is, an integral part of the solution to both involves finding ways to limit per capita natural resource consumption in both developed and developing nations and ways to substitute renewable resources and "waste products."

As depicted in Table 1.1, sustainable development includes several elements. There is widespread agreement that population

stabilization in developed and developing countries alike must be a first priority. Similarly, it is widely agreed that more sustainable technologies must be developed and employed.

However, it is difficult to say which of the other elements is more important than the others. Clearly though, some of the objectives will take relatively long periods of time to effect: for example, population stabilization, refining market economies, adopting a systems thinking perspective, integrating environmental management approaches, education and changes in social thinking and cultural behavior. Hence it is important for all nations to begin initiatives, including research and pilot programs, incentives and transfer of appropriate technologies, which will support and effect these changes. An important next step is to set specific priorities and to establish programs to meet global and national sustainable development concerns within the national and local context of needs.

This is not to suggest, however, that all actions must await the development and funding of grandiose master plans. "Grass-root" movements are important to effect perception and attitude changes, which will lead to social and cultural changes. Personal, individual reflection and response to a sustainable ethic are vital.

It is also important for the private sector—where capital, information and expertise are concentrated—to grasp the business opportunities presented by sustainable development. By taking reasonable risks to develop new tools of analysis, products and services, which promote better management of natural systems, efficiency and reuse, the private sector can stimulate important new markets which will aid the transition.

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12. It should be observed, however, that such decisions run the risk of being based upon present knowledge. If species and genetic pools are eliminated, then the possibilities for discovering future benefits to humankind are also.

13. For example, criteria might include the "endangerment" of the species, the "uniqueness" of the species, the importance of the species in the food chain and ecological system, the ecological productivity of the habitat, the scarcity of the habitat and other alternatives for human settlement and use.
14. Note, too, that the product outputs are placed in a separate box, apart from the economic system, because products are a form of "storage." The return of matter from both "durable" and "nondurable" goods occurs over time, whereas pollutant wastes are returned immediately to the natural system.
15. Although an environmental ethic in Western countries is becoming an important part of purchasing decisions, it is frequently difficult for consumers to make intelligent decisions. At one level of analysis, product labeling and information are often confusing and misleading. However, at a deeper level of analysis, there are many factors to consider when trying to make a "sustainable" consumer decision. For example, it is not obvious whether vinyl siding for a house or wood shingles with paint is a better choice or whether an electric power mower or gasoline power mower is more desirable.
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29. In practice, this is a kind of "dynamic equilibrium" in the long run because natural factors such as climate and ecological productivity vary from year to year. It should also be noted that when the harvest rate exceeds the replenishment rate, a new state of equilibrium with a lower resource base is reached.

30. Unfortunately, during the Reagan administration there was a backlash against the notion of land use planning and the Land Use Planning Branch within the U.S. Environmental Protection Agency was terminated. During the 1980s the "deindustrialization" of the United States, together with the large number of plant closings, probably also meant that the immediate applications of land use planning for air quality were more related to transportation issues than industrial-related air quality.

31. From the standpoint of sustainable development, one has to be rather analytical and cautious about what is sometimes called "alternate" sources of energy. Certain "alternate energy" forms may be counterproductive, such as wood-fired power plants which compete for limited forest resources or so-called "resource recovery" plants which are designed to burn garbage without separation, reuse and recycling of nonorganic materials. Even some forms of solar collectors are very resource-intensive in terms of the amount of glass, metal and land consumed in relation to the amount of energy produced.