Perspectives on the Role of Science and Technology in Sustainable Development

Office of Technology Assessment

Congress of the United States

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Foreword

Resource degradation and depletion, exponential population growth, widening econoimc gaps between and within industrial and developing countries, and resource-driven conflicts all have contributed to the growing concern about sustainability of our societies, nations, and the Earth. Discussions about integrating environment and developrnent now include issues of intergenerational equity, resource substitution, and irreversibility of impacts. In this setting, sustainability has emerged as a central goal for international development. Yet, many development models exist, each with slightly different imperatives and underlying assumptions about the meaning of the term sustainable *development.*

This report examines an array of *sustainublc development* definitions and discusses their common elements. Current agriculture, energy, and industry technologies are described as well as the strides being made in education, communication, and information technologies that could support sustainable development. Access to these technologies, however, remains a challenge for many in developing and industrial countries alike. Several central issues are discussed that have clear policy implications. First, sustainable international development involves multiple themes that cross U.S. foreign and domestic policy boundaries (e.g., energy efficiency, sustainable agriculture, and resource conservation); thus, coordinating these policies will be fundamental. Second, eliminating institutional, social, economic, and political barriers to sustainable development is 1 likely to be a key challenge. Finally, developing and disseminating technologies that can advance sustainability will require significant collaboration and investment on the parts of industrial and developing countries.

The following congressional committees requested the Office of Technology Assessment (OTA) to review its technology assessments of the past 20 years and distill the key science and technology areas underpinning sustainable development: the House Committee on Foreign Affairs, the Senate Committee on Foreign Relations, and the House Committee on Natural Resources.

OTA greatly appreciates the contributions of the working group participants and contractors. We are especially grateful for the time and effort donated by numerous contributors who seined as reviewers and as liaisons with the many groups and organizations involved in these issues. The information and assistance provided by those individuals proved invaluable to the completion of this assessment. As with all OTA studies, the content of this report is the sole responsibility of OTA.

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Director

Project Staff

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Assistant Director. OTA

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Until February 1994

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Environment Program
From March 1994

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Perspectives on the Role of Science and Technology in Sustainable Development

Sustainable development (SD) has emerged as a new goal for international development in the wake of a host of changing environmental, social, and economic conditions. Some of these are global environmental problems arising from industrial development patterns, resource degradation and depletion, widening economic gaps between and within industrial and developing countries, and resource-driven conflicts. Evolved from past foreign development paradigms that focus on economic aspects of development, SD expands on the social, environmental, and institutional components. Yet, SD is most notable in taking a world-view that seeks to promote equity among and within nations and generations. The role of science and technology in SD is viewed in a new way as well, with an emphasis on technologies for empowerment (e.g., education, information, communication) and environmental sustainability (e.g., sustainable agriculture, renewable energy. improved resource efficiency) and a focus on whole systems.

INTRODUCTION

The end of the Cold War left U.S. foreign aid without its main rationale, and Congress and the past two Administrations have been unable to agree on a new one. All parties seem to agree that the foreign aid program is plagued with many conflicting purposes but there is less agreement as to the few essential purposes on which scarce aid dollars should focus (47,1 07).

The Clinton Administration has attempted a major effort to redefine and clarify post-Cold War development assistance policy and strategy. The *Wharton Report,* representing the first initiative, articulated a rationale and purpose and objectives of foreign assistance (123). The Administrator of the U.S. Agency for Inter-

national Development (US AID) developed strategy papers for sustainable development and drafted proposed foreign assistance legislation with SD as one of its major purposes (The Peace, Prosperity, and Democracy Act of 1994) (99). Although the proposed initiative would go further than any previous attempt to define SD and make it the centerpiece of development assistance, key questions remain about the meaning of SD and how programs and projects would change under this new SD paradigm (85).

SD has been embraced by a wide spectrum of foreign-aid interests who have traditionally been at odds over purposes and goals of aid. This may bean indication that there is agreement about one of the main purposes of development assistance, or simply that disagreements are masked by the differing interpretations of SD. If the latter is true, then the public policy task remains of finding a new post-Cold War rationale for aid that the American people will support (84,85).

This report draws from the literature and from discussions with development experts to describe a range of "sustainable development" definitions and examine an array of associated issues (box 1). Over the last two decades, the Office of Technology Assessment (OTA) has conducted numerous studies on science and technology issues with application to developing countries and the renewable resource base (see appendix B). The technologies discussed in these reports are examined in the context of their potential contribution to sustaining the resource base in development efforts. Although developing countries are the focus of this report, past and present development patterns in industrial countries profoundly influence the potential for promoting SD in foreign aid. Thus, certain domestic issues are identified that are likely to be vital in furthering sustainable international development (e.g., promoting energy efficiency).

SUSTAINABLE DEVELOPMENT

The central idea of SD is one of the oldest in economics—that to live beyond the moment, one must consume income rather than drain capital or the ability to produce future income (61 ,13,67). Equity[1] for existing populations and future generations also is a common theme in many definitions of SD. However, a universally accepted definition of SD has yet to emerge (box 2).[2] Some consider SD a goal (64), others prefer to view it as an organizing principle and a process (107). The definition cited most often comes from the Brundtland Commission: "development that meets the needs of the present without compromising the ability of future generations to meet their needs" (129). This is a concept that most people can relate to and accept. However, it leaves many questions unanswered. For example, '*development" has several meanings [3] and the "needs of current and future generations" is subject to differing interpretations (84, 107). Discussions of SD, thus, encompass a large number of movements with widely disparate reform agendas (80); a continuum of development paradigms exist under the SD label. Foci range from economic imperatives to nature conservation imperatives (table 1) (1 1). However, two models stand out for their sharply contrasting interpretations of sustainable development: the Conventional Economic Growth

[1] The term equity is also subject to differing interpretations. In terms of sustainable development, the equity issue deals with "fairness" to: I) future generations whose interests are not represented by standard economic analyses or by market forces that discount the future, and 2) current populations that do not have equal access to natural resources or to social and economic goods (132, 74).

[2] Some of the key elements of SD are the need to provide intergenerational equity, the finite nature of resources, enhancing environmental quality, and meeting human needs. It is the specifics of these elements that give rise to disagreements (84).

[3] Building productive capacity is the essence of what is traditionally meant by development(61). Yet, development is not necessarily synonymous with growth, where growth is defined as accretion or accumulation (107).

BOX 1: Summary of Findings

Improving the quality of life for poor populations in developing countries relies on availability of resources to meet basic human needs and the economic, political institutional and technical capacity to produce and provide equitable access to these resources

- Current environmental trends are toward degradation of resource systems The "business as usual with a treatment plant at the end" approach has mediated, but not reversed, the problems generated by a highly consumptive Industrial engine
- Technology can be a positive force for sustainable development by providing new "tools" or expanding the use of existing tools but should be understood as involving a social process with costs and benefits
- Demographic momentum means that global population will continue to grow even with **successful** family plannlng programs Current projections suggest a global population of 85 billion by 2025 and nearly 90 percent of this growth is projected to occur In developing countries
- Many question the long-term capability of the Earth to support current or Increased population or the ability of technology to Intervene and expand the Earths carrying capacity sufficiently to meet the demand over the long term
- Poverty and environmental degradation are intertwined, most notably in developing countries Rapid population growth existing inequalities in land tenure, conversion of farm land to nonagricultural purposes, unsustainable production practices used by commercial and subsistence farmers, and inequitable food distribution policies all contribute to this manifestation of poverty
- The link between environment and development began to emerge clearly in the literature in the late 1960s and the basic tenets of sustainable development were prominently discussed by the mid-l 1970s
- In practice, aid allocation is often determined by practical considerations such as foreign policy objectives and commercial needs, which may not necessarily be consistent with the principles of sustainable development
- Development is not necessarily synonymous with growth In Industrial countries, sustainable development may mean a shift from quantative and material growth to qualitative and nonmaterial growth, in most developing countries it will mean a coordinated measure of both types of growth
- Equity, whether defined in terms of development benefits, income, consumption levels, or overall economic Indicators, is a consistent (although not always apparent) underpinning of sustainable development
- The concept of a "sustainable society" challenges many aspects of existing social reality, power relations, economics and marketing
- Appropriate measurement methods for evaluating efforts for sustainable development will need to be broad-based and at a minimum should account for human development factors, quantity and quality of natural capital, social satisfaction, and self -reliance factors

i(CEG) model and the Environmentally Sustainable Lifestyles (ESL) model .[4] Advocates of each of these models are not clearly differentiated and many development professionals would describe their own position as a mixture of the two (84).

[4] This characterization of competing views about SD is adapted from material prepared by the OTA Working Group on "Approaching Sustainable Development" (84, 49, 50).

BOX 2: Defining Sustainable Development

Many definitions of sustainable development have been offered, some general and some more precise, The following definitions Illustrate the variety of foci evident in discussions of SD

- " is development that meets the needs of the present without compromising the abillty of future generations to meet their own needs " The World Commission on Environment and Development, *Our Common Future (New* York: Oxford University Press, 1987), p. 4,
- requires meeting the basic needs of all people and extending opportunities for economic and social advancement Finally, the term also implies the capacity of development projects to endure organizationally and financially A development initiative is considered sustainable if, in addition to protecting the environment and creating opportunity, it is able to carry out activities and generate its own financial resources after donor contributions have run out " Bread for the World, *Background Paper A/o.* 129, Washington, DC, March 1993,
- "[Improves] the quality of human life while living within the carrying capacity of supporting ecosystems " International Union for the Conservation of Nature and Natural Resources (lUCN), World Conservation Union, United NatIons Environment Programme (UNEP), and World Wide Fund for Nature (WWF), *Caring for the Earth* (Gland, Switzerland IUCN, UNEP, WWF, 1991), p 10,
- "[uses] natural renewable resources In a manner that does not eliminate or degrade them otherwise diminish their renewable usefulness for future generations while maintaining effectively constant or nondeclining stocks of natural resources such as soil, groundwater, and biomass " World Resources Institute, "Dimensions of Sustainable Development, " *World Resources 1992-93. A Guide to the Global Environment (New* York Oxford University Press, 1992), p. 2
- '([maximizes] ., the net benefits of economic development, subject to maintaining the services and quality of natural resources " R Goodland and G Ledec, "Neoclassical Economics and Principles of Sustainable Development, " *Ecological Modeling* 38:36, 1987
- "[is based on the premise that] current decisions should not impair the prospects for maintaining or improving future living standards This Implies that our economic systems should be managed so that we live off the dividend of our resources, maintaining and improving the asset base " R Repetto, *World Enough and Tine (New* Haven, CT Yale University Press, 1986), pp. 15-16,
- " is taken to mean a positive rate of change in the quality of life of people, based on a system that permits this positive rate of change to be maintained Indefinitely. " L,M Eisgruber, "Sustainable Development, Ethics, and the Endangered Species Act, " Choices, Third Quarter 1993, pp. 4-8,
- is development without growth-a physically steady-state economy that may continue to develop greater capacity to satisfy human wants by Increasing the efficiency of resource use, but not by increasing resource throughput " H E Daly, "Steady State Economics Concepts, Questions, and Policies, " Eco*log\cal Economics 6333-338,* 1992
- is the search and the carrying out of rational strategies that allow society to manage, in equilibrium and perpetuity, its Interaction with the natural system (biotic/abiotic) such that society, as a whole, benefits and the natural system keeps a level that permits its recuperation " E. Gutierrez-Espeleta, "Indicadores de Sostenibilidad: Instruments Para La Evaluacion de Ias Politicas Nacionales, " unpublished paper presented at *50th Anniversary Conference of the Economic Sciences Faculty* sponsored by the University of Costa Rica, San Jose, Costa Rica, Nov. 19, 1993

TABLE 1: Basic Distinctions Between Five Paradigms of Environmental Management in Development

Paradigm dimension	Frontier economic	Environmental protection	Resource management	Eco-development	Deep ecology
Dominant imperative	"Progress" as Infinite economic growth and prosperity	"Tradeoffs" as in ecology versus economic growth	"Sustalnablllty" as necessary constraint for "green growth"	Codeveloping humans and nature, redefine "security"	"Eco-topla " anti-gro~~, constrained harmony with nature
Human nature relationship	Very strong anthropocentnic	Strong anthropocentnc	Modified anthropocentnc	Ecocentric	Biocentric
Dominant threats	Hunger, poverty, disease, and natural disasters	Health impacts of pollution, endangered species	Resource degradation, poverty, population growth	Ecological uncertainty, global change	Ecosystem collapse, "unnatural" disasters
Main themes	Open access/free goods, explotation of infinite natural resources	Remedial/defenswe, "legalize" ecology as economic externality	Global efficiency, economize ecology, interdependence	Generative restructuring, "ecologlze social systems, " sophisticated symbiosis	Back to nature, biospecles equality, simple synbiosis
Prevalent property regimes	Prlvatlzation (neoclassical) or nationalization (Marxist) of all property	Privatlzation dominant some public parks set aside	Global commons law for conservation of oceans, atmosphere, climate, biodiverslty	Global commons law and local common and private property regimes for inter-generatlonal equity and stewardship	Private plus common property set aside for preservation
Who Pays?	Property owners individuals or state	Taxpayers (public at large)	Polluter pays (producers and consumers) poor	Pollution prevention pays. lncome-index environmental taxes	Avoid costs by foregoing development
Responsibility for development and management	Property owners individuals or state	Fragmentation development decentralized, management centralized	Toward integratlon across multiple levels of government	Private/public Institutional Innovations and redefiniton of roles	Largely decentralized but Integrated in design and management

(continued)

TABLE 1 (cont'd.): Basic Distinctions Between Five Paradigms of Environmental Management in Development

Paradigm dimension	Frontier economic	Environmental protection	Resource management	Eco-development	Deep ecology
Environmental management technologies and strategies	Industrial agriculture high inputs of energy, bioclde, and water; monoculture, mechanized production; fossil energy; pollution dispersal: unregulated waste disposal; high population growth; free markets	End-of-the-pipe cleanup, command and control market regulation: some prohibition or limits, repair and set asides; focus on protection of human health, "land doctoring" environmental impact statements	Impact assessment and risk management, pollution reduction, energy efficiency, renewable resource conservation strategies, restoration ecology, population stabilization and technology-enhanced carrying capacity, some structural adjustment	Uncertainty (resilience) management, Industrial ecology/ ecotechnologles (renewable energy, waste recycling, scale reduction, agroforestry, low-input agriculture, extractive forest reserves), population stabilization and enhanced carrying capacity	Stability management, reduced scale of market economy (including trade); low technology; simple material needs; nondominating science; indigenous technology systems; "intrinsic values;" population reduction
Analytic, modeling, and planning methodologies	Neoclassical or Marxist closed economic systems; reversible equilibria, production limited by humanmade factors, natural factors not accounted for; net present value maxlmlzatlon; cost-benefit analysis of tangible goods and services	Neoclassical plus: environmental impact assessment after design; optimum pollution levels equation of willingness to pay and compensation principles	Neoclassical plus: include natural capital; true (Hicksian) income maximization in UN system of national accounts; increased freer trade ecosystem and social health monitoring, linkages between population, poverty, and environment	Ecological economics. biophysical-economic open systems dynamics; sociotechnical and ecosystem process design; integration of social, economic, and ecological criteria for technology; trade and capital flow regulation based on community goals and management; land tenure and income redistribution	Grassroots bioregional planning; multiple cultural systems; conservation of cultural and biological diversity; autonomy
Fundamental flaws	Creative but mechanistic, no awareness of rellance on ecological balance	Defined by frontier economics in reaction to deep ecology, lacks vision of abundance	Downplays social factors, subtly mechanistic, doesn't handle uncertainty	May generate false security magnitude of changes require new consciousness	Defined in reaction to frontier economics, organic but not creative how to reduce populatlon

SOURCE M E Colby, "Environmental Management and Development, " World Bank Discussion papers, February 1990

1 Conventional Economic Growth Model

The CEG model resembles the traditional model of economic growth but places additional emphases on the costs of environmentally degrading activities, and on the allocation of natural resources among generations. It also considers a longer time horizon. Under this model, SD represents an opportunist y to integrate development approaches to achieve sustained growth to meet human needs, improve living standards, and providc the basis for environmental protection.

The CEG model seeks a higher standard of living for industrial as well as developing countries by making the economic pie larger through: technological innovations to improve productivity of resources. reduced barriers to international trade, and increased investments in human capacity. Efficiently functioning markets are the key to resource allocation. The government is needed to create the proper environment for markets, provide institutions to support a market economy, and make investments in infrastructure and human capacity building. Education, information about family planning and informed personal choice about family size arc seen as keys to stabilizing world population at levels consistent with an improved standard of living. The CEG model assumes no 1imits to physical or capital growth (84).

I Environmentally Sustainable Lifestyles Model

The starting point for the ESL model is the finite nature of global resources and the necessity of adopting less resource-intensive lifestyles. Advocates of this model attribute much of the environmental degradation in poor countries to industrial country exports of ecological deficits through trade and investment as well as to inappropriate bilateral and multilateral aid. Industrial countries arc called upon to curb resource consumption and population growth, adjust international trade rules to give equity to poor countries. provide access to information and technology, and require industry to internalize the full costs of production (i.e., environmental costs of consuming scarce natural resources or polluting the environment).

Renewable energy sources, such as wind offer an alternate to traditional fuels and reduce the Impact of energy use on the environment Opportunities to enhance the productlvity of these types of energy resources could Improve their dlsseminatlon and use in development.

Stabilizing or reducing world population is viewed as critical to social and ecological well-being, and family planning efforts would be a key component of aid programs under the ESL model. Other components of an ESL development strategy focus on meeting basic human needs, expanding opportunities for the poor. protecting the environment, and promoting participation at the local or grass-roots level.

The ESL model of development has roots in the international environmental movement and is consistent with most of the recommendations coming out of the United Nations Conference on Environment and Development (UNCED). To many ESL advocates, SD as a development strategy is synonymous with environmental sustainability. For example, the Rio Declaration on Environment and Development (at UNCED) proclaimed that environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it(91). This concept of SD is expected to influence the scientific and public policy debate about development (84).

Similarities exist between the CEG and ESL development models. In common with almost all definitions of SD, both models embrace the notion of maintaining, enhancing. or preserving the environment and natural resource base for future gen -

erations. In addition, SD is viewed as heavily dependent on industrial country policies and goals; in fact, many feel that achieving SD rests on industrial world commitment (107).

The models diverge with respect to the social and economic dimensions of SD. ESL proponents point out that most benefits of past economic growth have gone to the wealthy with little improvement in quality of life for the vast majority of people. CEG model proponents cite the benefits made possible by technological advancement fueled by resource use and the potential for similar advances in the future. Nevertheless, the concept of a *sustainable society* challenges many aspects of existing social reality, power relations, economics and marketing (17,82).

~ Challenges in Sustainable Development

Conceptual problems may pose serious barriers to the adoption of SD. The Brundtland concept contains elements that are open to debate. Lack of consensus over the meaning of "intergenerational equity," ● 'substitution of resources, " and "irreversibility of actions" could impede efforts to operationalize SD (84).

Intergenerational Equity

Inherent in most definitions of SD is an obligation of the present generation to preserve the stock of natural resources for future generations. This implies the need for some measure of equity among generations. Operationally and analytically, however, intergenerational equity can present a dilemma in determining appropriate use of resources (80). What level of resource use, particularly nonrenewable resource use, constitutes equity for present and future generations? According to economic theory, market forces will allocate the best use of a resource over time and over generations. The critical policy issue is the extent to which market forces should guide use of natural resources and the extent to which resource use and consumption should be regulated (84).

Substitution of Resources

A simple but powerful concept in economics is input substitution in the production of goods or services and product substitution in satisfying consumer wants. Firms change the mix of inputs along a '*production possibility curve" in response to shifts in prices or changes in technology. A classic case of input substitution occurred in agriculture where the substitution of capital inputs for labor and land over a period of several decades resulted in dramatic structural adjustments.

The theory of wide substitution is the subject of considerable debate, however. Neoclassical economics espouses that as each generation uses up some of the total capital,[5] it should add to the social capital in equivalent measure. According to this school of thought, "A sustainable path for the economy . . . is not necessarily y one that conserves every single thing or any single thing. It is one that replaces whatever it takes from its inherited... endowment" (83). Arriving at a true valuation of resources is crucial to this approach. Possible mechanisms for valuation of natural resources have been identified, but not yet developed adequately (83).

Environmentalists argue that the substitutability concept can promote exploitation of finite resources by present generations. However, because renewable and humanmade resources can substitute in some degree for finite natural resources, some economists argue that SD criteria are met if the productivity of the system as a whole is preserved for future generations. For example, in North America much of the land that was formerly forested has been cleared and is now used for food crops. Although the forest resource has not been sustained, the overall capacity of' the system to feed and shelter people has been increased (80). The broader environmental impact of this sub-

[5] tofal *capital* is the combination of all the various forms of capital. including natural capital (renewable and nonrenewable resources), human capital. cultural capital, institutional capital, and physical capita] (67, 83, 6 l).

stitution, however, is not commonly incorporated in traditional economic analyses (84).

Proponents of the ESL model are skeptical about the ability to create substitutes for the finite global stock of natural capital. “Sustainable development is development without growth—a physically steady-state economy that may continue to develop greater capacity to satisfy human wants by increasing the efficiency of resource use but not by increasing resource throughput,” according to Daly (18). Goodland echoes this theme: “the imperative is to maintain the size of the global economy to within the capacity of the ecosystem and to sustain it” (figure 1) (31). This view of sustainable development considers the economic system a subset of the larger global ecosystem (19,3 1,61) and calls for equitable access to the benefits generated by careful stewardship of these resources (box 3).

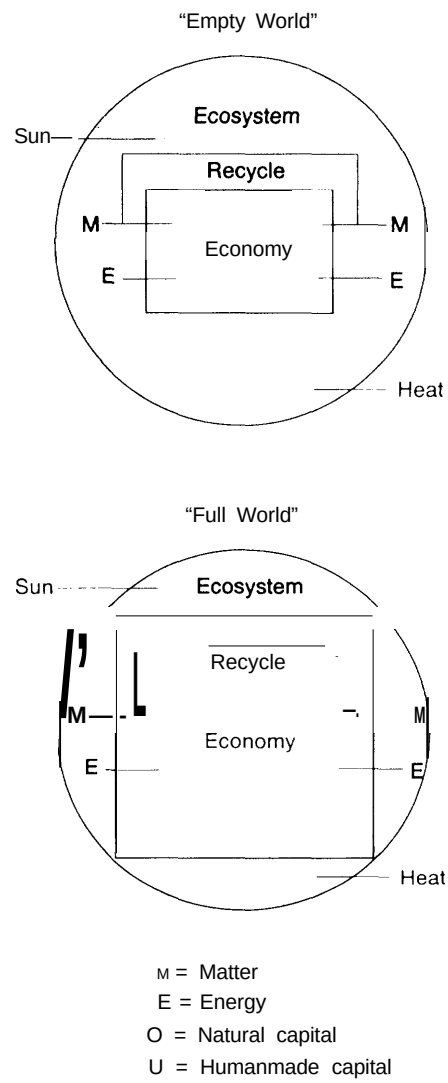
Knowledge about the range of substitution is incomplete at present, making confident projections about future substitution impossible. Nevertheless, science and technology will have an important role to play in broadening the potential for substitution among natural resources, and between natural and human-made resources. Much of the progress that has been made in improving the standard of living in industrial as well as developing countries is a result of new discoveries and new technologies that can extend this potential.

Uncertainty and Irreversibility

Closely related to the substitution issue is the concern about the irreversibility of certain alterations to the Earth’s ecology and imperfect understanding of the complex links among ecosystem components. The ultimate impact of biodiversity loss, for example, is an unknown.

Graham-Tomasi distinguishes between "technical optimists” and “technical pessimists” (33). Much traditional economic development theory rests on “technological optimism, ” while more extreme sustainability critiques might be characterized as “technological pessimism” (84). Definitions of SD based solely on maintaining an

FIGURE 1: The Human Economic Subsystem in Relation to the Global Ecosystem



The scale of the human economic subsystem relative to the global ecosystem *has increased over time from a near/y “Empty World” to a “Full World “In the “Full World” figure, the activities of the economic subsystem are at such a* sea/e *that they can interfere with the complex /Irks and interactions of the* global ecosystem

SOURCE R Goodland, The Only True Definition of Environmental Sustainability!’ paper presented at The Environmental and Natural Resources Policy and Training Project discussion Sept. 15 1993, EPAT/MUCIA, U S Agency for International Development Environmental Forum, Rosslyn, VA

BOX 3: Natural Capital: Opportunities for Reclaiming Lost Land Productivity

"In a very real sense the land does not lie; it bears a record of what men write on it. In a larger sense a nation writes its record on the land, and a civilization writes its record on the land-a record that is easy to read by those who understand the simple language of the land. "

—Dr. W.C, Lowdermilk 1953, former Assistant Chief, U S Soil Conservation Service

The world's population, which reached 25 billion in 1950 by the time Lowdermilk wrote these words, is 55 billion today and is projected to reach about 11 billion by 2050 Currently, world population increases by nearly 250,000 each day, with the majority of this growth occurring in the poor countries in the tropics.

The continuous demands of expanding populations and unsustainable land-use practices have a severe adverse impact on the land's Natural Capital: destroying vegetation, making surface water supplies undependable; and causing watertables to fall, wildlife habitats to disappear, and soil losses to Increase Eventually, agriculture fails and land is abandoned. Damaged, degraded and abandoned lands have been linked to all periods of history and exist in all countries In many places, the land has not recovered even where humans have Imposed little demand on itfor hundreds and even thousands of years.

In view of this, many international assistance institutions are trying to assure that their efforts are compatible with sustainable development, Many define SD as use of resources to provide for the needs of current populations without reducing their availability for future generations (1 32),

Many of the world's damaged, degraded, and abandoned lands could be made productive once again by focusing science, technology, and human experience on this problem bringing degraded lands back into productivity offers a unique opportunity for sustainable development activities Potential benefits Include growth of the renewable resource base, growth in economic opportunities through applying sustainable land-use practices, and growth in output of goods and services from previously unusable land

economy's natural capital, however, may obscure judgments about the significance of the resources. If nonrenewable inputs are essential to an economy, then inadequate technical progress and open access to environmental resources may lead to unsustainability. Alternatively, if renewable resources are essential to an economy, then anything that threatens their renewability threatens sustainability (e.g., population growth, unsustainable land-use practices) (16,68,73). Most economies depend on renewable and nonrenewable resources; thus, creating a proper policy framework to sustain renewable resources and find alternatives to nonrenewable resources becomes key (68)$_0$

Theories of substitution notwithstanding, a system that is economically and ecologically sustainable must be based on a set of sustainable consumption and production objectives (13,67). In the final analysis, public policy officials will have to make some decisions with less than perfect knowledge. Policy could focus on decisions that allow us to live within the ecosystems' means *currently* as determined by the productive, regenerative, and absorptive capacities of the resource base and by the technological means within which resources are transformed into needed goods and services (19,87). As these boundaries are expanded through science and technology, policies may be adjusted appropriately.

1 Mechanisms To Measure Sustainable Development Progress

Measuring development progress often proves difficult and is the subject of considerable discussion. Various indicators are used to measure conditions and rates of development improve-

ments in developing countries. Traditionally, economic indicators such as gross national product (GNP) or gross domestic product (GDP) have been the primary method for such measurements.[6] This method has the advantage of being reproducible and useful for international comparisons. However, economic indicators may be misleading as a sole measure for development.

Alternative methods for rating development incorporate economic and noneconomic indicators. The United Nations Development Programmers Human Development Index (HDI) is designed to reflect the quality of 1 life more accurately than possible by using GNP alone. Three key components are included in the HDI: 1) longevity—measured by life expectancy at birth; 2) knowledge-measured by adult literacy and mean years of schooling; and 3) income-adjusted to reflect income's diminishing returns for human development as the difference increases between the median income and the poverty line. Thus, industrialized countries do not necessarily have HDI ranks above developing countries, although only industrialized countries are ranked at the top 19 positions and only developing countries are represented in the lowest half of the index (92) (table 2).

These methods for measuring development, however, may still beg the question of sustainability. Use of an expanded array of indicators to measure progress is likely to be more appropriate, given the broad objectives of SD (107). The inextricable link among quality of life, population pressure, and environment argue for a method that weighs economic and noneconomic indicators (such as the HDI), measures the quantity and quality of a country's natural capital (e.g., forest, soil, water), and assesses population pressure relative to resource abundance. Key measurement indicators would need to be identified to avoid creating too cumbersome a measurement method. At a minimum, these indicators could capture education, longevity and health, personal wealth, per capita resource abundance and quality, and the extent to which national productivity reflects self-reliance[7] and avoidance of "exporting" environmental problems. Efforts are now being made to refine sustainability indicators and improve development measurements (e.g.. the University of Costa Rica's Theoretical Sustainability Index (TSI); UN refinement of the HDI) (36. 92).

GLOBAL TRENDS AND CONSUMPTION PATTERNS[8]

Renewable resource concerns have increased significantly in recent years, along with evidence of adverse effects from pollution and resource overexploitation, and mismanagement. Some impacts are of global proportions (e.g., climate change, fishery depletion, biodiversity loss). Yet. resource trends vary broadly around the globe, with some systems showing positive signs of recovery and others showing disturbing signs of depletion. Thus, it is extremely difficult to predict future trends in environmental indicators or to project accurately the consequences of those trends on sustainable food and fiber systems and the populations they support.

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[6] *GNP is a* measure of the total dollar value of all the goods and services produced within the nation, including foreign investments, over a specified period of time (usually one year). *GDP is* a similar measure but excludes foreign investment.

7 Self-reliance as it is used in this report is defined as the ability of a nation to rely on its own capabilities,judgment. or resources. This allows for trade or exchange of goods, ideas, or resources, but suggests that the exchange occurs among partner\, each with similar bargaining power and none wholly dependent on another. It is important to note that many other factors operate internationallly that make true ~elf-reliance difficult, if not impossible, to achieve. Yet the concept may have merit as a target toward which developmentt efforts could be directed.

[8] For expanded discussion and graphic representation of the trends discussed in this section, see the OTA charbbook on Global Trend\, expected date of publication January 1995.

Country[a]	HDI	[illegible] INDEX	HDI adjusted for ncome distributior	Difference between HDI & income-distribution-adjusted ranks[b]	HDI adjusted for gender disparity	Difference between HDI & gender-disparity-adjusted ranks[c]
Japan	0.983	1	0.981	0	[illegible]	-16
Canada	0.982	2	0.947	-4	[illegible]	-9
Norway	0.978	3	0.956	-2	[illegible]	1
Switzerland	0.978	4	0.958	1	[illegible]	-10
Sweden	0.977	5	0.958	1	[illegible]	4
USA	[illegible]	6	[illegible]	-3	[illegible]	-3
Australia	[illegible]	7	[illegible]	-4	[illegible]	1
France	[illegible]	8	[illegible]	-2	[illegible]	5
Netherlands	[illegible]	9	[illegible]	7	[illegible]	1
United Kingdom	[illegible]	10	[illegible]	2	[illegible]	0
Korea, Republic of	[illegible]	33	[illegible]	2	[illegible]	-3
Kenya	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0
Zambia	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	d
Pakistan	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	d
India	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	d
Cote d'Ivoire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	d
Bangladesh	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	d
Nepal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	d
Somalia	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	d

[a]Developing countries are shown in boldface.

[b]A positive figure shown that the HDI income-distribution-adjusted rank is higher than the unadjusted HDI rank; a negative shows the opposite.

[c]A positive figure shows that the HDI gender-disparity-adjusted rank is higher than the unadjusted HDI rank; a negative shows the opposite.

[d]Data not available.

SOURCE: United Nations Development Programme, *Human Development Report 1993* (New York: Oxford University Press, 1993), pp. 11-14.

I Population and Environment

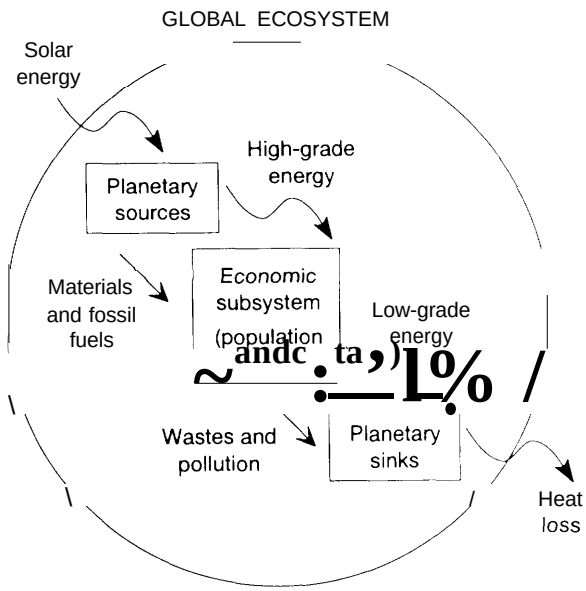
Sustaining natural capital [9] on a global scale is fundamental to the concept of SD. Under this paradigm, resource withdrawals cannot exceed their regenerative capacity; use of nonrenewable resources occurs in relationship to research and development efforts to identify appropriate substitutes; and waste production cannot exceed the environmental absorptive capacity (figure 2) (1 8,31 .61). Developing countries are faced with the considerable challenge of providing for basic human needs, stabilizing populations, and alleviating poverty, as well as sustaining the natural resource base that underlies their capacity for long-term sustainability and development.

Population Growth

Rapid population growth is seen by many as one of the most critical issues facing the world today (23,34,59,78). Many developing countries are those with the greatest growth rates and the constraint that this puts on economic development and quality of life improvements can be massive. The rate of global human population growth, expressed as a percentage of the existing population, has declined since the 1970s, but the number of new births each year still is increasing because of demographic momentum (21 ,22,70). The world population nearly doubled between 1950 to 1985, from a total population of 2.5 billion people at mid-century to 4.85 billion in 1985. During this recent 35- year period, more surviving human offspring were created than during the previous two and a half centuries (21) (figure 3). In just the past 12 months, population growth exceeded that of the entire first half of last century. The planet now supports 5.5 billion people (70).

Distribution of this growth, however, is heavily weighted toward developing countries. China, the rest of Asia, and Europe have held the largest share of human population for centuries (figure 4) and are the most densely inhabited lands today. Today, Asia and Africa are the fastest growing populations, and are of the greatest concern to many demographers (8). In Africa, concern centers on the inability of productive systems, such as agriculture, and of the economy to keep pace with the rapid population growth. Increases in rates of agricultural and economic growth often turn out to

FIGURE 2: Rules for Sustainability of Natural Capital



Renewable resources should not be harvested faster than they can regenerate

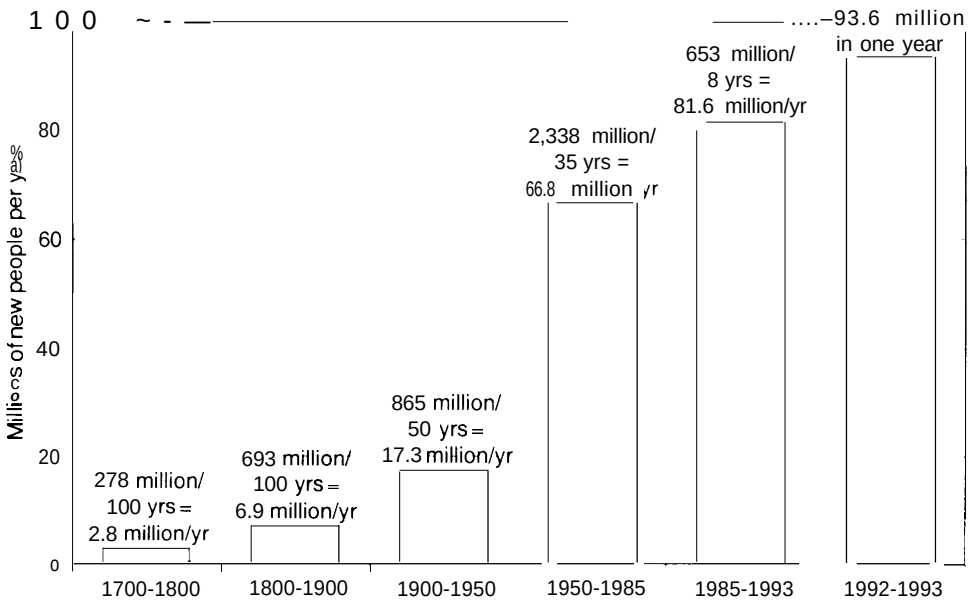
Nonrenewable resources should not be consumed faster than a renewable substitute can be developed for them

Polllution and waste should not be emitted faster than they can be absorbed, transformed, digested, or otherwise rendered harmless to natural systems

SOURCE D Meadows, "A Systems View o f Sustalnable Development contractor report prepared for the Off Ice of Technology Assessment February 1994

[9] Natural capital means the planetary sources from which the economy takes materials and energy and the planetary skins to which the economy emits pollution and waste. The sources include forests, nutrients in soils, groundwater, wildlife Population, and mineral and fossil fuel deposits in the earth. Sink\ include the bacteria in streams that degrade organic waste, the capacities of landfills, the process that regulate greenhouse gases in the atmosphere or form the ozone layer in the stratosphere (6 I).

FIGURE 3: Three Centuries of Exponential Human Population Growth



Despite declining fertdity rates, world population continues to grow. World population growth since 1950 exceeds all the growth of the previous 250 years by 63 percent

SOURCES *Data pnor to 1990* P Demeny, in Turner, B L et al "The Earth Transformed by Human Act Ion, "*Global and Regional Changes/n the Biosphere over the Past 300 Years* (Cambridge Cambridge Universitiy press with Clark University 1990), p 44 *1993data* Population Reference Bureau, Inc. 1993 *World Popu/at/on Data Sheet* (Washington, DC 1993) (1 993 data)

be declining rates when calculated on a per capita basis.

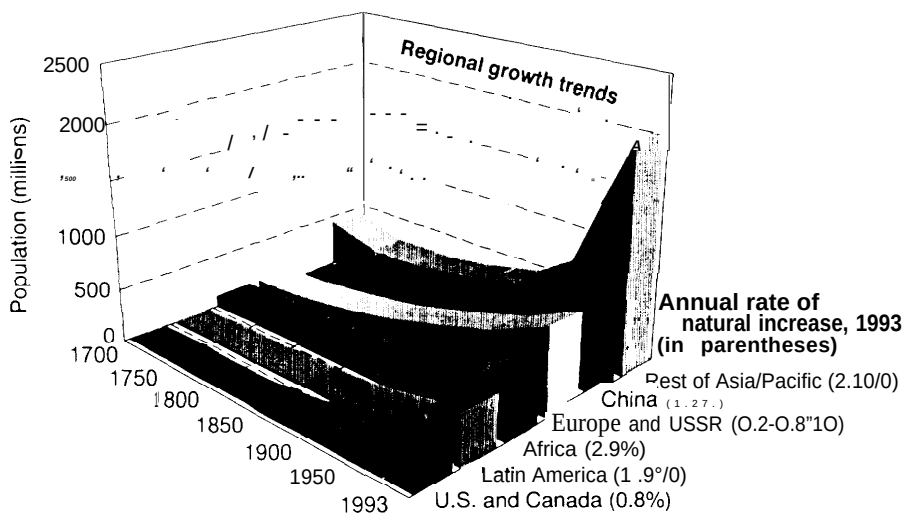
Population size and demographic structure profoundly influence population increase. For example, 33 percent of Asia's population is under age 15, and has not completed the childbearing years (70). While the percentage of Asian youth is equal to or less than the worldwide average (46 percent of Africa's population is under 15 years old), the number of people in this age bracket ensures that Asia's population will grow substantially for some time.

Fertility anti Family Planning

Life-extending and sustaining technologies typically are adopted more quickly than corresponding technologies for family planning. The result is lowered mortality rates unmatched by lowered birth rates. In most countries, lower fertility rates do not emerge until infant mortality rates decline to 150 per 1.000 live births or less (133). There is also a close inverse correlation between contraceptive use and under-five mortality (figure 5). Contraceptives have become much less controversial than they used to be, but use still lags in developing countries, especially in Africa (figure 6). Health and fertility rates are also closely linked to education. As adult female literacy rises, infant mortality and fertility rates decline steadily (13 1, 132).

Fertility rates have been declining worldwide over the past several decades, falling faster and from higher starting points in developing regions than in industrial countries (figure 7). Meanwhile, life expectancy has been rising dramatically in all developing countries (figure 8). Fertility rates of

FIGURE 4: Human Population Growth, 1750-1993



Asia leads in population and numbers of new births in spite of higher percentage growth rates in Africa and comparable rates m Latin Amer/ca

SOURCES Dafa points prior to 1990 P Demeny In Turner, B L et al "The Earth Transformed by Human Act Ion, " Global and *Regional* ***Changes*** *in the Biosphere Over the Past* 300 *Years* (Cambridge Cambridge University Press with Clark University 1990) p. 44 For7993popu/at/on *data and annual rate of natural increase* population Reference Bureau Inc., 1993 *World Population Data Sheet* (Washington DC 1993)

Asia and Central America have declined most notably, while Africa has changed only slightly. Despite this, net population gains are greatest in Asia, followed by Africa. and then Latin America. Annual population growth rates, like fertility, are highest in Africa (97,13 1,1 32,133).

Among poorer populations, children are seen, in part, as a form of social security: a labor source for the farmer and an income source in old age. Very few residents of low-income and some middle-income countries are covered by social insurance: India (5 percent covered), Dominican Republic (6 percent). Ecuador (9 percent), Kenya (10 percent), and Indonesia (13 percent) (1 28).

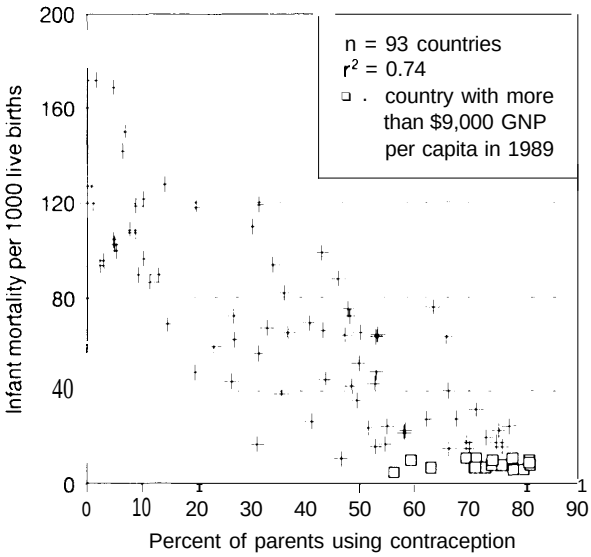
At the first-ever summit of the world's scientific academies held in 1993 in Delhi, India, 56 institutions endorsed a call for "zero population growth within the 1ifctime of our children. " However, the African Academy of Sciences (AAS) refused to sign the agreement. The AAS identified population as a key resource for developing the continent's natural resources (46). Development, rather than population growth, was stated as the most important issue now facing Africa.

Although the current U.S. budget for international family planning programs has been increased significantly ($462 million) (98), experts suggest it may still be inadequate given the magnitude of the problem. Increased support for family planning would clearly identify population issues (including growth rates, health, education) as a critical underpinning for SD (48,107).

Population Density

Areas with high population densities of-ten experience the greatest population pressures. National population figures do not reveal the uneven distribution of settlements within a country. nor the ability of the land to support the inhabitants. Many densely populated nations effectively extend their "land base" with food and natural resource supplements extracted from the sea and imported from other nations (6).

FIGURE 5: Infant Mortality and Contraceptive Use—Analysis of National Statistics



In nations with high levels of contraceptive use, infant survival *generally is more favorable than in nations where access to or acceptance of contraceptives is low.*

SOURCES Analysis based on data from World Resources Institute, *World Resources 1992-93 A Guide to the Global Environment,* Data Base Diskette (Washington, DC 1992), tables 15102, 16302, and 16601

WORLD BANK

Migration to urban areas can result in overcrowding that overwhelms existing infrastructure, employment, housing, and food availabililty

Developing countries contain 77 percent of the human race but just over one-half of the Earth's arable land, leaving the remaining 23 percent of the world's population with 47 percent of the Earth's arable land. People of Asia have the greatest challenge; although they make up nearly 60 percent of the planet's human inhabitants, Asians survive on just over 30 percent of its arable land (1 32,1 33).

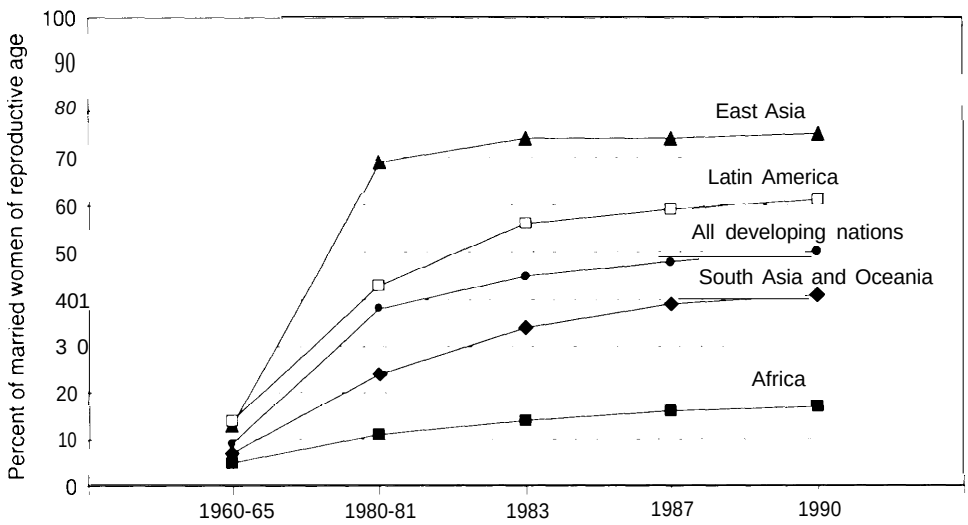
Africans make up 12 percent of the world's population, a small number compared with other parts of the world, particularly if measured relative to the continent land mass. The proportion of arable land, however, is small due to a general water deficit on the continent (box 4). This leaves it with a rather dense population relative to its arable land mass. At 3.7 people per hectare of arable land, Africa is near the world average (3.8), and well below that of Asia (7.2) and developing countries as a block (5.5). In contrast, industrialized nations taken all together carry an average of 1.8 people per hectare of arable land (132,133).

Many developing countries are already experiencing demographic transition as did the industrial world, [10] however, two differences will affect the outcome. First, the reduction in mortality in developing countries has been rapid largely because of imported public health technologies and improved nutrition. Secondly, the pretransition population growth rates of developing countries were typically higher than those in industrial countries at the beginning of transition. The demographic momentum inherent in the system means that developing country population will continue to grow even with family planning programs that succeed in slowing the growth rate (22).

The links between population growth and the environment are critical in anticipating the potential impact of projected population growth fig-

10 Demographic transition describes the change from high to low mortality and lower fertility. This occurred in industrial countries without any specific policy.

FIGURE 6: Trends in Contraceptive Use in Developing Regions (1960s-1990)



Some regions have *responded more rap/d/y than others in adopting family-planning technologies The United Nat/ens estimates that contraceptive prevalence must reach 66 percent of all couples in Africa and 79 percent in East Asia by 2025 in order to produce a desirable decline in fertility.*

SOURCE United Nations Department of International Economic and Social Affairs, *Levels and Trends of Contracep tive Use as Assessed in 1988,* Population Studies No 110 (New York, NY 1989), table 5 p 26 and table 7, p 33

ures. Resource degradation and population displacements are the most evident of these links. Conversion of farmland to nonagricultural purposes, use of unsustainable practices by commercial and subsistence farmers, farming of marginal lands, and inequitable food distribution policies all have fostered displacement of rural populations (48,1 07). Results include resource loss, widespread malnutrition and famine, and urbanization leading to overwhelmed social and physical infrastructure.

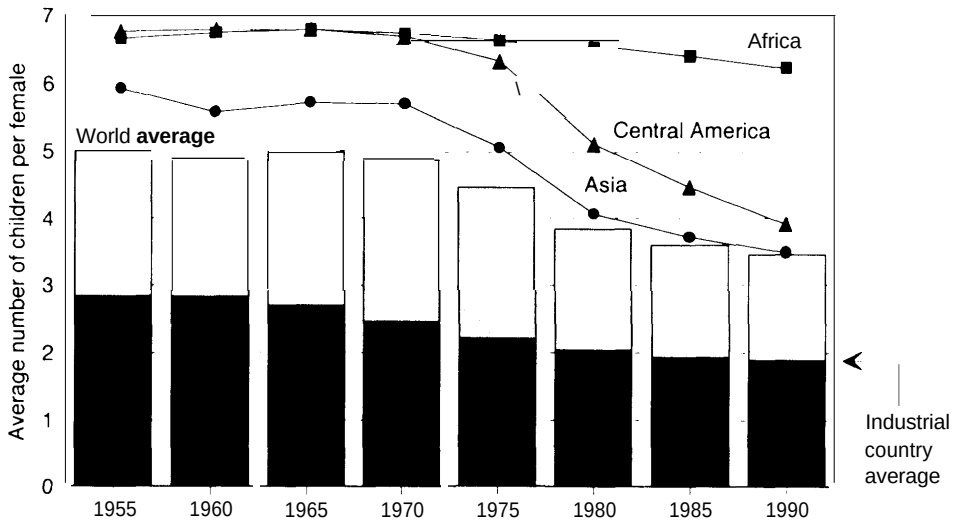
Despite the significant impact that population growth has had on the global environment, today's environmental crises are also a result of the demands created by this increase and the technologies used to satisfy these demands. Consumption patterns, particularly in Northern countries, and dependence on certain ecologically unsound technologies play major roles in existing environmental problems (23,24, 107).

I Food Production

Two major issues arise in discussions of meeting increasing demand for food: 1) deteriorating production factors (e.g., soil erosion and water availability), and 2) opportunities to increase production, adjust consumption patterns, and improve distribution systems. Total global food production per capita maintained a slow but steady increase until the mid- 1980s when it began to level off (133). It is not yet clear whether growth will resume. World protein shortages seem likely as worldwide per capita production of meat, soybeans, and fish all level out (9,1 22).

In the past, growth in food output was sustained by agricultural expansion to new areas. Now, cropland expansion seems to be slowing down as the best quality farming land has already been converted (8,1 32). Per capita cropland has declined in all regions and, based on current population projections, the world average is expected to decline from 0.28 to 0.17 hectares by 2025 (1 33). The "Green Revolution" introduced technologi-

FIGURE 7: Aggregate Fertility Rates by Region, 1955-90

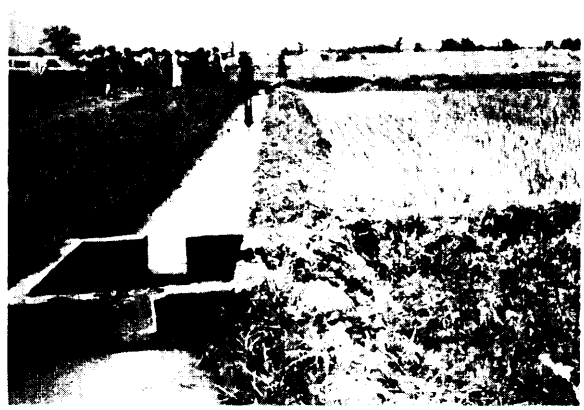


Declining fertility rates in most regions of the world area notable development success story On a regional basis at least, declining fertility correlates with economic development as evidenced by rapid changes in Asia and Central America, and relative stagnation in Africa.

SOURCE World Resources Institute, *World Resources 1992-93 A Guide to the Global Environment*, Data Base Diskette (Washington, DC 1992), table 16203

cal interventions, such as genetically improved crops, enabling agricultural intensification and yield increases. This saved the conversion of vast areas of natural landscape to cropland and helped to feed growing populations (3,126). Critics now characterize the "Green Revolution" technologies and cropping systems as unsustainable and socially inequitable because they require costly, energy-intensive, and often unobtainable agricultural inputs. Proponents can claim success, however, in terms of total grain output at the global, regional, and even national levels. Some question whether these yields can be sustained.

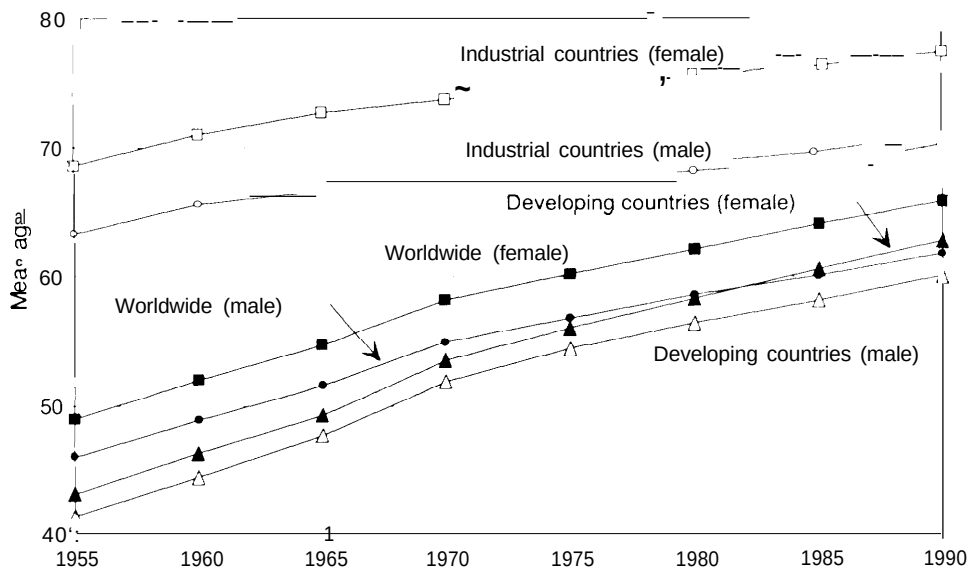
Agriculture accounts for two-thirds of current global freshwater use. Regional variations in food production reflect water distribution to a great extent. Global food security rests in part on sufficient water supplies, especially in areas that cannot produce food without irrigation, such as much of the Middle East, the Aral Sea basin in the former Soviet Union, and vast grain-producing areas of China, India, and the U.S. Great Plains (72). On the other hand, some lands receive substantial, often disastrous, levels of precipitation (e.g., midwest America in 1993 and Bangladesh nearly every monsoon season) that also may complicate agricultural production.



U.S. DEPARTMENT OF AGRICULTURE

Over the past two decades, irrigated area has expanded steadily around the world Shown here, a field in Kenya dependent on irrigation for productivity

FIGURE 8: Life Expectancy at Birth, 1955-90



/reproved health care technologies and delivery systems have lengthened human survival in all regions of the world Life expectancy is one of the components of the Human Development Index (HDI) developed as *an indicator by the United Nations Development Programme This* socially *positive trend has resource management implications, however,* as *resulting population growth places increasing demands on Infrastructure and resource supply systems*

SOURCE World Resources Institute *World Resources 1992-93 A Guide to the Global Environment* Data Base Diskette (Washington DC 1992), tables 16207 and 16208

Over the past two decades, irrigated area has expanded steadily around the world (figure 9), however, expansion rate and existing coverage of irrigation are greater in developing regions than in industrial countries (table 3) (72). Rapid expansion was funded by increasing worldwide economic growth, and motivated by the promise of new, high-yield grain varieties.

The world's current irrigated land area (237 million hectares in 1990) covers only 16 percent of total cropland, but produces more than one-third of the global harvest, Increasing demand for food production is likely to increase the pressures on available water reserves (8,71). However, increasing water-use efficiency in agriculture could allow larger areas to be irrigated. For example, increasing efficiency by 10 percent in Pakistan could provide water to irrigate two million additional hectares (72). Companion needs include attention to crop water-use efficiency, more efficient water management systems, and technologies and policy structures promoting efficiency.

In general, food production increases will depend on the ability to mobilize resources to that end, but of equal concern is whether the resource base can support or sustain the needed increases in the long term (15). Most agricultural production uses environmentally unsustainable practices. Although modest efforts toward sustainable agriculture are evident in industrial countries, population growth and poverty in developing countries undermine efforts to introduce and expand sustainable production practices (132). Limiting capital elements in food production include:

- ***Energy.*** Energy availability for fertilizers, irrigation, and mechanization is likely to be constrained increasingly by supply, costs, and environmental impacts associated with discovery, extraction, and use of certain fuel types (e.g., fossil fuels): renewable energy sources

BOX 4: The Gambia's Soil and Water Management Project

The Gambia, a small Impoverished country on the fringe of the Sahel in West Africa, has long faced a myriad of problems familiar to countries in sub-Saharan Africa the need to Increase food production to feed a growing population (now at 1 million); the challenge of stimulating economic growth to in-increase per capita income (currently $235/year), and a deteriorating environment and natural resource base, which threatens to diminish productivity and Increase the food-population gap In 1978, the Government of the Gambia, USAID, and the German Technical Assistance Agency launched a long-term effort to reverse these trends. The resulting Gambia Soil and Water Management (SWMU) project was aimed at halting and reversing environmental deterioration associated with some traditonal cultivation practices, Increasing the production of food, forage, and wood, and reducing susceptibility to drought The project Included strong Institution-building, participatory, and technology components

An evaluation team reported in 1988 that farmers who participated in conservation activities had resounding praise for the easy applicability of the methods and their effectiveness not only in conserving soil and water but in increasing agricultural production beyond expectations (1 00, 102) An end-of-project review reported that a majority of the 78 villages participating in the project area doubled overall food production, and two villages reported a four-fold increase in land under cultivation (1 01, 120) The returns seem to provide sufficient Incentive for villages to continue or expand conservation practices and for the government to support the SWMU. However, the project area represented no more than 2 percent of the people and land area in a very small country.

Implications for public policy from the SWMU experience include. interventions with a greater "multiplier effect" wiII have to be found if significant overall progress is to be made in Africa; the internal rate of return was insufficient to attract international capital, suggesting that concessional aid remains critical; and the SWMP addressed a rather narrow set of economic and environmental problems, whereas if sustainable development is to be achieved, many other problems will need attention simultaneously

The challenge is always to learn from success and failure and the Gambia soil and Water Management Project is rich in lessons for new undertakings Some useful lessons include:

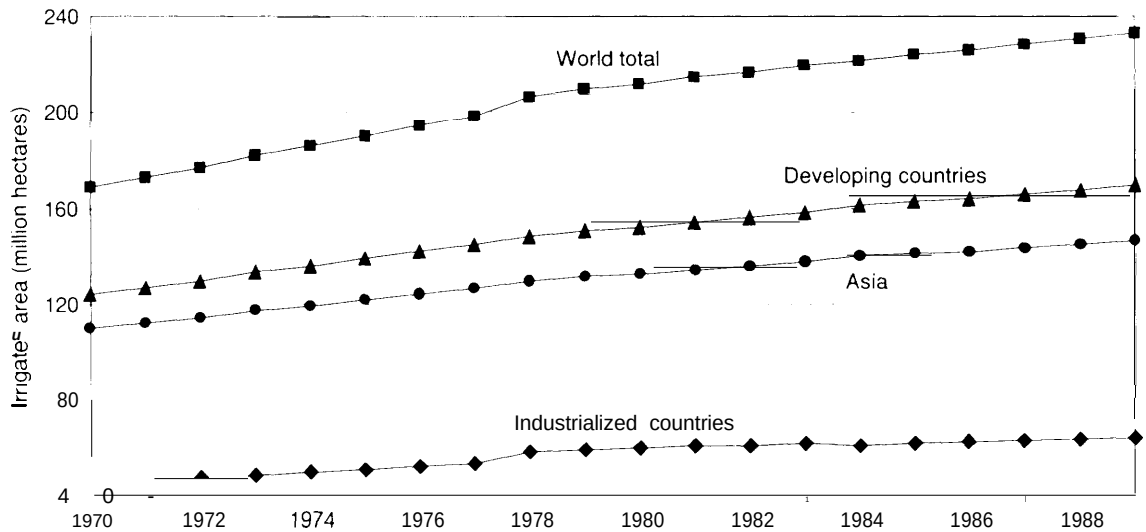
- Investment in human capital offered the highest payoff in terms of agricultural productivity gains and natural resource base preservation.
- The payoff from investments in human capital requires time and patience There are seldom shortcuts or quick fixes.
- The U S science and education system has much to contribute toward achieving sustainable development, especially in solving food and environmental problems in Africa
- "All development is local, " to borrow from apolitical adage, and the village level m rural Africa holds the key to development.

SOURCE J G Stovall, "Sustainable Development In Practice Does It Work?" contractor report for the Off Ice of Technology Assessment, April 1994

will be critical to meeting long-term energy needs.

- ***Land and water resources.*** About one-half of the estimated land area potentially suitable for crop production is currently under production. However, this estimate fails to account for issues of distribution, competition for other uses (e.g., forest conservation), conversion costs (capital, social, environmental), production costs (e.g., irrigation), degradation rates, or the potential effects of climate change.
- ***Genetic materials.*** These will be critical to sustaining agriculture through breeding new varieties able to withstand increasing pressures from pests, disease, and changing climatic conditions; gene pool protection is deemed ad-

FIGURE 9: Expanding the Reach of Irrigation



Irrigation can help increase crop production by extending the growing season, bringing new lands under cultivation, or boosting yields from existing fields in areas of low precipitation Limited water resources, energy for pumping, and soil conditions may impede the use of irrigation technologies, but high/y efficient rnicro-irrigation systems can extend the benefits of exlsting water resources

SOURCE World Resources Institute *World Resources 1992-93 A Guide to the Global Environment,* Data Base Diskette (Washington, DC: 1992), table 18203

equate, if support continues to keep it in its current state of health.

- ***Knowledge.*** Expanding the knowledge base to deal with the changing global food demand scenario will be fundamental; although improved practices have accounted for a 2.5-to 3-fold increase in global agricultural production since World War II, there is no guarantee that such a pace will continue (15).

1 Energy in Development

Industrial country development has been made possible largely through the use of high-quality fuels. Quality is determined by a fuel concentration, flexibility, need for processing, and end-use efficiency (i.e., petroleum is higher quality than coal which is higher quality than wood). Energy, substituting for labor, powered the large productivity increases of previous centuries (37,38). Today, however, burgeoning world population growth may have created the need for the reverse substitution.

Developing countries continue to need energy to raise productivity and improve living standards. Traditionally, industrial and developing countries have met their energy needs by expanding the supply base without regard for use efficiency, Today the focus has clearly become efficiency. Commercial energy consumption is projected to triple during the next 30 years, driven by population growth and economic development (associated structural and social changes include urbanization, infrastructure development, increased use of commercial fuels, and increased demand for consumer goods) (11 1). The investment required to meet the expanding need will be significant. Investment in capital-intensive electricity-generating stations and petroleum refineries—already a large part of all public investment budgets in developing countries—will have to

TABLE 3: Net Irrigated Area in the Top 20 Countries and the World, 1989

Country	Net irrigated area	Share of cropland that is irrigated
China	**45,349**	47
India	**45,039**	25
Former Soviet Union	**21,064**	9
United States	**20,162**	11
Pakistan	**16,220**	78
Indonesia	**7,550**	36
Iran	**5,750**	39
Mexico	**5,150**	21
Thailand	**4,230**	19
Romania	**3,450**	33
Spain	3,360	17
Italy	3,100	26
Japan	2,868	62
Bangladesh	2,738	29
Brazil	2,700	3
Afghanistan	2,660	33
Egypt	2,585	100
Iraq	2,550	47
Turkey	2,220	8
Sudan	1,890	15
Other	36,664	7
World	235,299	16

SOURCE S Postel *Last Oasis Facing Waler Scarcity (New* York, NY W W Norton &Co 1992)

double. Further, energy sectors in developing countries experience a wide range of operational problems—from crumbling infrastructure to massive training needs. Thus, even if finances were available it is questionable as to whether supply could be expanded rapidly.

The concerns surrounding energy needs and use focus on the forms of energy used, the relative supply, and associated environmental impacts. Much of the planned expansion in developing countries will be supplied by coal and hydropower followed by gas, nuclear, oil, and geothermal energy resources, Gas turbines may be **the most**

WORLD BANK

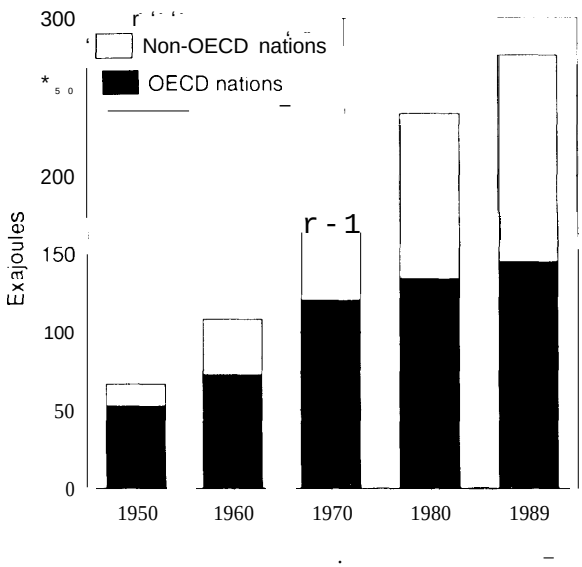
Energy, whatever the source, is a prerequisite for development Here, camel power provides the energy to draw water from a local well for use in crop Irrigation

promising for the developing world, yet gas currently is not widely used in developing countries (1 11). Environmental problems linked to fossil fuel use (e.g., global warming) by and large area result of Northern industrialization patterns; however, similar problems are evident from industrialization in the South (figure 10). For example, developing countries now account for 52 percent of the total energy-related carbon monoxide emissions, largely as a result of increased use of fossil fuels for transportation and energy (95,121). Renewable forms of energy are more likely to contribute to long-term sustainability, but they currently seem less economically competitive than traditional energy sources.

1 Developing Countries and the World Economy

Economic and institutional development in assisted countries and integration of developing country economies into the world economy have been consistent themes of international development efforts. Trade, translational corporations, commercial lending, and aid are the dominant realms of current international economic relations (55). Welfare gains generally are associated with international trade; however, trade-induced competition may lower costs by increasing efficiency

FIGURE 10: Global Fossil Fuel Consumption, 1950-89



Fossil fuel consumption has grown steadily worldwide with an increasing share of consumption coming from the developing world Collectively developing countries now emit more CO_2 (the primary effluent of fossil fuel combustion and the most prevalent greenhouse gas) *than the industrial nations*

OECD - Organisation of Economic Cooperation and Development

SOURCES United Nations *Energy Statistics Yearbook (New* York United Nations Statistical Off Ice 1982 and 1989)

or lowering standards (20). The former is consistent with SD as it reduces throughput. while potential for the latter is a major source of concern for many environmentalists. Indeed, one of the issues in recent General Agreement on Tariffs and Trade (GATT) negotiations concerned the potential for lowering of environmental standards as attempts are made to "harmonize" standards across trading partners (105). Economic growth without the proper policy framework is 1ikely to contribute little to SD.

Trade Liberalization

The basis for liberalizing trade is to increase wealth in industrial and developing countries by concentrating resources in the most productive and competitive sectors to enable countries to maximize their comparative advantage. In 1ight of the mobility of labor and capital in the world economy, liberalization can favor countries with low wages and minimal social or environmental regulations (20). Nevertheless, the trend is toward liberalization, and the current challenge seems to be to craft trade policies that can be consistent with SD. Debate centers largely on how trade expansion should occur and what safeguards should be in place to assure equitable access to expanded markets (5, 124).

Many view greater market access in developing and industrial countries as a vital component of economic development (81,92,94). International assistance efforts often promote export-led economic growth to integrate developing countries into the world economy. Outward-oriented development strategies emphasize greater reliance on market signals, reductions of import barriers, and removal of distortions that cause internal relative prices to deviate markedly from world prices. Economic diversification, lowering of trade barriers, and promotion of foreign direct investment were central to the current economic success of Malaysia, Chile, Thailand, and Indonesia. In 1965, for example, 89 percent of Malaysian exports were primary products as compared with only 28 percent in 1993 (69). Little access to higher-value markets in industrial countries has been identified as one constraint to developing country expansion beyond primary commodity exports (81). For example, tariff structures imposed by the United States and other major importing nations tend to escalate as products move through the processing chain, making imports less competitive (1 1 O).

Trade protectionism in industrial countries has been estimated to cost developing countries nearly $150 billion in lost potential revenues from agricultural and textile production ($100 billion and $50 billion respectively) (92,94). The percentage of industrial country imports subject to nontariff barriers has increased rather significantly since 1966-a highly debated 40 percent increase was estimated by the World Bank in 1988 (53). Policies established in some developing countries to protect infant industries and support domestic production also have been criticized for isolating these industries from competition and

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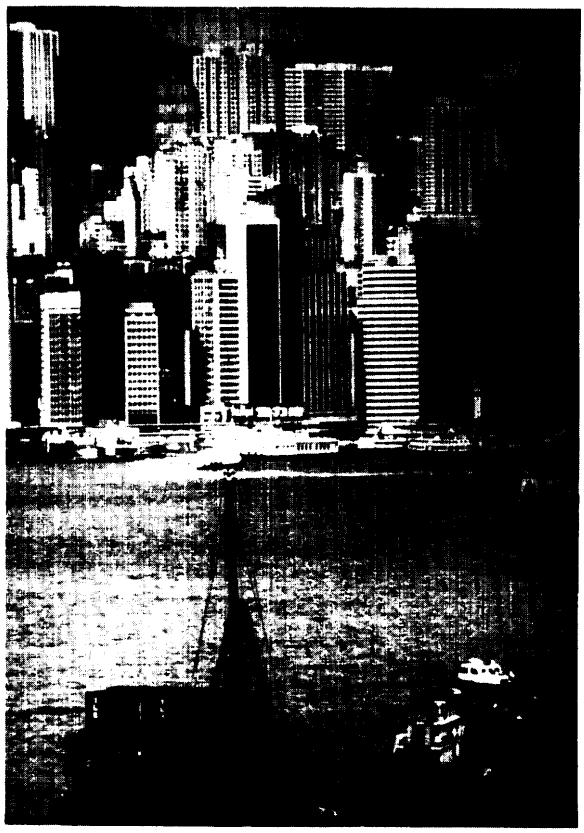


Trade has long been an economic strategy particularly for areas where phy.weal resources are limited, Hong Kong, shown here, has a small per capita land area, yet is one of the largest trade centers in the world

innovation, making them less able to move into the international marketplace (81 ,94). For certain countries (e.g., Zambia, Uganda), dependence on single commodity export places even greater constraints on economic development and stability.

Yet, some analysis suggests that a global policy shift toward greater outward orientation could worsen the terms of trade for some developing countries (5), particularly those heavily dependent on primary commodities. Since 1980, commodity prices have dropped by at least one-half in real terms, representing an annual loss to developin$_g$ countries of almost $100 billion in 1993 (69). World trade in commodities has grown much more slowly than trade in manufactured goods and services; a surge in commodity production and export could spur the decline in international commodity prices (69). Although liberalization could stimulate production in developing countries and benefit food exporters, food-importing countries would likely be hurt (132). Lifting of nontariff agricultural barriers by industrial countries could increase developing country export earnings from fruits and vegetables by almost 25 percent. However, the impact of liberalization on coffee, cocoa, and tea could result in lowering the international trade value of these important tropical agricultural commodities by promoting increased production (1 32). Free-trade proponents acknowledge that the gains from trade may be unevenly distributed among countries, implying that there will be some winners and some losers (55,124).

The latest round of GATT seeks to liberalize four areas of economic activity previously the domain of national legislation: trade in services, intellectual-property rights, international investment flows, and agriculture. The projected beneficial effects of GATT are debated, however. Although analysts project a gross world product (GWP) increase in the trade sector of 4 to 5 percent above the comparable level as a result of trade liberalization, only an estimated one-third of the income effect will benefit developing countries.[11] The agricultural component has been criticized as inequitable to developing countries, which tend to be agrarian-based. Although export subsidies would be reduced, some observers believe that the reduction is too small to halt dumping of cheap agricultural products on developing country markets. Other problematic clauses in GATT from the developing country perspective are the ability of countries to limit the required 3 to 5 percent increase in agricultural market openings to certain products, and the inability to dispute the regula-

I [1] China would account for at least one-half of this amount followed by the rest of Asia and Latin America and the Caribbean. Some poor countries are likely to run net losses (27, 124).

D. LOWE

Informal markets characterize much of the rural developing world and are important in local economies Opportunities to enhance markets could offer one avenue for local development

tions for the next six years (10,27,124). Disagreement is by no means limited to developing countries; in the United States, debate continues over how to meet the projected shortfall in tariff revenue (a projected $13 billion shortfall over five years) (90).

Environmentalists suggest that GATT should address the needs to eliminate trade barriers that adversely affect the environment and development, and to allow intervention in trade to protect primary interests (e.g., tropical forests, biodiversity, food security, climate, etc.)(124). Opportunities for integrating environmental protection policies and international trade also have been discussed in the context of other trade agreements (e.g., North American Free Trade Agreement, NAFTA). Although the economic and national benefits of such agreements have been questioned, some analysts suggest that, at a minimum, these agreements provide the first legal framework for enforcing environmental standards in production. [12]

Encouraging trade and investment in the developing world is likely to depend on government stability, sound macroeconomic policy. transparent financial policy, investment in education and training, and ability to rely on domestic savings to finance investments (81). Policies that focus on export orientation to the exclusion of other companion priorities (e.g., environmental sustainability, human development) are unlikely to fit within a SD paradigm.

Multinational Enterprises and Development

Multinational enterprises (MNEs) control a substantial part of the global economy today, perhaps as much as one-quarter of all economic activity in their host countries. These economic units can take many different forms such as resource-based, export-oriented, regional, translational, global, and distributed (108). Translational corporations (TNC) may control as much as 70 percent of world trade and can provide a source of capital for developing countries, accelerate technology transfer, and develop human resources (94).

The large role played by TNCs evokes a wide range of concerns from national governments, rival firms, and strategic partners. Some TNCs may be less concerned with advancing national goals than with pursuing organization interests—largely growth, profits, proprietary technology, strategic alliances, return on investment, and market power. Foreign TNCs may make few national in-

[12] In the first organizational meeting of the environmental ministers of NAFTA, the need for rapid implementation of the Commission 'or Environmental Cooperation (CEC) was highlighted (65). CEC is charged with ensuring that participating members adhere to their national environmental regulations. The language, however, is not strong and only provides for intervention in the case of persistent failure to enforce environmental laws (29).

vestments; drive local firms from the marketplace; import complex parts for assembly; fail to provide commensurate pay, benefits, or training for workers; or extract subsidies from state and local resources. Corporations that operate this way can hardly be viewed as national assets. Similarly, firms that move abroad to take advantage of low wages and lax environmental regulation are not acting in a nation's interest (108) nor in the interest of SD.

Nevertheless, broad opportunities exist for TNCs to promote development through technology transfer and direct investment. Foreign direct investment (FDI) in developing countries grew substantially in the 1980s, reaching $32 billion in 1990. However, the percentage of total FDI these countries attracted declined over the same period of time. Further, these FDI flows were not evenly distributed.[13] Investment outflows from many of the newly industrialized countries (NICs) grew as well during the 1980s, reflecting efforts to penetrate new markets and access new technology or provide for other corporation needs. In fact, in 1990, outflows exceeded inflows in the Republic of Korea and the Taiwan Province of China (94).

The mobility of capital and labor through TNCs could offer potential for enhancing technology transfer among developing and industrial countries and promoting education, training, and information exchange. Yet, the pattern of investment does not favor the least developed countries—those most in need of development aid. Further, the potential for organizational interest to override the national interest argue for careful examination of TNC/FDI as a mechanism for development. There are indications that German and Japanese policies result in greater domestic social benefits derived from multinational activities than is evident in the United States (108). These policies might provide a template for developing country governments to ensure that FDI does not derail national efforts toward SD.

Economic Stability

Sound macroeconomic policies are a vital underpinning of SD and it has long been established that economic and environmental goals can be complementary and mutually supportive. There are many examples of good economic policies that are also good for the environment and human development (e.g., removal of energy subsidies to promote energy-use efficiency or clarification of property rights to promote sustainable land-use practices and provide landowners with a sense of security and continuity). The USAID economic strategy states that leadership on macroeconomic reforms will be largely the purview of the World Bank, multilateral development banks, and the International Monetary Fund (IMF) (99).

The structural adjustment programs of the IMF and the World Bank are intended to create macroeconomic stability and fiscal-monetary discipline. Structural adjustment activities typically include economic stabilization and other measures (e.g., budget deficit reductions, devaluation of currency, price and subsidy reforms, and privatization or reform of public enterprise). The ability of developing country institutions to undertake some program components may affect significantly the potential for successful transition to macroeconomic stability. For example, the rush to privatization may be inappropriate in a setting where institutional and technological problems remain major constraints and where the private sector and financial markets are weak. Identifying the appropriate public sector institutional development needs vis-a-vis private sector capabilities is vital in many developing countries. Central donor questions are: 1) what is the desirable ratio of

[13] In 1990, the majority of inflows to developing countries was concentrated in Asia (61 percent) and Latin America and the Caribbean (32 percent). Very little 1990 FDI went to Africa (7 percent) or the least developed countries (0.7 percent) (69, 94). High rates of domestic growth, low production costs, and increasing consumer purchasing power are cited as the attractions for the heavy FDI in Asia and the Pacific (94).

public/private sector development to support sector growth, and 2) how can these sectors be supported/strengthened properly to achieve a yet undetermined desirable size and shape (56).

Critics point out that the typical measures undertaken in structural adjustment may have a disproportionate adverse effect on middle and lower economic brackets (66, 107) at least in the near and middle term (box 5). Although spending cuts may not be disproportionate across sectors, the lower economic sectors may be less able to absorb additional burdens generated by spending cuts or monetary control measures (e.g., devaluation). Alternatively, the argument can be made that governments willing to undertake structural adjustment tend to be in such fiscal trouble that wide-reaching budget cuts would be likely with or without structural adjustment measures (16). In either case, the challenge to the lending institutions becomes one of addressing institutional factors that will affect the success of a structural adjustment program and identifying appropriate avenues for capacity building. Further, the issues of corruption and governance, although perhaps beyond the control of IMF or the World Bank institutional authority, may profoundly influence the outcome of structural adjustment activities (75).

The interface of structural adjustment and other institutional development programs also may create problems in satisfying loan conditionalities. On the one hand, World Bank lending can influence public sector spending and may generate a need for large bureaucracies to implement projects. For example, World Bank-financed projects in Kenya accounted for at least one-half of the development expenditures of the Ministry of Agriculture during 1977 to 1982 (56). On the other hand, structural adjustment focuses on reducing budget deficits, government employment, and overall size of public sector. Clearly, satisfying both criteria would be difficult at best and depend in large part on a well-established and capable private sector.

The IMF and the World Bank share a weakness in creating macroeconomic strategy plans/programs in concert with national governments and identified beneficiaries (14,66). The World Bank notes that the commitment of borrowers to funded operations (i.e., ownership) has received little attention in the past, but also acknowledges that host-country participation and commitment to operations are essential to success (66,127). The World Bank's new "Action Plan" identifies the need to address the issues of participation, project ownership, nongovernmental organization involvement, and project monitoring (127). The challenge will be for the World Bank to create effective and appropriate conditionalities for its loans that will reflect equally the needs of the lender and the borrower.

TECHNOLOGY AND SUSTAINABLE DEVELOPMENT[14]

Technology can affect sustainability in a positive way by reducing throughput and waste and by increasing efficiency and finding alternatives to scarce resources. Environmental benefits are not the sole measure of a technology's contribution to SD. Appropriateness of scale, use of local resources, and equity are important considerations as well. For example, raising efficiency in commercial energy use in developing countries could generate large benefits for the global environment, yet may have little bearing on the poor, rural majority (figure 11). This group perhaps would benefit more from widespread availability of more efficient biomass stoves and technologies to produce fast-growing trees.

Great strides have been made in the past decade in pollution prevention and creating cleaner technologies for industrial production. These efforts encompass production processes as well as

[14] See appendix B for a more detailed description of the OTA reports summarized here.

BOX 5: Structural Adjustment in Costa Rica

By the late 1970s and early 1980s many developing countries had created significant debt loads through a variety of external loans, including development-oriented lending programs. The ensuing global debt crisis gave rise to the development of structural adjustment programs Structural adjustment programs include economic reforms to expand exports to earn foreign exchange with which to repay creditors. At the same time, debtor nations become more attractive to foreign investors and thereby shift foreign borrowing into foreign equity investment. Growth has accompanied these reforms in many cases, but observers also note that much of the basis of national economies has passed to foreign ownership and natural resource extraction for export has Increased (51).

Costa Rica has been described as the most recent of casualties in the structural adjustment arena. Despite Costa Rica's political stability and relatively high living standard, economic distress became evident in 1980 largely due to dependence on export agriculture and attendant price declines in coffee, increased demand for imports, and high levels of government spending on social programs leading to a balance of payments deficit Costa Rica undertook structural adjustment under the guidance of the International Monetary Fund (IMF) and the World Bank (WB) with U.S. Agency for International Development (USAID) funding. The program contained mechanisms to curb inflation, increase the private sector role, increase exports, and reduce government deficits.

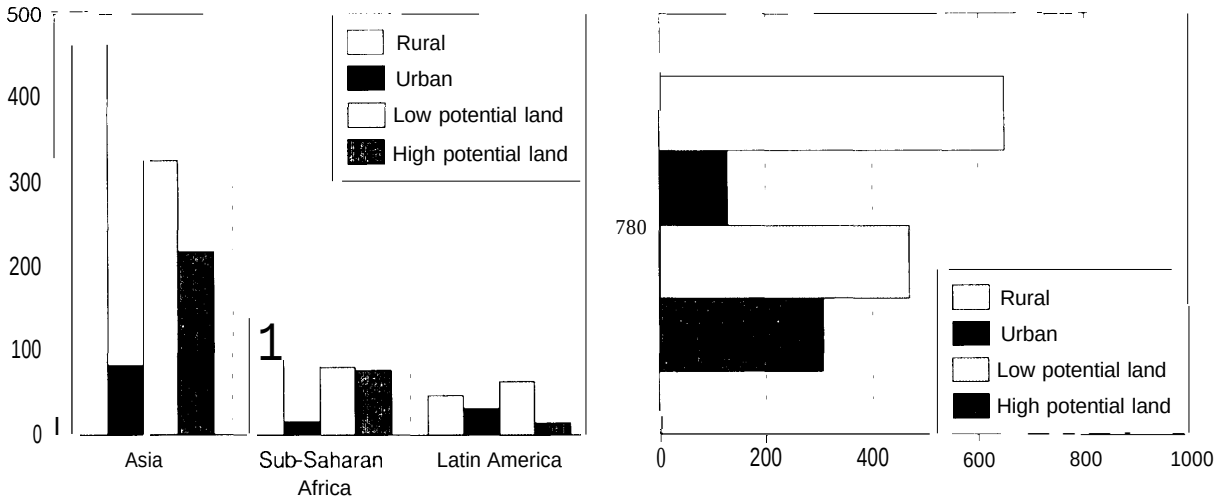
Indications are that Costa Rica is in poorer condition currently than it was when it entered into its first structural adjustment in 1980 Costa Rica's trade deficit has increased, fiscal deficit and inflatlon continue at high levels, and the increased orientation toward an export economy has exacerbated rural poverty, environmental degradation, and economic instability. Further, gross domestic product has in-increased while real wages have decreased, indicating inequitable distribution of benefits. Infant mortality rates have begun to rise as has the Incidence of disease, which many link to the declining government budgets for health, nutrition, and sanitation under the structural adjustment program.

On the other hand, narrow commercial interests have benefited in Costa Rica. For example, export incentive bonds are available to exporters of nontraditional agricultural products and can be used to offset taxes or sold for cash Eighty to ninety percent of these bonds (equivalent to 43 percent of the fiscal deficit in 1991) are held by five translational corporations Import duties have been decreased and tax concessions and other subsidies drain resources from the government, The impact on small producers is large prohibitive costs prevent their entrance into the nontraditional export production and price supports, credits and protection from imports have been slashed for traditional crops (domestic consumption). Costa Rica now imports nearly one-half of its food supply, as opposed to being nearly self-sufficient, as it was in the early 1980s (39)

Success or failure? In the case of Costa Rica, it would seem that structural adjustment has failed with respect to the social, environmental, and economic dimensions of sustainable development, On the other hand, some adjusters such as Mexico, Chile, Argentina, and Indonesia appear to have been successful (2) Careful examination of the factors contributing to success or failure of these efforts could yield Important information for developing countries

material inputs. Some new and emerging technologies such as recycling, renewable energy, and low-input agricultural production systems have been generated primarily to reduce waste. Others exist to reduce extraction and increase throughput efficiency. For example, designing products to be

FIGURE 11: Population Distribution and Poverty



Of the nearly 780 million Impoverished m the developing world, the majority live m rural areas (83 percent), nearly 79 percent of the poor of the developing world live m Asia

SOURCE H J Leonard, ' Overview, ' *Environment and the Poor Development Strategies for a Common Agenda* (Washington, DC U S Government Printing Off Ice August 1993)

durable, '5 repairable, and recyclable could increase maintenance efficiency, and reduce system throughput, depletion, and pollution (1 12). Designing living patterns that reduce the need for certain commodities also can contribute to increased maintenance efficiency (18,3 1,107). Areas in need of technology development include food and fiber production, energy production, industrial processes, and waste management. U.S. executive agency efforts have been moving in this direction (e.g., the U.S. Department of Agriculture's Low Input Sustainable Agriculture Program and the U.S. Department of Energy's Renewable Energy Program), and legislative initiatives have been explored to speed progress (e.g., Environmental Technology Act of 1994).

Identifying and promoting technology that is most suitable to the socioeconomic, environmental, and political conditions of a specific development site has been one of the greatest challenges for assistance organizations (box 6). Introducing costly advanced technology into developing nations can create as many social and economic problems as the technology was intended to solve. Rather, building on traditional methods and technologies to increase productivity or efficiency may be more likely to fit the local site conditions. Appropriateness of scale is a fundamental feature of successful technology implementation. Improved or low-impact technologies might include renewable energy technologies, small-scale light industries, and solid-state communications for education and/or health care (125,40, 119). Ability to promote appropriate technology has been hampered by lack of familiarity with traditional systems, aid program designs based on donor commercial interests (e.g., tied aid, mixed credits), and bureaucratic needs to "move money" through the programs (62,40).

Leapfrogging describes a development approach that blends appropriate technology and SD. The goal of leapfrogging is for developing

[15] It is important t. note that durability can also be a disadvantage, particularly if it implies continued use of poorly designed, Inefficient, polluting technologies. In such cases, regulatory measures might become a predominant form of working toward SD.

BOX 6: Indonesia's Rice Integrated Pest Management Program

The Importance of rice in Indonesia can hardly be overstated It is the major component of diet; it is the country's principal wage good, and it provides the main source of employment for about 50 million farmers and farm workers. Research in the early 1980s showed that Infestations of the highly destructive brown planthopper was a result of Indiscriminate insecticide applications that suppressed natural predators of the planthopper This key finding led to the beginning of one of the most aggressive integrated pest management (1PM) programs ever undertaken

With the help of the USAID and other donors, the Government of Indonesia enlisted the Food and Agriculture Organization (FAO) m a massive training program to educate farmers about the benefits of 1PM and how it could work at the farm level, Launched in 1986, the goal was to train 1,000 pest observers, 2,000 field extension workers, and 100,000 farmers in three years (41, 42)

Far exceeding original project goals, approximately 2,000 IPM specialists and at least 5,000 extension workers have received intensive field training in 1PM and 250,000 farmers have graduated from season-long Farmer Field Schools The impact of this training has been great, catching the attention of international organizations and governments of other countries where traditional rice culture depends on massive amounts of chemical pesticides Some of the program results included: a 60 percent decrease in pesticide use from pre-IPM years, cessation of pestlclde-induced pest outbreaks in 1PM areas, dramatic yield and economic return Increases in 1PM areas as compared to non-l PM areas, a $120 million annual savings from declining pesticide subsidies, and reduced environmental damage and health risks from pesticide use, and spreading grass-roots support for 1PM (42)

Clearly, the 1PM Program is a small step in the overall context of sustainable development There are many other threats to a sustainable environment in Indonesia and 1PM alone cannot provide the productivity Increases necessary to feed the growing Indonesian population Nevertheless, the Indonesian Rice IPM Program Incorporates many elements essential to success in sustainable development efforts

- The Indigenous people were fully involved in and "took ownership" of the problem-solving effort
- The central, regional, and local governmental bodies were committed to the program.
- The program was an "Indonesian Program, " not a donor program To USAID's credit, support was through a grant, leaving the key decisionmaking to the Indonesians.
- The "Improved practices" (I PM) were economically viable and their adoption was in the economic self-interest of farmers.
- The involvement of an International organization—in this case the FAO—provided experience from other countries and disseminated the lessons learned globally,

SOURCE J G Stovall, "Sustainable Development in Practice Does it Work?" contractor report for the Office of Technology Assessment, April 1994

countries to bypass the environmental and social ills (e.g., pollution, overconsumption) resulting from the development pattern of the industrial countries of the North. However, there is much disagreement over the potential for leapfrogging. Lack or inadequacy of environmentally sustainable technologies (e.g., renewable energy) is cited by some critics. Others doubt that following another development pattern would yield a standard of living comparable to that in the industrial countries. A large part of this challenge might be met through intensive, collaborative research and development efforts in sustainable technologies in conjunction with widespread education and information activities to demonstrate the benefits of a SD path in industrial and developing countries.

OTA has conducted many assessments of technologies with potential application in devel-

opment efforts (see appendix B). The information taken from OTA's reports covers a wide range of technologies and resource concerns, related research needs, and institutional roles in development assistance. Although many of the OTA reports reviewed do not address the concept of sustainable development directly, they nonetheless contain highly relevant material.

Agricultural Technologies

The goal of agricultural research and technology development generally has been to improve productivity and soil and water conservation, and maintain reasonable costs of food and fiber. Other interests include improving human nutrition, food quality, and safety; improving the international trade balance; and contributing to the economy as a whole. Recent1 y, more concern has been directed to reducing agriculture's adverse environmental impacts using a systems approach. Agricultural policy issues with respect to sustainable development include: research and development priorities; regulations and programs concerning trade, food prices, land ownership, and environmental quality; and food security and employment. In many developing countries these needs still are not met, sustainably or otherwise.

OTA's examination of the needs of industrial and developing country agriculture spans many significant developments: the emergence of appropriate technology and sustainability paradigms, technological advances with potential to improve agricultural efficiency and productivity, and the rise of commercial agricultural biotechnology. OTA has provided Congress with options for strengthening the cost-effectiveness of U.S. participation in international agricultural research, technology development, and assistance as well as specific considerations and options on technologies and policy initiatives to improve food production in developing countries.

WORLD BANK

Terracing, a traditional agricultural technology, allows food production on sloping lands while reducing loss of soil and fertility to erosion forces

OTA finds that in developing countries much of the land available to small farmers is only marginally suitable for most forms of agricultural production, and often progressively deteriorates. Poor soils, characteristic of many moist tropical forest regions, quickly lose their nutrient content, and exposure to wind and rain, often on steep slopes, leads to rapid soil erosion. In arid and semi-arid regions, low soil productivity also prevails and is accompanied by a short growing season, low and erratic rainfall, and possibility of drought. Production practices, such as shifting cultivation,[16] can accelerate the degradation process as well. Given these conditions, erratic, declining yields are common, and generally expanded cultivation or off-farm employment are used to make up for these losses. Catastrophic crop losses, in a climate of chronic food insecurit y, can prompt large-scale civil conflict and migra-

16 Shifting cultivation involves cutting and burning forest, producing crops for a couple of years, abandoning the land for a "fallow" period, and then, at some time later, repeating the cycle. Shifting cultivation has increased in many areas during the last few decades: many people have migrated from established farming areas into forest areas, often along logging roads, and they generally are using shorter fallow periods than in earlier years (110, 114, 117).

tion, as has occurred in parts of Africa over the past two decades.

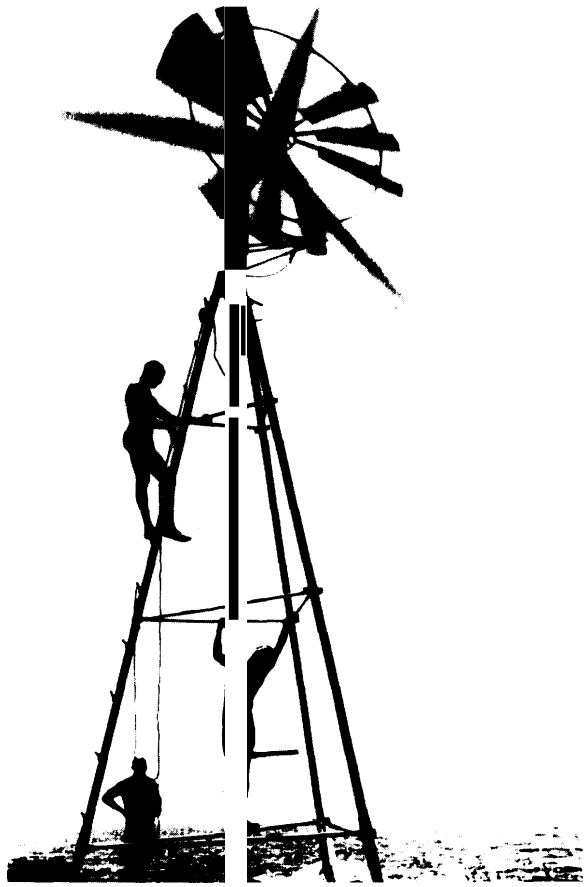
OTA has concluded in several reports that greater U.S. contributions to domestic, bilateral, and multilateral agricultural assistance will be necessary to increase agricultural production worldwide. For production increases to be sustainable, however, farmers need technologies with potential in the following areas (1 10,115,1 17):

- improving the use of local natural resources, including indigenous plants and animals,
- improving soil fertility,
- improving water availability and efficiency of use,
- fostering genetic improvement in plants and animals appropriate to local conditions,
- improving integration of animal and cropping systems,
- reducing food losses, and
- enabling farmers to modernize as this becomes feasible to them.

Energy Technologies

Energy efficiencies vary in the developing world but, on average, appear to be much lower than in the industrialized countries. Low technical efficiencies with which energy is produced, converted, and used in developing countries could be improved through adoption of proven technologies. On the demand side, these include efficient lights, cookstoves and refrigerators, cars and trucks, industrial boilers, electric motors, and a variety of new manufacturing processes for energy-intensive industries such as steel and cement. Moreover, numerous technologies at various stages of development and commercialization could enhance the efficiency of delivering energy services.

Technologies to provide and improve energy services for developing world populations might include, more efficient biomass stoves to reduce fuel use and reduce the hazardous smoke emissions, simple motor-driven systems for pumping water or grinding grain to reduce the burden of these physically demanding tasks on women, and energy-efficient pumps, fertilizers, and mechanical traction to improve agricultural productivity. Technology also could boost efficiency, quality, and productivity of traditional small-scale industry, which accounts for one-half to three-quarters of manufacturing employment in many developing countries and is an important source of income for rural and urban poor.



Alternatives to fossil fuels may offer a more sustainable source of energy for developing communities. Here a windmill provides energy to generate electricity and pump water from a local well.

New energy supply technologies have provided benefits in several areas. Characteristics that make some technologies more suited than others to developing country needs include:

- ***Modular, small scale, and short lead times.*** Energy supply technologies that are small, modular, and rapidly implemented can match

demand growth and prevent large amounts of capital from being tied up over long periods of time.

- ***Reliability and performance.*** In developing countries, frequent blackouts, brownouts, and sharp power surges result in lost operating potential, lost production, and more waste for commercial, residential, and industrial consumers. Technologies that improve operating and maintenance procedures can improve plant reliability and performance.
- ***Rural access.*** Smaller scale technologies (modern biomass and decentralized renewable) can bring high-quality energy sources to rural areas and, thus, promote rural development and employment.
- ***Environmental benefits.*** Increased emphasis on natural gas and other alternative fuel sources (e.g., biomass systems, renewable energy) could reduce adverse environmental impacts compared with conventional sources, and avoid some of the problems of large hydroelectric and nuclear projects.
- ***Foreign exchange savings. New*** technologies that develop local energy resources can reduce energy imports—which currently account for at least 50 percent of export earnings in several of the poorest developing countries.
- ***Employment.*** Decentralized renewable energy sources could stimulate employment. Even though developing countries would, at least initially, import much of the technology, renewable sources need installation and servicing that could create local jobs.

Widespread adoption of improved technologies could achieve substantial energy savings, while providing the energy services needed for development. Capturing these energy savings could help environmental quality and ease the burden of high energy import bills. However, adoption of new energy technologies depends on not only the intrinsic superiority of the technology itself but also on whether financial and institutional factors favor adoption. The policy environment that determines patterns of incentives and disincentives to energy efficiency is crucial to the adoption of new technologies (11 1).

Environmental Technologies

OTA recently looked at environmental protection issues in terms of the economic and industrial opportunities they may present (106, 109) Environmental awareness, liberalization of trade, and the presence of multinational firms is leading, in some developing countries, to more environmental technology imports. Transfer of environmental technologies can reduce day-to-day operating inefficiencies, emissions of environmental contaminants, worker exposure to hazardous materials, and risks of technological disasters.

For many developing countries, provision of basic water, sewer, and refuse disposal services are major environmental priorities. These are the areas where spending on environmental technologies is concentrated. While such expenditures can strain scarce fiscal resources, lack of such services leads to disease problems. Developing countries need more sanitary services systems serving rural and urban areas. Opportunities exist to address some of these community service needs with appropriate technology (11 9).

Electric power, chemical, petroleum refining, steel, pulp and paper, food, textile, and other process industries are potential major buyers of environmental technology. Technologies that lead to more efficient and cleaner uses of energy and materials can be applied to many industries. with long-term economic and environmental benefits. Technologies such as forest management and improved agricultural practices are primary environmental needs in some countries (1 10,1 17).

Pollution prevention and cleaner production technologies are often more cost effective than end-of-pipe waste treatment technologies. Several OTA reports have discussed the potential of industrial pollution prevention (106,1 12). As noted in *Development Assistance, Export Promotion, and Environmental Technologies (* 1993), pollution prevention would be a logical candidate for

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

Preventive health care has contributed significantly to infant mortality reductions in many parts of the developing world.

more attention from bilateral and multilateral aid agencies.

Tropical Disease-Related Biomedical Technologies

The broadest measurements of human health have shown improvement in all developing regions over the past few decades (e.g., life expectancy at birth, mortality of children age 5 and below). Nevertheless, of total deaths in 1985, 84 percent were in developing countries and of these nearly one-half were caused by infectious and parasitic diseases. Of these, 37 percent were children under 5 (versus 3 percent in industrial countries). Causes were respiratory infections, neonatal and perinatal complications, and diarrhea (132).

Vectorborne, tropical diseases remain pervasive problems in the developing world:

1. Malaria is on an upward trend due to insecticide-resistant mosquitoes and resistance of the parasite to antimalarial drugs; a 7 percent increase was noted between 1985 and 1990.
2. Schistosomiasis is endemic in 76 countries; 200,000 people die of this each year; 200 million are infected and 600 million are at risk.
3. Filariasis affects 76 countries; 90 million people are infected and 900 million are at risk.
4. Onchocerciasis is endemic in 26 African, two eastern Mediterranean, and six Latin American countries; 17.6 million to 17.8 million people are infected and 85 million to 90 million are at risk (132).

Two OTA documents about tropical disease emerged in response to congressional uncertainty over whether to continue funding the Gorgas Memorial Laboratory in the Republic of Panama: *Quality and Relevance of Research and Related Activities at the Gorgas Memorial Laboratory (1983)* and *Status of Biomedical Research and Related Technology for Tropical Diseases (1985).*

U.S.-supported tropical medicine research is carried out by several multinational programs, government agencies, universities, and private research foundations and corporations, but OTA identified the now-defunct Gorgas Memorial Laboratory as one of the few high-quality, broadly relevant, tropical research institutions located in a tropical country. OTA suggested such institutions were needed in the Tropics to provide field information on the occurrence, natural history, and transmission of diseases, and to test research results-e. g., drugs, vaccines, vector control programs—where diseases occur. It was also pointed out that research institutions in developing countries can serve as training facilities and can help developing countries retain health science and other science professionals who otherwise would likely seek positions in industrialized countries.

International health research centers along the lines of the International Agricultural Research Centers (IARCs) could make a large contribution to improving the health care/maintenance systems in developing countries. Such centers could identify and analyze the sources of health problems as well as conduct local research on design and delivery of health maintenance systems (79). Public

WORLD BANK

Shistosomiasis, continues to be a problem in the developing world, particularly as new areas are accessed for development bringing vector and host closer together Here, a stream is being sprayed to kill the worms that cause the disease

expenditure on health in developing countries grew from 1.0 percent of GNP in 1960 to 3.7 percent in 1988 to 1990; during the same time period, public health expenditures in industrial countries rose to 4.2 percent of GNP (92).

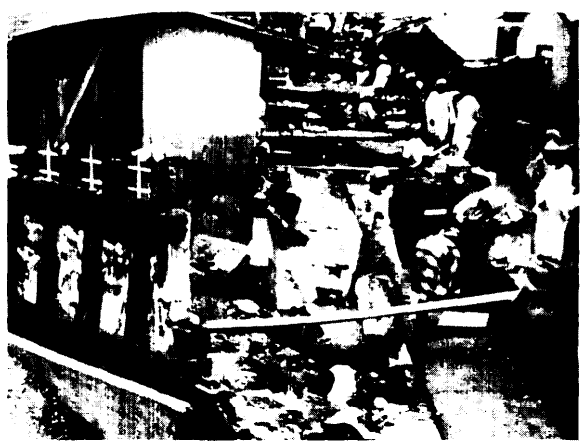
Developments in basic and applied biomedical research also hold promise for more specific disease control measures (11 6). In *Status of Biomedical Research and Related Technology for Tropical Diseases (1985),* OTA provided an overview of the major U.S. tropical research and development supporters (e.g., National Institutes of Health, Center for Disease Control, U.S. Department of Defense, and US AID) as well as policies concerning medical technology development, research funding, and congressional oversight. OTA also assessed biomedical laboratory research and some field research pertaining to selected tropical diseases.

Many developing countries are still at a stage where increased investment in sanitation and clean water would have tremendous benefits for controlling tropical diseases. Small and regional wastewater, drinking water, and municipal solid waste systems used in U.S. rural areas, which might be applicable in developing country settings, are discussed along with metropolitan public works in *Delivering the Goods: Public Works Technologies, Management, and Finance (1991).* Most options available for addressing public works problems in the United States would require considerable support to be duplicated in developing countries.

Technologies for Local Development

OTA assessed the potential for reducing the costs of community services using appropriate technology in *An Assessment of Technologies for Local Development (1981).* Case studies were conducted of community-based projects for resource-efficient residential architecture, solar greenhouses, small farm systems, farmers markets, resource recovery from municipal solid waste, wastewater treatment, energy generation, and health care systems. Critical to all the projects were public interest; availability of technical information and expertise; material, capital, and financial resources; and various types of financing (e.g., grants, cost-sharing, contracts, subsidies, conventional financing).

Appropriate technology projects are developed according to special conditions and available resources at the community level, thus transfer to other settings can be problematic. This is already an observed problem for local-level development projects overseas, although often for other rea-



WORLD BANK

Environmental priorities in many urban settings are provision of basic water sewer, and refuse disposal services Here, a shanty town in Indonesia Illustrates the problems that may arose when population exceeds infrastructure capacity.

D. LOWE

Participatory development is one avenue to promote local "ownership" of development interventions and ensure that interventions match the existing environmental, social, political, and economic setting.

sons. Local development and transfer of appropriate technologies in foreign projects is facilitated most by provision of reliable information on the design, cost, and performance of the technologies themselves. Provided these needs have been met, the remaining barriers are otherwise institutional: opposition from commercial interests, reluctance of donors to accept innovative project designs, insensitivity to social or cultural factors, and insensitivity to regulations at various levels of government or bilateral agreements (119).

Technological Underpinnings for Sustainable Development

Information, education, and communication technologies are seen as fundamental to the pursuit of sustainable international development (107). Attention to these areas will facilitate dissemination and application of previously discussed technologies.

Expanding opportunities for developing countries to determine their own SD path will depend in large part on the free exchange of information among the industrial and developing nations. Such exchange could be useful domestically as well, as many local and regional governments strive toward SD objectives. It may be possible to choose demonstration sites, for example, places within the industrial and developing world that are already on the way to a sustainable solution to a problem. The state of Maine and the city of Seattle have sustainability projects, for example. Funding for information and idea exchange could help multiply similar activities.

Information Sharing

Sharing of information and appropriate technologies has been an underpinning of foreign assistance under the rubric of technology transfer. The question is how best to transfer information and technology broadly for SD (box 7). The trend is toward privatization, in the form of intellectual-property rights, which can slow the movement of relevant research into the public domain. However, without such protection, technology developers may be disinclined to invest in research and development. The challenge will be to find avenues to fund the cost of producing knowledge in a way that facilitates distribution. One opportunity might be the creation of international centers for SD that would be cooperatively funded and focus on collaborative research and technology development.

U.S. academic institutions could take the lead in sharing information with sister institutions in developing countries. Alternatively, governments could consider subsidies to private organizations as incentives for information exchange. Other incentives might include a change in the university system to link personal gain and prestige with conducting developing country research. Ten years ago, for example, U.S. scientists were working on agricultural technologies for developing countries, and built careers on this. Now the em-

BOX 7: Criteria for Technology Transfer

1. Technology should fit the local biophysical and socioeconomic environment of the adopters and should have proven successful elsewhere under similar conditions, at least on a pilot scale
2. Technology IS transferred most effectively by direct people-to-people actions involving individuals with experience in applying the technology. Media presentations (e. g., pamphlets, books, radio) may assist, but personal Interactions are necessary.
3. Technology transfer agents must be well-qualified and experienced in applying the technology and able to communicate effectively to potential adopters. Development of expertise in local organizations IS necessary to continue technology transfer beyond the bounds of development assistance projects and time frames.
4. Even capable adopters may need assistance from facilitators or middlemen in addition to transfer agents to make the transition from established resource-use methods to new technologies
5. Adopters and transfer agents should be involved in choosing, planning, and Implementing technology transfer so that it wiII meet actual needs and IS appropriate to the setting in which be wiII be Implemented
6. Interests of all parties involved in technology transfer should be identified and addressed in the technology transfer effort, each must see how the technology wiII benefit them.
7. Early definition of participant roles is needed so that each is aware of the subsequent steps in the transfer process and the relationship between their actions and those steps
8. Demonstrations of the technology should take place under environmental, economic, and sociocultural conditions similar to those where it wiII ultimately be Implemented.
9. Commitment of financial resources should be sufficient to carry out the technology transfer until it IS self-supporting
10, The transfer process must Include mechanisms through which all participants can contribute effectively to Interim evaluations and adaptations.

SOURCE Derived from a Technology Transfer Workshop held for the Off Ice of Technology Assessmentstudy of *Technologies* to *Sustain Tropical Forest Resources,* OTA-F-214 (Washington, DC U S Government Printing Off Ice March 1984)

phasis increasingly is on high-tech discoveries that are hard to apply and transfer to developing countries. Research institutions in many developing countries have collapsed, and few facilities exist for U.S. scientists to work there (107).

Other mechanisms for getting more knowledge into the public domain might include creating national institutes/centers where governments could monitor technology development and have some rights of eminent domain to buy promising technologies at a fair price and make them available. Collaborative Research Support Programs (CRSPs) could provide a model for foreign cooperation in research and development, and partially circumvent the information monopolization trend.

Education

Education is one mechanism through which many SD objectives might be realized. Needs range from education at the local level for self- and quality-of-life improvements to education at the deci - sionmaking level to foster wise planning and policy choices. For example, access to primary education for females has shown clear benefits in reducing fertility, improving nutrition, and decreasing infant mortality (31,1 32).

Achieving SD will rest largely on broad understanding of the interdependence of the Earth's social, economic, and environmental resources and the costs and benefits of adopting sustainable practices. Educational programs at all levels that

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

Education has been shown to be a powerful tool for empowering women and promoting fare@ planning. Here, a PVO sponsors an educational film on family planning for local *women,*

effectively teach the interrelationship among poverty, population growth, unsustainable production and consumption patterns, and environmental degradation will be needed.

Numerous **educational** technologies exist **that** promote quick understanding of complex issues. For example, computer simulation technologies that present a problem and a variety of possible solution pathways allow individuals to observe the results of their choices and increase their awareness of the downstream impacts of decisions (e.g., Plato, SimEarth). Such tools could be developed to promote informed decisionmaking on complex SD issues such as the desired ratio of births to immigrants. Educational tools that would allow decisionmakers to examine the myriad components of such issues could promote wise planning.

Communication Technology

Communication and information technologies are playing an increasingly important role in business, trade, health, and education. If current trends continue, the gap between industrial and developing countries in the use of communication technologies will continue to widen. Unless means are found to include developing countries in the global information networks now being developed (e.g., the Internet), they may fall further behind.

Computer-based information systems and modem communications are high-tech, high-cost enterprises. Large investments and considerable technological resources are needed to support these enterprises. Currently, well-financed, high-tech, multinational corporations are actively competing to position themselves to benefit from the need for worldwide communication. Many of the systems being designed will be capable of delivering immense amounts of information to remote areas worldwide. Systems such as satellite-based personal communication systems (PCS) can link remote areas without expensive fiber optic cables. However, wireless technology also is extremely costly and technically sophisticated. Domestic providers of telecommunication services in the United States tend to avoid low-density, widely dispersed rural areas for information and network services in favor of urban, high-density, business-intensive areas. Similarly, international service providers may favor industrial over developing countries.

Several organizations are working toward various aspects of improving communications networks and information availability. The United Nations Sustainable Development Network (SDN) is one example of how modem information technology can be used to assist developing countries maintain and apply data for domestic development activities. The SDN goal is to provide global access to data on development activities. Similarly, USAID is improving its Management Information System (MIS) as a programmatic tracking mechanism. The Peace Corps is placing computer Internet connections in its in-country offices to promote access to a variety of international information sources. Other environmental data sources are supported through the United Nations Environment Programme, the U.S. Environmental Protection Agency, and the Consortium for International Earth Science Information Network (CIESIN).

These are just a few examples of how information and communication can be linked and

D. LOWE

/formation and communication are key underpinnings for sustainable international development Here, local educators and extension officers are being shown new techniques via international telecommunications

deployed to assist resource professionals and decisionmakers and to promote education. The potential payoff for application of this advanced technology is enormous, and clearly a vital need for achieving development goals. Coordination of these and other efforts could generate greater benefits.

U.S. INTERNATIONAL ASSISTANCE POLICY

The United States is experiencing changes in its development assistance approach. In the past decade, underlying concerns centered on the need to identify and provide solutions that were socially, culturally, economically, and environmentally suitable to the development site. The 1990s ushered in increased concern about the proper role and responsibility of the industrial nations in solving developing country problems. Social, environmental, economic, and political conditions suggest that new U.S. foreign assistance legislation will be adopted that specifically identifies sustainable development as a goal. A number of countries (e.g., Netherlands, Norway, Japan) already have embraced the SD concept to various degrees (44,45), and the Administrator of the U.S. Agency for International Development has identified SD as a fundamental goal for international development:

> . . . we have an abiding interest in joining with other industrial powers in promoting sustainable development. This does not require—and is not consistent with—an international welfare program; this does not require—and is not consistent with—investments in societies whose governments do not take the steps necessary to help themselves. Rather we recognize that SD is most likely to take place within relatively stable political systems and sound economic policy structures (99).

USAID's Post Cold-War Rationale for Foreign Assistance

Increasing global environmental concerns, geopolitical restructuring, and revisions in national security interests have led to a new vision for U.S. bilateral assistance. The new USAID Administrator has taken steps to reorganize the agency to improve its ability to address:

- poverty and unsustainable patterns of economic growth,
- hunger, malnutrition, and lack of food security,
- population growth and rapid urbanization,
- new diseases and endemic ailments,
- environmental degradation which may ultimately be manifested on a global scale, and
- persistent autocracy, oppression, and human rights abuses (99).

These threats are similar to those identified at the creation of the U.S. bilateral assistance agency; however, their order of magnitude has increased as population has nearly doubled during the past 30 years. Today, US AID plans to address these threats with four strategic elements: 1) encouraging broad-based economic growth; 2) protecting the environment; 3) stabilizing world population growth and protecting human health; and 4) building democracy. As this suggests, the traditional development approach will be adjusted to include dimensions of SD.

Foreign policy, commercial, and assistance interests all tend to affect the allocation of U.S. aid in practice and, thus, attempts to operationalize SD. For example, tying assistance to trade and procurement requirements with the donor coun-

BOX 8: Official Development Assistance and Export Promotion

Development aid can be used to encourage donor country exports. Whereas tied aid opens export opportunities more directly, untied aid may also serve this purpose. Although the precise export promotion effect is hard to determine, such practices are widely used by many major donors, many of which also provide substantial non-aid-related export promotion for manufacture goods. In principle, it might be preferable for all donors to agree to forego tying of aid and let development priorities and the market determine where aid money is spent. However, such an agreement is not likely to be achieved in the near term; for the United States to forego use of such practices could mean that U.S. exports would suffer in time.

Some contend that the use of aid for export promotion can compromise environmental and developmental goals. Increased costs for purchases restricted to bidding only among donor country firms can Increase the cost of capital projects and reduce the amount of real aid A capital-projects orientation could diminish direct aid for basic human needs, although some capital projects may be needed to assure safe drinking water or treat waste. However, overemphasis on export promotion could bias projects toward overly expensive Infrastructure, with more sophisticated technology than is needed to meet basic human needs or is economically sustainable in the target site. Use of such technology can drain resources from more pressing problems and create dependency on industrial countries. If projects are paid for with soft loans, they can aggravate developing country debt burdens or balance of payments problems. Difficulties such as these can reduce a country's capacity to buy environmental goods or services without aid and can encourage mismanagement of the environment.

Export promotion could create a stronger development constituency in donor countries, making continuation of aid more likely. But from a practical standpoint, the efficacy of using aid projects to promote exports is ultimately limited by aid budgets. The U.S. official development assistance budget has declined as a percentage of gross national product over time and is now well below the OECD's Development Assistance Committee average. Nevertheless, avenues exist to prevent or mitigate the potential for the use of development assistance to promote exports to hinder environmental or developmental goals, including

try-tied aid—"is used to support donor commercial interests in concert with providing development assistance. Yet, problems may result. For example, recipient countries may structure development to match what the commercial sector of the donor country supplies, rather than to meet their own social, cultural, or ecological needs (62, 63, 81, 109). When the recipient country has a wide choice of what goods or services it may purchase with tied aid, it often will be able to spend the aid on items that it would have purchased from the donor anyway. This is true for U.S. commodity aid, and may be true for some aid offered by other donors (109) (box 8; figure 12).

| SD Issues for New Foreign Assistance Legislation

The Foreign Assistance Act of 1961 as amended is the legislative authority for U.S. international assistance activities. There is almost unanimous agreement that the Foreign Assistance Act of 1961 is in need of a complete overhaul (47,85). Numerous studies, task forces, and commissions have called for reforms, citing dramatic changes in the world with implications for foreign aid. Examples include the end of the Cold War era, the breakup of the former Soviet Union, the transition to democracy in many countries, and fundamental

BOX 8 (cont'd.): Official Development Assistance and Export Promotion

1 Environmental studies to identify real needs and priorities, Donors Increasingly fund developing country environmental studies, environmental profiles, and conservation strategies. DAC has noted the need for coordination and use of "good practices" in these assessments, USAID has increased the use of host country organizations to undertake these studies in its [goal] for capacity building. Additional measures could be taken to assure opportunity for public review and input from NGOs

2 Use of guidelines in project reviews. Conscientious efforts by donors to ensure that appropriate guidelines are applied could reduce the potential for transfer of inappropriate technology. Sustainable terms of reference for proposed development activities, most notably infrastructure, could be developed to support this effort To some extent this is already done by some donors and multilateral Institutions, yet these ongoing efforts might be broadened to Incorporate additional themes embodied in a sustainable development paradigm.

3 Evaluation of technologies, Potential technologies could be evaluated for their suitability to the Identified need and target site in the recipient country. Evaluation teams comprised of donor- and host-country counterparts could contribute to building recipient country expertise in evaluating alternatives Developing countries may find in many cases that locally available technology is more suitable to the identified need, or that exogenous technology can be adapted to fit local conditions.

4 Provision for operation and maintenance, Projects could be screened to assure that adequate provision is made for their operation and maintenance requirements once construction is completed Education and training is a critical need, but is often overlooked or Inadequately addressed Similarly, costs for spare parts or routine maintenance materials need to be reviewed for their compatibility with the economic conditions of the Implementation site.

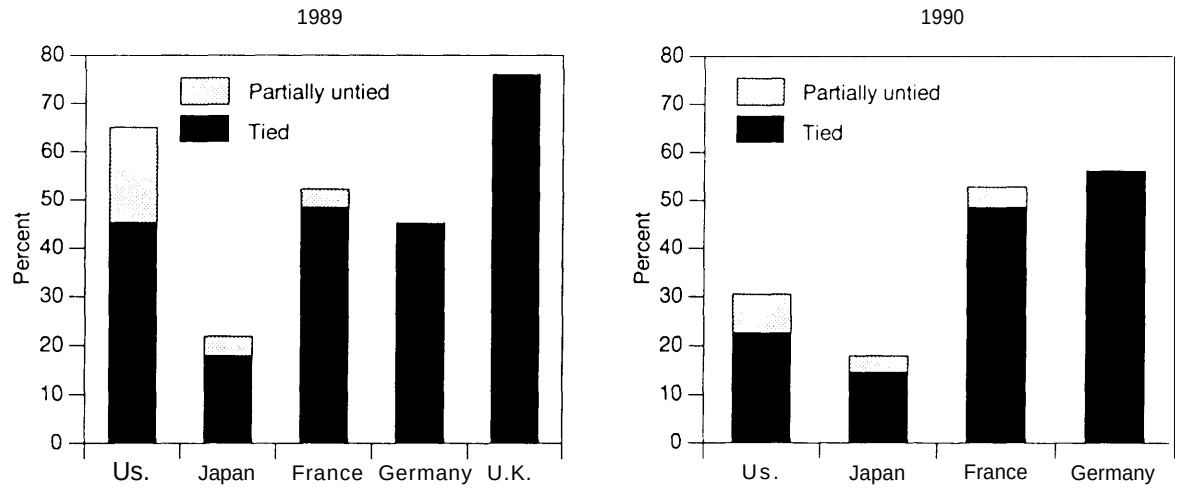
SOURCE U S Congress, Office of Technology Assessment, *Development Assistance, Export Promotion, and Environmental Technology,* OTA-BP-ITE-107 (Washington, DC U S Government Printing Off Ice, August 1993)

changes in the global economy. These changes have called into question some of the basic assumptions and objectives of assistance to developing countries.

Despite repeated calls for reform and several attempts to rewrite the act, Congress has not rewritten the basic law guiding foreign aid since 1961, and has not revised economic aid strategies since 1973, when the "New Directions" legislation refocused development on basic human needs (104). However, amendments have been added to it each year for some 30 years. A recent congressional review ("Hamilton Task Force") concluded that conflicts among some of the act's 33 objectives, unfocused policy directives, excessive earmarking, and obsolete provisions undermine effective implementation of the program (103).

Efforts are ongoing in the 103d Congress to craft a revised Foreign Assistance authority and conditions appear to be more favorable for the rewrite of the act for several reasons. First, the Clinton Administration has given priority to redefining the purposes of foreign aid, restructuring USAID, and proposing a new foreign assistance bill. Second, with the White House and Congress controlled by the same party, there is a better chance that the legislative and executive branch will work together to pass a revised act—a missing element in past efforts at revision. Third, with the end of the Cold War, there is a closer consensus about the basic goals and objectives of foreign aid. The major interest groups supporting development assistance (private voluntary organizations), universities, environmental organiza-

FIGURE 12: Formal Tying of Total (Bilateral and Multilateral) Overseas Development Assistance Commitments



SOURCE U S Congress, Office of Technology Assessment, *Development Assistance, Export Promotion, and Environmental Technology* (Washington, DC U S Government Printing Office, August 1993)

tions, and development professionals) seem to agree on SD as a new overarching theme (85). [17]

If Congress chooses to define, clarify, and enunciate a new policy and strategy for SD, it will likely need to resolve a number of related issues. For example:

How and in what detail should sustainable development be defined?

A policy that embraces SD might best be understood and supported by the public if its meaning evolves out of the legislative debate and is articulated in understandable language. There are numerous definitions of SD, some more precise than others, some conflicting. Still to be resolved is how much detail is appropriate for authorizing legislation; how much should be spelled out in appropriation language; how much should be left to executive branch strategy and policy documents; and what guidance Congress should give the Administration in designing and implementing SD programs.

Given the conflicting notions of SD, there may be a need to spell out its meaning more carefully than policy documents ordinarily would. The implementing agency would need to go further and spell out in detail not only what it expects to accomplish under the rubric of SD, but also *how* it is to be accomplished and what the indicators of progress will be and how we will know when it has been accomplished. The Clinton Administration has made a start on defining SD but still has yet to fully articulate answers to these questions (85).

How much should foreign assistance programs focus on sustainable development?

There are several purposes that foreign assistance programs have served historically. Some of these programs may fit well with SD, but others may not. Public policy, in the form of authorizing and appropriating legislation, could spell out what other purposes and programs still are viable and the resources to be devoted to each. If SD is to be the centerpiece, how many other purposes can be

17 Agreement on SD as the overarching theme would only remove some of the barriers to passage of a foreign assistance act since it covers a number of programs, including military assistance. But, agreement on SD would certainly be a significant step.

accomplished without diluting or countermanding these efforts? The Administration legislative proposal spells out five objectives besides SD: 1) building democracy, 2) promoting peace, 3) providing humanitarian assistance, 4) fostering trade and investment, and 5) advancing diplomacy. It is not clear what the priorities are among objectives, the level of resources required to achieve objectives and where responsibility will rest for the programs authorized under each objective—in USAID, the Department of State, or elsewhere. There is also ambiguity as to how those programs with development implications will relate to SD. These are questions that Congress will have a chance to address in a new foreign assistance act (85).

How much of the sustainable development program should focus on science and technology?

A number of experts have stressed the inadequacy of the knowledge base to implement SD programs and have pointed to science and technology as the means through which the knowledge base could be increased. Some have suggested that since so little is known about how to meet the needs of future generations in environmentally sustainable ways, public policy should invest heavily in a research agenda for SD (44,79). Investment in science and technology, then could be the best means of ensuring that the needs for the next generation are met. The research agenda would seek to develop substitutes for critical natural resources and increase the productivity of all resources. With a shrinking budget for foreign aid, the question is how much to invest in science and technology with a payoff in the distant future, and how much to devote to solutions for more immediate problems.

Most development experts agree that research is most likely to be relevant and put to use if it is the product of collaborative efforts among scientists and institutions in industrial and developing countries. SD is not likely to be achieved by conducting research in industrialized countries and applying it in developing countries. Rather, it is the actions of people who live in those countries that will matter. If developing country scientists or

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

Developing countries have only 6 to 7 percent of the world's active scientists and engineers (RSL/NAS, 1992) The challenge is as enormous for these professionals as it is for bilateral and multilateral assistance organizations active in international development

institutions need strengthening to address the challenge of SD, then development assistance could be used to help improve these conditions (85).

What institutional capacity is necessary to advance sustainable development programs?

Designing and implementing SD programs is much more difficult, many would argue, than traditional development projects. SD involves complex interactions between the ecosystem and development interventions, more sophisticated approaches, and improved monitoring and evaluation systems. Consequently different kinds of skills and knowledge are required. Many SD advocates question whether USAID has the institutional capacity to administer such programs successfully and whether it has the mix of staff with the requisite skills and experiences.

Several studies and task forces have lamented the declining technical staff capacity in US AID as the agency has absorbed operating budget cuts and given priority to generalists and "process managers" in staffing decisions. Although much of the technical expertise needed for SD can be obtained through contractual arrangements, a solid core of

professionals who have advanced training and first-hand knowledge about the ecological, human, and economic variables involved in development is needed. In defining SD public policy, Congress may want to consider the steps USAID has taken or will need to take to strengthen its human resource capacity to design and implement SD programs.

Regardless of how different issues are resolved, it is clear that SD has changed the nature of the debate about what our development assistance program should be all about. It has brought disparate interest groups together to talk about how development can make life better for future generations and reverse environmental degradation. The evidence suggests that SD is the development concept of the 1990s, if not for the next century (84, 85).

CONGRESSIONAL POLICY OPTIONS

Sustainable development embodies multiple, complementary themes that cross U.S. foreign and domestic policy boundaries. Issues such as family planning, energy efficiency, sustainable agriculture, and resource conservation clearly are relevant to SD in the industrial and developing world. Working toward SD will involve more than simply retreading an existing foreign assistance system. The options discussed below relate to opportunities for Congress to support or advance SD and are presented under the following policy themes: [18]

- coordinating U.S. foreign and domestic policies so that they are mutually reinforcing,
- eliminating barriers to SD, and
- developing and disseminating technologies for SD.

Coordinating U.S. Foreign and Domestic Policies

An integrated approach to creating SD policy would involve domestic and foreign policy. In fact, many experts agree that the United States must adopt a SD approach domestically if it is to succeed with the approach internationally. In USAID Administrator's Brian J. Atwood's words:

> [The development agenda is] not radically different from the agenda we face here at home. We must empower people in South Central Los Angeles as well as Somalia; we must create the kind of infrastructure and training and economic policy that will create jobs in Rhode Island as well as Russia; we must build the kind of respect and human understanding that brings peace to Detroit as well as to Bosnia . . . . It is hard to solve our problems here; it is even more difficult to solve them abroad. But both must be addressed because they are interrelated (l).

Similar concern for applying SD domestically exists in other countries (44). Japan, for example, has drafted a plan to promote sustainable domestic lifestyles, development of environment-related technologies, and technology transfer to developing countries (45). Differences in the goals of foreign and domestic policies could contribute to an uncoordinated approach toward SD. Numerous organizations are examining various international and domestic aspects of furthering SD (54, 130). Integrating these findings and achieving complementarily between foreign and domestic policy relevant to SD is likely to be critical for success in both arenas.

Congressional Coordination of Domestic anti Foreign Policy

The movement toward SD has gained momentum in recent years and, given existing global environmental, social, and economic concerns, this effort is likely to intensify. Numerous reports have been and are being prepared that identify possible future scenarios and related needs for sustainability (e.g., Global 2000 Report to the President, Intergovernmental Panel on Climate Change, The President's Council on Sustainable Development

[18] Specific options related to sector issues, such as energy or agriculture, that are discussed in appendix B can be found in the referenced OTA report.

(PCS D), the 2050 Project). The work ranges from regional to global in scope (e.g., Sustainable Seattle versus the *2050* Project) and the potential for information overload for policy makers maybe great. Despite uncertainties, policymakers increasingly will be called on to make decisions regarding directions for future scientific research and development. This is already apparent in efforts catalyzed by concern over global climate change.

Definitional and conceptual differences among the numerous supporters of SD could mean that efforts will be fragmented and lack common direction. Opportunities to resolve these differences and build consensus may come from ongoing research efforts, [9] although experience tells us that such efforts do not always result in overwhelming support. The results of ongoing studies, such as the PCSD and the 2050 Project, may generate the needed information and suggest sensible policy actions to achieve sustainability in the United States. The information and policy suggestions that will arise from these efforts is likely to be substantial. If the United States is to take an integrated approach to SD, policy decisions must be made in a coordinated fashion. Currently, no single congressional committee exists to deal with all of the related aspects of SD. As the range of SD issues and potential actions increases, policy decisions may become fragmented without a congressional coordinating mechanism. For Congress to oversee the network of diverse activities and efforts under way in executive branch agencies dealing with SD, mechanisms to facilitate congressional oversight are likely needed.

Option: Congress *could* create *a special Joint Committee on Sustainable Development charged with jurisdiction for and oversight of U.S. SD efforts.*

Creating a joint, congressional committee designed to deal specifically with the many issues surrounding SD could expedite congressional actions on opportunities to work toward SD. U.S. executive agencies would have a focal point where integrated approaches to SD could be handled easily and effectively. Similarly, congressional oversight of executive agency SD programs and activities could be facilitated, providing a greater opportunity for a coordinated approach.

On the other hand, creating a new committee could be costly. At a time when Congress is trying to reduce the number of committees and subcommittees, creating anew committee could be politically untenable. Interest in deficit reductions could override concerns for establishing a single home for SD. Furthermore, joint committees can be hamstrung by political polarities that might create a bottleneck as opposed to streamlining decisionmaking. In addition, the range of issues associated with SD is so broad that it could be difficult for a single committee to address them all adequately.

OPTION: *Congress could establish Subcommittees for Sustainable Development in the House* Foreign Af*fairs and Senate Foreign Relations Committees.*

Sustainable development subcommittees in these two major committees with jurisdiction over foreign assistance could promote coordination of the broad range of activities that will emerge under the rubric of SD in international affairs. At one time, these committees contained Subcommittees for Development Assistance for similar reasons but subcommittee structure has since adopted a primarily geographic orientation (versus strategic or functional). Congressional oversight of development will be increasingly important to promot-

[19] The President's Council on Sustainable Development (PCSD) is a 25 member council charged with developing approaches integrate economic, social, and environmental policies to put the United States on a sustainable path by the year 2050. The final product of the PCSD will include recommendations for a sustainable development strategy and needed policy changes (54). The 2050 Project expands on this theme to provide guidance to policymakers worldwide to achieve a sustainable global system (130).

ing SD, particularly given the movement toward more objective-driven legislative initiatives (e.g., the proposed Peace Prosperity and Democracy Act) (58), and the understanding that continuous earmarking, and so forth can fragment development efforts. However, these sustainable development subcommittees would have jurisdiction only over the foreign assistance aspect of SD. Many feel that the domestic SD needs are the most critical in pursuing SD.

Coordination of International Assistance Activities

SD is a broad-based goal and the impact of one donor is likely to be small. Many bilateral and multilateral groups are adopting an SD paradigm for their development activities. Coordination of the numerous organizations involved in development poses a difficult problem, yet it could yield large benefits in achieving comprehensive SD goals. Further, many factors other than development assistance may contribute to successful development outcomes. For example, looking at agricultural development in Africa, one expert noted it is "difficult to find much connection between where donor assistance went and where growth occurred." In this instance, donor coordination was identified as a significant need. Although the increase in donor agencies has meant more assistance funds, it has been accompanied by inconsistent aid policies among donors, large administrative burdens being placed on inadequately prepared recipient institutions, lack of defined priorities and goals, and lack of a cohesive and integrated agricultural development strategy for Africa (56).

Lack of donor coordination can result in duplicative or counterproductive efforts. Development funds may be spent on similar projects without incorporation of "lessons learned." Similarly, lack of coordination can result in lost opportunities to concentrate resources on solving mutually identified problems. Such lost opportunities may have high costs in terms of overall donor funding.

OPTION: Congress could appropriate funding for an Interagency Development Coordinating Council (IDCC) with an express goal of supporting SD,

A coordinating council was formed during the Carter Administration to provide an avenue to improve communications among the array of U.S. agencies and organizations involved in various aspects of development (58,85). However, this body has been dormant since the late 1970s. Congress could reactivate this organization to promote coordination of all of the U.S. agencies with responsibilities in international development to ensure that activities promote SD. Although the body would be a bilateral coordinating effort, it could ensure uniformity among U.S.-supported activities.

Further, an IDCC could foster the exchange of ideas among U.S. assistance organizations. Broad exchange of ideas on issues such as participatory development, technology transfer, and institution-building could generate benefits for all participating agencies as they refine their sustainable development activities. For example, the Inter-American Foundation has developed significant expertise in grass-roots development over the last 25 years and could offer important insights into participatory development approaches.

On the other hand, an inadequate committee is often worse than no committee at all, and many organizations already perceive themselves as "over-coordinated." The additional bureaucratic requirements could divert valuable staff time from other action. Careful identification of the IDCC authority and goals would be key to addressing such potential problems. Congress could design the IDCC mandate based on the SD goals identified in the revised foreign assistance authority. In addition, for the council to be an effective coordinating mechanism it may be necessary to endow it with Cabinet-level authority and the appropriate financial resources (4). This may be difficult in the context of current concerns about government expansion and the budget deficit.

Eliminating Barriers to Sustainable Development

A variety of barriers exist in the industrial and developing world that may hinder efforts to advance SD. The most prominent is the lack of broad-based public awareness and a constituency for sustainable development. Addressing the popular perception that sustainable lifestyles will mean increased personal hardship and lower quality of life is likely to be a key need in pursuing SD anywhere. Other barriers include slow development of needed technologies to support SD, large developing country debt load and economic instability, lack of developing country partnerships for development, short-term assistance cycles, and inadequate mechanisms to measure development progress.

Creating a Constituency for Sustainable Development

Creating and implementing SD will depend not only on technological ability but also on international, national, regional, local, and individual commitment (box 9). Building public support for SD will be critical to success of policy actions designed to reduce consumption and advance sustainable living. Widely distributed information on SD could contribute to public interest in opportunities for adopting less resource intensive lifestyles.

OPTION: *Congress could create a special grant to promote development of educational materials on sustainable livelihoods/lifestyles for the public and national decisionmakers.*

Educational materials that provide opportunities for the public and decisionmakers to explore various SD options and potential consequences of certain actions could elevate public awareness of SD issues. Educational materials have been prepared for some years for USAID through the Futures Group, while the RAPID project has been providing Cabinet briefings internationally since the mid- to late- 1980s on a variety of similar issues (4). Specific focus on SD could be incorporated into these efforts.

A variety of interactive software packages have been developed around certain policy issues. For example, one simulation sponsored by the Smithsonian Institution demonstrated the potential problems and opportunities for accommodating human populations while protecting rain forest resources. Other packages have addressed issues such as city planning, population planning, and health care reform (e.g., Plato, SimCity, SimHealth). Similar materials could be designed to increase understanding of sustainable lifestyles for many educational levels (e.g., primary, secondary, advanced, adult). Other materials could be prepared to assist decisionmakers in understanding policy choices and the impacts of decisions on advancing SD. Educational materials would be needed that could promote systems analysis and demystify sustainable livelihoods (e.g., Netherlands Green Plan).

However, the time lag before completion could be lengthy and information and technology diffusion often can be slow. Nevertheless, benefits from investing in this information could be significant. Materials could be developed cooperatively with developing country counterparts to generate more immediate benefits and perhaps facilitate dissemination of the information on completion. Further, grant costs would likely be small compared with a full government program for information development and could encourage participation of the U.S. and international academic community. Associated requirements for distribution and display of some types of educational materials (e.g., computer networks or workstations) could be a problem in some instances. However, with the increasing emphasis on international communications and computer networking, these difficulties may be overcome (e.g., GLOBE program, Peace Corps) by the time materials are ready for dissemination.

Creating a constituency for development may also be hindered by the mixing of development and other foreign policy goals. Development is popularly perceived as taking money from poor people in rich countries and giving it to rich people in poor countries. In some respects this perception is driven by the significant level of cap-

BOX 9: Obstacles to Sustainable Development

1, Fragmentation of efforts. The sheer numbers of U.S. actors and agencies involved in development militates for a strong coordinating mechanism within the U.S. government.
2. Bureaucratic behavior and turf battles. Power structures, turf battles, and normal bureaucratic behavior within the Department of State and other governmental departments pose barriers to appropriate support for sustainable development,
3. Misconceptions about what sustainability means. The popular perception that undertaking a sustainable development path will result in revisiting problems overcome in the past hinders support for sustainable development domestically and internationally.
4. Internationally integrated and controlled markets and economies. The role of national governments in managing the economy is difficult because of the movement toward global markets. internationally integrated economies may be thought of as an obstacle to sustainable development or as a new condition that carries opportunities, for example, for bilateral development programs to work with and help national governments operate in the world economy.
5. Loss of community. Community development is fundamental to creating the commitment needed for sustainable development. Foreign assistance has had mixed results in strengthening communities.
6. Corrupt use and misuse of development assistance funds, Inadequate attention has been directed to the impact of corruption on how capital is organized in development assistance; in many cases, assistance transfers not capital, but foreign exchange. Yet nonfungible capital transfers have been criticized as well (e.g., tied aid, mixed credits).
7. Lack of a sustainable development role model. Domestic inexperience at developing and promoting sustainable opportunities hinders U.S. ability to do the same in international assistance.
8. Failure to follow up on successes. USAID has a tendency to recognize success but do nothing to spread the example; developing demonstration sites from successful activities could expand awareness of sustainable opportunities,
9. Privatization versus sharing of knowledge. The trend to monopolize or privatize knowledge in the form of intellectual-property rights precludes the broad Information exchange that is needed in sustainable development.
10. State of research and development institutions. Much U.S. research is irrelevant to ''real world" problems largely because of a failure to reward problem-oriented research,

SOURCE U.S Congress Office of Technology Assessment, Approaching Sustainable Development, working group held Washington DC, December 7, 1993

ital transfers under military and security assistance efforts. These transfers have been subject to widespread public scrutiny and various degrees of dissatisfaction, leading some to distrust foreign assistance in its totality.

OPTION: Congress could formally separate the budget and responsibility for administrating security and military assistance from the foreign operations account and @ace it with the Department of Defense.

Aid allocation in practice often is determined by practical considerations such as foreign policy objectives and commercial needs that can be at odds with pursuing SD. The underlying precepts for assistance identified by USAID and Congress (e.g., economic growth, democracy, population and the environment) might be able to promote SD better if they were unfettered by other political motivations (e.g., national security, military assistance, etc.). Separating the foreign policy and development agendas by explicitly separating associated budgets and responsibilities might be one opportunity to work toward this goal. Formally separating security assistance from foreign aid

programs in the legislative process could help Congress weigh the costs and benefits of each to the United States.

Internalizing the Costs of Production

Lack of internalizing the environmental costs (e.g., resource consumption, waste production) of many industrial production practices has been suggested as a major constraint to the development of more environmentally friendly industries. However, little quantitative research has been conducted to determine to what extent externalizing production costs may hinder development of environmentally sound industries (28). Environmentalists and many others have been calling for industry to internalize the total costs of production for at least a decade. While legislation has sought to discourage environmentally damaging industrial practices through "polluter pays" efforts, many see the need for greater, more comprehensive actions. Taxing consumptive industries to force internalization of externalities may slow growth in these sectors, but could be accompanied by growth in non-consumptive (e.g., service), recycling, and research and development (e.g., efficiency improvements) sectors.

OPTION: *Congress could direct the Congressional/ Budget Office (CBO) to conduct a study of the opportunities for revising U.S. tax laws to encourage industry to internalize the full costs of production using criteria that are consistent with SD.*

Rather than a series of specific fines and regulations for industry relative to the overall consumptive and polluting effects of production, Congress could examine alternative opportunities to promote positive efforts. Tax law revision, for example, could reduce the tax liability of industries that take steps to reduce their environmental/resource base impact. Incentives could be based on cleaner production processes, use of recycled production materials, conservation activities, and so forth.

A CBO study could identify a range of possible options and the potential associated environmental, social, and economic impacts. Although a '"polluter pays" approach collects revenue, it does not necessarily reduce contaminating activities. The CBO effort could identify mechanisms to shift industry/production toward sustainable practices simultaneously with internalizing costs. The study could include analyses of revenue needs at the transition end and potential opportunities for meeting these needs.

Developing Country Debt loads

Economic situations in assisted countries dramatically influence the effectiveness of development activities. Heavy debt loads can reduce national economic support for important development work and can result in redirection of economic resources to repay existing loans. For example, some countries' bilateral debt to the United States alone far outstrips their annual gross national products (e.g., Bolivia, Peru). This situation can lead to debt servicing that hinders national government investment in development activities.

The issue of developing country debt has been highlighted since the great debt crises in the 1980s. Although efforts have been made to reduce the debt burden through such vehicles as debt-for-nature swaps, developing country indebtedness remains a constraint to development efforts. In fact, developing country indebtedness is considered by many to be one of the largest constraints to promoting SD, as is the ease with which debt can be created and recreated through lending mechanisms (66, 107). Reduction of overwhelming foreign debt and excessive new borrowing is seen as fundamental to fostering effective national development strategies. Debt forgiveness may be an essential part of this approach, but it must be done in a framework that precludes immediately recreating debt. Development grants could offer an opportunity to slow debt buildup. USAID appears to have had success with its grant aid effort in the Philippines; an endowment for resource protection was created and is administered by host-country professionals, who in turn work with local organizations and communities (52).

OPTION: *Congress could create a Debt-for-Development swap tailored to the participating assisted countries' priority development needs (as identified by*

an interdisciplinary council) to promote national progress.

Debt swaps created specifically to meet priority needs of assisted countries would recognize the heterogeneity of developing countries and be designed to promote progress on a case-by-case basis. Different "swaps" would be appropriate for different participants. For example, if the priority need for an assisted country was secondary school education, the program could be created as a Debt-for-Education trust with appropriate criteria included. It was proposed at a recent United Nations Educational, Science, and Cultural Organization (UNESCO) conference in Nairobi, Kenya (93) that debt swaps could be used to finance science and education training partnerships with industries.

However, debt swaps alone will be insufficient to promote SD without adequate investment in supporting policies and technologies. Since these policies and technologies remain uncharted in many respects, it could be difficult to identify appropriate conditions for successful swaps. Enhanced abilities on the parts of national governments to monitor and evaluate actions would be a critical component for success.

Building Development Partnerships

The importance of participatory approaches in development has received widespread attention and has been expressly identified in existing U.S. foreign assistance legislation. A World Bank internal study showed strong correlation between participatory development and project success (66, 127). For example, the success of the USAID-sponsored Indonesian Rice Integrated Pest Management Program was largely attributed to broad participatory efforts (41 ,42,86). Nevertheless, local participation in project development and planning is not consistently part of assistance efforts, perhaps for reasons internal to USAID or due to resistance on the part of the host country government. Yet, increasing the local role in development activities could contribute to capacity-building in assisted countries as well as increase the likelihood of investing in activities that are suited to the local scale of need and the sociocultural, economic, and environment setting. The regional development foundations (RDFs) have a good record in promoting grassroots development and could offer an opportunity for increasing participatory development activities.

OPTION: *Congress could increase the role of the U.S. regional development foundations (e.g., Peace Corps, InterAmerican Foundation, African Development Foundation, Appropriate Technology Intemation-*a/) *in order* to *promote* participatory *development.*

USAID is reducing the number of its missions and simultaneously expanding its area of application with the dissolution of the former Soviet Union. In some developing areas, other assistance organizations may be the largest development presence. Giving an increased role to the U.S. RDFs could address the need for grass-roots development efforts and further catalyze policy and institutional change in assisted countries. Responsibility for the small project functions currently undertaken by USAID could be placed with the appropriate RDF (figure 13). The funding needed for foundation systems generally is small compared to current assistance expenditures because their activities tend to be small-scale at the grass-roots level. Foundations tend to be more flexible in their operations, have greater success in participatory project planning and development, have greater ability to mobilize local human and institutional resources, and be less susceptible to problems associated with large-scale projects (e.g., bribery, corruption, bureaucratic processes).

However, the existing U.S. RDFs tend to be small in terms of personnel and budget, and rapid expansion could be detrimental to their successful operating structure. In addition, some assisted countries are not covered by RDFs. A decision would have to made on whether to create a new RDF, leave responsibility with USAID, or expand regional foci. Alternatively, the RDFs could take on strategic as opposed to regional foci and restructure their operating areas. In any case, a paced transition to expand RDF responsibilities and increase staffing and managerial capacity would be

needed. The transfer of responsibility y and funding from USAID to specific RDFs could take place over several years, perhaps based on strategic priorities as identified in U.S. foreign assistance legislation. This transition period could promote information and idea exchange among the U.S. assistance organizations and foster more formal coordination either through an IDCC or some other body.

Length of Commitment

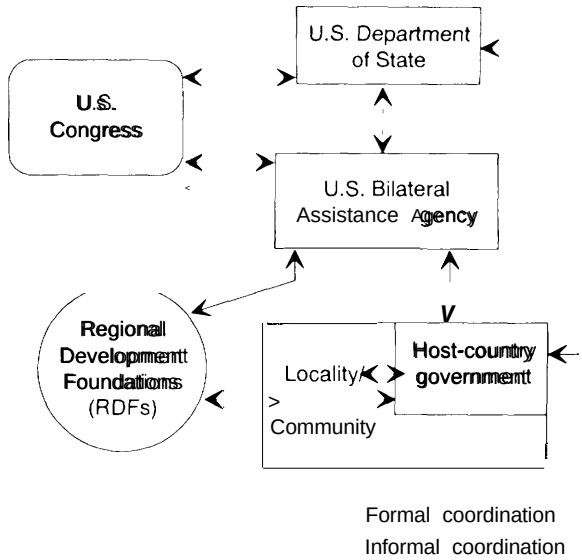
The long-term nature of SD is likely to require a revised approach to donor interventions, including lengthening project cycles and opportunities for gradual discontinuance of aid. Long-term efforts will be necessary to promote development and adoption of sustainable options as well as to provide necessary support during transitional stages. Nevertheless, short-term project cycles are standard in U.S. development activities, due in part, to financial management requirements.

In some cases, assistance is discontinued too early in the development transition or there is failure to make a gradual but steady transition from USAID-based to host country-based management over the course of a project *(88)*. Thus, when the transition occurs it may be difficult for insufficiently prepared nationals to continue the activity without assistance.

OPTION: Congress could expressly identify "no year" funding status for USAID development projects to remove the current constraints associated with fiscal year spending and short-term project deadlines.

Risks to natural resource systems and development assistance recipients may be reduced if projects have: 1) an extended technical planning phase, 2) a gradual phase-in period for adaptation of technology to the site's ecological and social conditions, and 3) a sufficient time frame to achieve results despite likely mid-term project realignment. However, internal organization impetus to keep funds moving and to achieve measurable results quickly operate against these approaches. Short project duration makes it difficult to introduce technologies or implement projects gradually, and presents a serious obstacle to making mid-term corrections in response to monitoring and evaluations. Similarly. contractors and aid organization staff are keenly aware of the urgency for each project to produce substantial, quantifiable results by the end of its period. Production targets stated at the beginning of three- to five-year projects often necessitate rapid implementation of technology interventions and, therefore, major project realignments may be viewed as counterproductive. Further, managers of short projects cannot easily accommodate major unexpected changes in their projects. Instead of today's common three- to five-year USAID projects, a duration of 10 to 20 years maybe more appropri-

FIGURE 13: Possible Institutional Links for Sustainable International Development



Expanding the role of regional development foundations to undertake the small-project activities of U S intemational assistance efforts could offer an opportunity to increase participatory development at the local level. Communicatlon and coordination among all of the involved agencies would remain a critical condition for successful activities

SOURCE Off Ice of Technology Assessment 1994

ate, particularly in light of the long-term nature of SD goals (40).

Congress normally requires USAID funds to be spent within one fiscal year. However, other approaches have been tried. For example, Congress acted to make funds "available until expended" for the Sahel Development Program. Reportedly, the experiment was only somewhat successful. Some agency personnel still believe that, even though unspent funds from the current year will not be "lost," the next year's funding is likely to be reduced by at least the unspent amount (40).

However, extending project budget cycles by invoking "no year" project funding might promote inefficiency. Strong mechanisms for monitoring and evaluation would be necessary to eliminate or reduce this possibility. Alternatively, Congress could allow USAID the authority to deobligate and recommit funds if projects are not working (4). Much of the motivation to "move the money" is generated by bureaucratic pressure to expend each year's budget as support for future year requests.

OPTION: *Congress could direct USAID to investigate opportunities to develop sustainable development demonstration sites for countries moving toward SD,*

USAID could identify opportunities to continue a certain level of support for assisted countries demonstrating successful transitions toward sustainability. One opportunity to continue support after initial development successes would be to identify and support sustainable development demonstration sites (107). Sites could be selected from those development cases demonstrating success in efforts toward sustainable development. Such demonstration sites could help to clarify the benefits and costs of adopting sustainable lifestyles. Another option might be to create a category of "partnership status" with the United States that could promote information and technology exchange.

However, budget concerns may argue for ending support as soon as possible after certain development goals are met. Lower-cost alternative methods of assistance could be identified in the investigative effort. For example, support might be maintained through joint donor funding with other countries adopting a SD approach to international assistance. In addition, international enterprises might be appropriate partners in certain cases.

Measuring Sustainable Development Progress

Reliance on GNP as an indicator of development progress or quality of life may mask real changes in human welfare. The individual factors that contribute to GNP fluctuations are not easily apparent because they are incorporated under a single indicator. Disaggregating the reporting of GNP could make transparent what specific factors are changing and improve ability to direct efforts more appropriately. For example, a country's GNP could increase due to increasing costs of health care, but this does not necessarily translate into benefits that accrue to the population on a broad scale. The lack of a direct correlation between GNP and improvement of the human condition argues for a broader approach to measuring development (107). "Green" accounting efforts are being made by the U.S. Bureau of Economic Analysis to devise a method of including the environmental costs of economic growth in economic statistics (12, 35).

OPTION: *Congress could direct the Secretary of the Treasury to disaggregate the reporting of GNP into its constituent pieces to reflect more accurately the quality of life in the United States.*

A sharp distinction exists between standard of living and quality of life. They may be complementary, but they are not proxies for one another. Nations with high standards of living do not necessarily have similar ratings in terms of quality of life or human development. Disaggregating the reporting of GNP would assist in identifying what factors are responsible for fluctuations in the indicator and improve ability to determine if these fluctuations beneficially or adversely affect quality of life.

Similar benefits could be derived from improving assisted country reporting systems. Such reporting could also be used to identify appropriate areas/sectors for development efforts, as well as indicate success/failure of activities. Creating this capacity in assisted countries would promote their ability to choose desirable development paths as well.

However, even disaggregated, economic indicators alone are ill-suited to measuring sustainability. Existing indicators are unable to reflect sustainability or changes in quality of life as they do not distinguish the difference between quality of life and standard of living. The United Nations Development Programme has gone a long way in improving the process by incorporating noneconomic indicators to increase the accuracy of the output vis a vis actual improvements in quality of life. Nevertheless, these indicators still can be improved (as UNDP notes in its *Human Development Report* 1993) since some of the themes of SD are unaccounted for.

OPTION: *Congress could create a cooperative task force composed of representatives from the U.S. Department of Health and Human Services, U.S. Department of the Interior and the U.S. Department of the Treasury to develop a Sustainable Development Index (SDI) designed to reflect the sustainability of the United States more accurately than GNP or the UN Human Development Index (HDI).*

In addition to the indicators incorporated in the HDI,[20] an SDI would at a minimum include:

- quantity and quality of natural capital (renewable and nonrenewable resources);
- internal migrations (reflecting contentment of populations, etc.);
- tensions/conflict (more sensitive than just measuring conflicts like those in Bosnia or Somalia but also local level tensions leading to crime, etc.; this indicator would also pick up such things as human rights abuses); and
- self-reliance factors (measurements of imported/exported resources, use of local resources versus imported resources, etc.).

Measuring development progress implies availability of functioning national information systems capable of compiling and generating needed data. Many assisted countries lack national data/information systems. Yet, information will be critical in developing capacity for assisted countries to identify and weigh their development and sustainability options. Further, development efforts that focus on providing the tools for developing countries to make their own decisions may, themselves, be adopted and sustainable.

OPTION: *Congress could direct the Secretary of the Treasury to direct the U.S. Executive Directors of the multilateral development banks to make national information/data system development a priorly in assisted countries.*

Extending options for creating or measuring sustainability of policy decisions will require that heads of state be equipped with adequate information on existing conditions. The increasing focus of development activities on information and communication could support the development of national accounting systems. Cooperative efforts among assisted and donor countries to identify critical data points could be a first step. An incremental approach that would allow for gradual building of national information systems might generate immediate benefits. Initial data areas might focus on productive or human resource sectors (e.g., natural resource information, health and education data) that could assist in national decisionmaking, and ultimately move toward broader data sets.

[20] The HDI indicators include: longevity—measured by life expectancy at birth; knowledge—measured by adult literacy and mean years of schooling (weighted 2/3 to literacy and l/3 to mean years of school); and income—adjusted to reflect income's diminishing returns for human development as the disparity between median income and poverty line increases (92).

D. LOWE

New cultivars developed through crop breeding efforts over the last decades have improved plant characteristics and yields. Here, a Mexican farmer explains the qualities of a maize variety to a geneticist interested in conserving crop genetic resources for future crop Improvements.

Developing national information systems is a long-term undertaking and would likely require significant national and international investment in terms of funding and personnel resources. In some developing countries, other development aspects would be greater priorities.

Technologies for Sustainable Development

Improving the United States' ability to promote SD will depend largely on availability of appropriate technologies and opportunities. Partnerships among industrial and developing countries could promote mutual problem identification and likely lead to development of acceptable and innovative solutions to problems. Guidelines that identify sustainable solutions to development problems could help assisted country policy makers make development choices A critical aspect of improving partnerships and sustainable solutions is increasing the availability and accessibility of information. Communications development could generate large benefits in this realm and currently is a large part of certain development approaches.

Industrial-Developing Country Research Partnerships

Sustainable development has been clearly articulated as a global goal for industrial and developing countries. Successful development efforts have been highly correlated with participatory or collaborative approaches to problem solving. However, the lack of reward systems in existing U.S. academic structure has reduced international research efforts. While ten years ago U.S. scientists were working on agricultural technologies for developing countries, and built careers on this, today such activity does not attract the same level of interest. The emphasis now is on high-tech discoveries that are hard to apply and transfer to developing countries.

OPTION: Congress could provide funding to USAID to create International Institutes for Sustainability Research (IISRs).

Partnership arrangements may be the best way to encourage SD in assisted countries and the United States and other industrial nations. The U.S. could learn from Costa Rica's successful school systems, for example. In addition, future work could be conducted under a partnership umbrella. The IISRs could be modeled after the International Agricultural Research Centers (IARCs) and would represent partnerships between the industrial and developing worlds. IISRs could have three functions: 1) collaborative research on sustainability problems of mutual interest to the United States, other industrial nations, and developing-country scientists; 2) grants to strengthen institutions; and 3) education grants for developing country and U.S. students to study SD issues. Such arrangements would facilitate information sharing, institution/capacity building,

and communications among industrial and developing nations. The strategic focus of the institutions could be to assure access to environmentally and socially beneficial technologies, particularly as they pertain to creation of domestic employment and meeting basic population needs. Stress could be placed on appropriate and effective technology transfer activities designed for permanence.

The costs for creating IISRs, however, would be large. Opportunities may exist for enhancing existing research centers that are strategically located to entice collaborative research efforts (e.g., on regional bases in areas of greatest need). Alternatively, existing international research institutions (e.g., International Agricultural Research Centers) increasingly may adopt sustainability agendas and these resources could support or obviate the need for IISRs. Effective incentive mechanisms to influence such organizations might spur this kind of activity, but also would likely involve additional expenditures.

OPTION: Congress could create an Endowment for Sustainable Development (ESD) to promote development and dissemination of information and technologies for SD.

The ESD'S initial activity would include defining sustainability and creating an agenda for action. Information generated by the various ongoing sustainability projects could provide a starting point for ESD action. The ESD would be an authoritative institution charged with raising the fundamental paradigm issues and taking the long-term development view. The endowment should be independent of the Department of State, have flexibility, and integrate disciplines. It could provide incentives for appropriate technology development, directing monies to successful models and ideas. Existing foreign debts could be transferred into the endowment as a funding kickoff.

Expanding opportunities for developing countries to determine their own SD path will depend in large part on the free exchange of information among the industrial and developing world. The trend toward privatization or proprietary knowledge can work to the disadvantage of development goals by slowing the movement of effective discoveries into practice and the public domain. However, without such protection, innovators may be disinclined to invest in research and development. The challenge will be to find alternative avenues to fund the cost of producing knowledge in order to facilitate distribution. One opportunity discussed previously might be the creation of international centers for SD that would be cooperatively funded and focus on collaborative research and technology development.

OPTION: Congress could create an Electronic Peace Corps (EPC) designed to facilitate the flow of information to developing country institutions.

The role of the existing Peace Corps could be expanded to incorporate an EPC or it could be initiated under a new independent agency along the lines of the development foundations or Volunteers in Technical Assistance. The agency could have a strategic focus of information exchange and implanting communication technologies. Key functions could include training in information and communication technologies. Volunteers could be drawn from U.S. institutions, academia, and the public and private sectors. Because telecommunications allows remote location, many volunteers would be able to continue their regular employment and donate after-hours time. Public sector employees might be made available through Participating Agency Service Agreements (PASAs) or similar exchange programs. Field volunteers would bean essential component as well, with expertise in communications applications, maintenance, and repair (76, 77). The Peace Corps is currently expanding its international communications capability with the installation of Internet connections in certain field posts. Additional funding could be made available to speed this process if it is demonstrated to be effective. Alternatively, many networks currently exist among academic and nongovernmental organization circles and these might be encouraged to undertake such an information delivery role if support were available. A coordinating mecha-

nism would be a central need to assure that expansion occurred in a desired fashion and commensurate with SD goals.

Guidelines for Planning and Implementing SD Activities

Application of systems analysis (e.g., analysis of an entire system, including all components and links among components) in the planning and design phases for SD projects could increase the use of "lessons learned." Guidelines that assist officials and development agency personnel identify optimal, sustainable solutions to development needs also could reduce capital and environmental costs. For example, officials in Bangkok, Thailand, were in the process of committing significant fiscal resources to build a dam to relieve a shortage in the city's water supply. In a systems review of the potential project, it was discovered that the water shortage was a distribution rather than a supply problem—freshwater was being lost through leaks in the existing system. Repairing the faulty distribution system was a far less costly operation (one-tenth the amount of building a new dam), and simultaneously increased water availability, reduced water loss, and eliminated the need for a large infrastructure project. Thus, systems analysis of the project led to a more practical and efficient answer for Bangkok (60).

OPTIONS: Congress could direct USAID to promote development of Sustainable Terms of Reference (STOR) for development projects.

Sustainability would be the guiding principle for STOR development with end goals of minimizing consumption, throughput, and waste concurrent with meeting the needs to be addressed by the activity. STOR guidelines for international lenders and local, regional, and national officials could improve their ability to select SD paths for infrastructure projects. Separate sets of guidelines could be developed for priority systems such as agriculture, transportation, water, energy, and waste systems (i.e., those that most often are associated with high capital and environmental costs). These guidelines could be further combined with one another to provide information on integrated development of these separate systems.

STORs would: 1) identify key questions for officials to use as they investigate and select among various technological options and 2) outline specific design aspects that would enhance system sustainability. The final product could be prepared as a booklet; written in terms suitable for nonexpert understanding, yet amenable to incorporation in more formal contract or agreement language; and made available in the users' language. In addition to the STORs, information could be included that would identify technical experts with qualifications in design and planning of sustainable systems. Alternatively, technical resources could be organized into a larger information database made available through computer networks. Once STORs were available, all U.S.-supported international activities could incorporate these guidelines in project planning and development. STORs also could be distributed internationally as a decisionmaking resource to promote sustainable infrastructure projects.

The Center for Development Information and Evaluation (CDIE) in USAID has extensive information on lessons learned in development projects, but these reference materials are not commonly worked into new ventures. Nevertheless, information contained in this literature could provide a resource for STORs across a variety of development scenarios. CDIE could work closely with appropriate USAID agency offices to develop pragmatic STOR guidelines. Outside technical experts could be drawn into the process as needed and as appropriate to the specific task.

OPTION: Congress could direct the U.S. Ambassador to the United Nations to support creation of a database on technical resources qualified in design and planning of sustainable projects to be made available through its Sustainable Development Network (SDN).

The STORs could be installed in an interpretive database and updated as new technologies or information become available. In addition to the guidelines, the database could contain information on technical experts who could provide assis-

tance/consultation to project managers, and developing country decisionmakers on specific aspects of identified projects. Under the UN umbrella, this information would be broadly accessible to the full range of assistance organizations and developing country decisionmakers.

CONCLUSION

The economic profiles and development paths of developing countries have become more varied. Assisting developing countries that are regressing economically, and the still poor majority in countries that have made moderate economic gains, requires a different set of motives, expectations, and goals than assisting rapidly industrializing countries. If even a conservative interpretation of sustainable development is adopted as a U.S. foreign policy objective, it is likely to require Congress to think about and question U.S. interests and actions in considerably broader terms.

One step could be consistent monitoring and analysis of the impacts of U.S. policies on developing countries and their potential contribution to SD. Technology and policy issues specific to developing countries have not been consistently analyzed in past OTA reports, however, increasingly this is changing. Nevertheless, in many instances developing countries are viewed only in the context of being potential markets, resource providers. or strategic partners without sufficient attention to the potential impact that might be delivered on their national development. Although human resources are as vital to developing country economic progress and quality of life as technology. OTA has not assessed human resource needs to the same extent as other areas. To move toward sustainable development, policymakers could consider not only domestic economic concerns, but also the major scientific and technological challenges affecting all countries.

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Appendix A: Working Group Participants

A

Approaching Sustainable Development ▪ December 7, 1993

Richard Bissell
Overseas Development Council
Washington, DC

Herman Daly
University of Maryland
School of Public Affairs
College Park, MD

Paul R. Ehrlich
Department of Biological Sciences
Stanford University
Stanford, CA

David C. Korten
People Centered Development Forum
New York, NY

Donella Meadows
Dartmouth College
Plainfield, NH

Sandra Nichols
Sandra Nichols Productions, Ltd.
Oakland, CA

Bruce Ross
Chemonics, International
Washington, DC

B Appendix B: OTA Reports Related to Resource Management and Developing Countries

The accumulation of knowledge, the discoveries of science, the products of technology, our ideas, our art, our social structures, all the achievements of mankind have value only to the extent that they preserve and improve the quality of life.— Charles Lindbergh

Although discussion of sustainable development commonly evokes divergent views, one point upon which many agree is that scientific and technological advances could offer the means to resolve some critical development-related natural resource problems. Conserving natural capital (renewable and nonrenewable resources) is fundamental to the concept of sustainable development. Thus, renewable resource withdrawals would not exceed regenerative capacity; use of nonrenewable resources would occur in relationship to research and development efforts to identify appropriate substitutes; and waste production would not exceed the environmental absorptive capacity. Technology can support sustainability of natural capital by: 1) reducing waste, 2) raising efficiency standards, or 3) finding substitutes, hence reducing extraction or consumption of resources or use of toxic substances and other hazardous materials. Of the various dimensions of sustainable development (i.e., economic, political, environmental, and technological), technology seems to be the most eagerly explored.

The Office of Technology Assessment (OTA) has examined issues, technologies, and policy trends of importance to foreign assistance and environmental sustainability for Congress since 1976 (Technology Assessment Act of 1972, P.L. 92-484). Many OTA assessments from the past two decades contain information of director indirect relevance to sustainable natural resource use and management in developing countries. (See table B-1 for a list of OTA reports covered in this overview.) OTA has analyzed a wide range of technologies and resource concerns, related research needs, and the roles of governments and private and public sector national and international institutions in development assistance. Many OTA reports did not address the concept of sustainable development directly but nonetheless contained highly relevant material.

This overview of OTA's work on developing countries and technologies to support sustainable development also examines:

- factors that affect technology transfer to developing countries;
- global environmental concerns as they relate to developing countries; and
- the principle areas in which scientific and technological effort can support sustainable development: agriculture, energy, industry, local development, and human resource development.

THE TECHNOLOGY CONTEXT

The gap between the technology development options of industrial and developing countries has, in many cases, grown considerably in the 20th century (60). This view, also expressed in international development 1iterature, foresees the poorest developing countries steadily losing access to the potential benefits of technology.

At the same time, industrial and developing countries increasingly share common problems. The United States, like many developing countries, has a large debt burden and areas with rural poverty. Most countries share concerns about global Climate change, spread of infectious diseases, ocean pollution, and education of their workforce (60). As greater recognition is given to the global environmental costs of industrial development, economic growth, and population growth, the question of sustainability has been raised with increasing frequency in domestic and foreign policy circles.

How science and technology are used for development—which technologies are selected, how they are applied, and for what purposes-will determine, in part, the effectiveness and sustainability of the development process. The process by which such choices could be made by Congress when it sets and implements a science and technology agenda for development were explored broadly in *Science and Technology for Development (1989).*

The sociocultural, political, economic, and ecological setting for development constitutes the framework for development assistance efforts. Each of these factors will affect the sustainability of the development project. Regardless of the cause of resource degradation or damage, developing countries generally cannot afford even a temporary decline in food or foreign exchange derived from their natural resources, and commonly they lack sufficient economic resources to implement reclamation or restoration activities. Thus. selection of ecologically appropriate technologies becomes imperative (2). *Aid to Developing Countries: The Technology/Ecology Fit (1987)* explored the concept of ecologically appropriate technologies and identified organizational factors that contribute to inappropriate technology choices, as well as approaches to make development assistance activities more ecologically sound (figure B-1).

Development assistance organizations arc frequently faced with difficult choices. For example, raising the efficiency of commercial energy use in developing countries urban areas could strongly benefit the global environment, yet it may offer little to the poor majority in the rural areas. On the other hand, regional, community, and household-specific technologies like power generators more efficient wood stoves, or assistance to produce fast-growing trees could benefit rural sectors. Balancing different needs in assistance does not necessarily minimize the potential for adverse environmental impacts from development assistance projects (2). These can occur from the failure to consider such relevant questions as:

- Are the eventual practitioners likely to have cultural aversions to the technology?
- Is the technology within the means of these practitioners?
- Will governmental or other institutions provide the necessary support to ensure continued operation of the technology in a manner appropriate to local conditions?
- Identifying and promoting “appropriate technology” for different settings can be difficult. Inappropriate choices often result from a lack of familiarity with more suitable practices (e.g., improving traditional systems); inadequate technical and management training for long-term project operation and maintenance (i.e., human resource development); aid programs that are motivated by donor commercial interests (e.g., tied aid, mixed credits); and bureaucratic needs to “move money” through the programs (2).

Scale and cost are significant factors in determining appropriate technology for specific sites or development settings. Technologies designed for implementation in industrial country settings can be too costly for developing countries, or in-

TABLE B-1: OTA Reports Related to Sustainable Development in Developing Countries

Food and Renewable Resources Program

Alternative Coca Reduction Strategies in the Andean Region, OTA-F-556 (July 1993)
A New Technological Era for American Agriculture, OTA-F-474 (August 1992)
Combined Summaries: Technologies To Sustain Tropical Forest Resources and Biological Diversity OTA-F-515 (May 1992)
New *Opportunities for U.S. Universities* in *Development Assistance: Agriculture, Natural Resources, and* Environment—Background Paper, OTA-BP-F-71 (September 1991)
A P/ague ofLocusts—Special Report, OTA-F-450 (July 1990)
Science and Technology for Development—Staff Paper (February 1989)
Enhancing Agriculture in Africa: A Role for U.S. Development Assistance, OTA-F-356 (September 1988)
Grassroots Development: The African Development Foundation, OTA-F-378 (June 1988)
Aid to Developing Countries,' The Technology/Ecology Fit—Staff Paper (July 1987)
Integrated Renewable Resource Management for U.S. Insular Areas, OTA-F-325 (June 1987)
Technologies To Maintain Biological Diversity OTA-F-330 (March 1987)
Continuing the Commitment: Agricultural Development in the Sahe/—Speclal Report, OTA-F-308 (August 1986)
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Africa Tomorrow: Issues in Technology Agriculture, and U.S. Foreign A/d—Technical Memorandum, OTA-TM-F-31 (December 1984)
Technologies To Sustain Tropical Forest Resources, OTA-F-214 (March 1984)
Plants: The Potentials for Extracting Protein, Medicines, and Other Useful Chemicals—Workshop Proceedings, OTA-BP-F-23 (September 1983)
Water-Related Technologies for Sustainable Agriculture in Arid/Semiarid Lands: Selected Foreign Experience—Background Paper, OTA-BP-F-20 (May 1983)
An *Assessment* of *the U.S. Food and Agricultural Research System,* OTA-F-155 (December 1981)
Pest Management Strategies in Crop Protection—Volume 1, OTA-F-98 (October 1979)
Nutrition Research Alternatives, OTA-F-74 (September 1978)
Food /formation Systems: Summary and Analysis, OTA-F-35 (August 1976)

Industry Technology and Employment Program

Industry *Technology, and the Environment: Competitive* Challenges and Business *Opportunities, OTA-ITE-586* (January 1994)
Multinationals and the National Interest, OTA-ITE-569 (September 1993)
Development Assistance, Export Promotion, and Environmental Technology—Background Paper, OTA-BP-ITE-107 (August 1993)
U.S,-Mexico Trade: Pulling Together or Pulling Apart? OTA-ITE-545 (October 1992)
Trade and the Environment: Conflicts and Opportunities—Background Paper, OTA-BP-ITE-94 (May 1992)
Making Things Better: Competing in Manufacturing, OTA-ITE-443 (March 1990)

Energy and Materials Program

Fueling Development: Energy Technologies for Developing Countries, OTA-E-516 (April 1992)
Energy Technology Choices: Shaping Our Future, OTA-E-493 (July 1991)
Copper: Technology and Competitiveness, OTA-E-367 (1988)
Nuclear Power in the Age of Uncertainty OTA-E-216 (February 1984)
World Petroleum Availability 1980-2000-Technical Memorandum, OTA-TM-E-5 (October 1980)
Alternative Energy Futures—Part 1, The Future of Liquid Natural Gas Imports, OTA-E-110 (March 1980)

TABLE B-1 (cont'd.): OTA Reports Related to Sustainable Development in Developing Countries

International Security and Commerce Program

The *Future of Remote Sensing from Space Civilian Safe//de Systems and Applications, OTA-ISC-558* (July 1993)
Global Arms Trade, OTA-ISC-480 (June 1991)
Energy Technology Transfer to Ch/na—Technical Memorandum, OTA-TM-ISC-30 (September 1985)
International Cooperation and Competition in Civilian Space Activities, OTA-ISC-239 (July 1985)
Technology Transfer to the Middle East, OTA-ISC-173 (September 1984)
Remote Sensing and the Private Sector, Issues for Discussion—Technical Memorandum, OTA-TM-ISC-20 (March 1984)

Oceans and Environment Program

An *Analysis of the Montreal Protocol on Substances That Deplete the Ozone* Layer—Staff Paper (February 1988)
Changing by Degrees. Steps To Reduce Greenhouse Gases, OTA-O-482 (February 1991)
Wastes in Marine Environments, OTA-O-334 (April 1987)

Health Program

Status of Biomedical Research and Related Technology for Tropical Diseases, OTA-H-258 (September 1985)
Quality *and Relevance of Research and Related Activities at the Gorgas Memorial* .Laboratory-Technical Memorandum, OTA-TM-H-18 (August 1983)

Telecommunications and Computing Technologies Program

The 1992 World Administration Radio Conference Technology and Policy Implications, OTA-TCT-549 (May 1993)
The 1992 World Administration Radio Conference: Issues for U.S. International Spectrum Policy—Background Paper, OTA-BP-TCT-76 (November 1991)
Rural America at the Crossroads Networking for the Future, OTA-TCT-471 (April 1991)

Biological and Behavioral Sciences Program

Biotechnology in the Global Economy OTA-BA-494 (October 1991)
Commercial Biotechnology. An International Analysis, OTA-BA-218 (January 1984)
World Population and Fertility Planning Technologies: The Next Twenty Years, OTA-HR-157 (February 1982)

Science, Education, and Transportation Program

Delivering the Goods. Public Works Technologies, Management, and Finance, OTA-SET-477 (April 1991)
An *Assessment of Technologies for Local Development,* OTA-R-129 (January 1981)

Exploratory Program

U S Disaster Assistance to Developing Countries: Lessons Applicable to U.S. Domestic Disaster Programs—Background Paper, OTA-BP-X-1 (January 1980)

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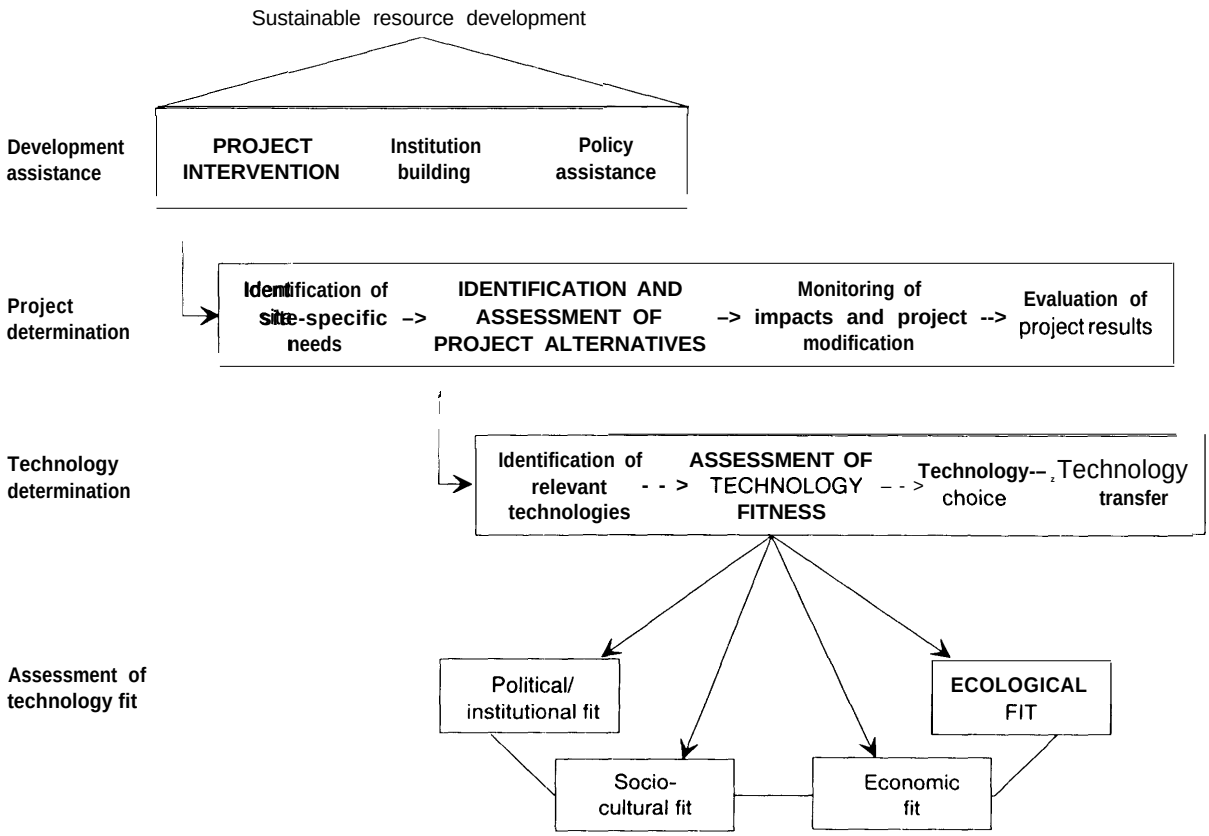
adequate to satisfy companion development needs (e.g., employment). These incompatibilities can sometimes be avoided by building on indigenous methods and technologies. However, some argue that site-appropriate technology is "second rate" and unable to satisfy the long-term needs and aspirations of developing countries (2,52).

"Leapfrogging" describes a development approach that blends appropriate technology with sustainable development. The goal of leapfrogging is to allow developing countries to bypass the environmental and social ills associated with development in the industrial countries of the North. However, there is considerable disagreement over the potential for leapfrogging. Some think that too few sustainable technologies exist for use in development programs. Others question whether leapfrogging would provide a satisfactory quality of life in developing nations. Intensive research and development efforts in science and technolo-

FIGURE B–1: The Role of Technology/Ecology "Fit" in Development Assistance



SOURCE A L Hess, B Ross-Sheriff, and P Durana, *Aid to Developing Countries: The Technology/Ecology Fit—Staff Paper,* staff paper prepared by the Food and Renewable Resources Program (Washington, DC Office of Technology Assessment, U S Congress, June 1987)

gy **are** needed, in conjunction with widespread education and information activities, to demonstrate the benefits of a sustainable development path in industrial and developing countries. The question of how best to transfer information and technology broadly for sustainable development remains to be answered.

GLOBAL ENVIRONMENTAL PROBLEMS

Transboundary problems like global warming, pollution of international waters, destruction of biologically diverse resources, and depletion of the stratospheric ozone layer illustrate the extent of environmental impacts from human population growth and activity, and provide adequate reason for concern over impacts of industrialization and economic growth.

Most developing countries continue to experience much higher population growth rates than industrialized countries, such that the vast majority of new people added to the world in recent years (at least 90 percent in 1991) live in developing countries. Developing countries currently make a far smaller per *capita* contribution to global environmental problems than industrialized countries. However, developing countries' per capita and net contributions to global environmental problems could potentially experience significant increases.

OTA has analyzed each of the global environmental priorities identified by the Global Envi-

ronmental Facility [1]—global warming, ozone depletion, biodiversity loss, and international waters—as well as population growth and tropical forest management.

Population Growth

Population growth may be the most important and most difficult issue confronting policy makers today. It is a key factor limiting the ability of nations to manage their resources sustainably. *World Population and Fertility Planning Technologies: The Next Twenty Years (1982)* included analysis of population growth projections; determinants of fertility change: then-current reproductive research and contraceptive research and development; factors that influence the acceptance, distribution, and use of fertility planning technologies in developing countries; and past and current U.S. funding arrangements in support of population assistance requests from developing countries. Significant fertility declines most often are associated with indirect measures (e.g., government encouragement and promotion of equal status and opportunities for women, higher age at marriage, and more equitable distribution of wealth and education opportunities). U.S. government options to directly assist developing country population programs include federal support of contraceptive research and development (R&D), export of non-Federal Drug Administration approved drugs, improved levels of funding for international population assistance, and distribution of population assistance funds.

Global Warming

Documented scientific interest in the impact of atmospheric carbon dioxide on the planet's surface temperature dates back to the 1820s. Current public and policy interest in global warming stems from widespread agreement that warming has resulted primarily from human activity and. thus, could be addressed by government policy (4). OTA's *Changing by Degrees: Steps To Reduce Greenhouse Gases (199 1)* examined technologies to reduce carbon dioxide and other greenhouse gas emissions in the United States and overseas. actors and initiatives needed to implement such reductions, and the economic cost and time frame. OTA's discussion of developing countries in 1991 centered on tropical deforestation and its contribution to global warming. Developing countries recently overtook industrial countries in generating carbon emissions, however, producing an estimated 52 percent of the global total in 1993 (59). As predicted by OTA and others, this transition occurred due to increasing combustion of fossil fuels in association with developing country urbanization and industrialization (27,59). According to OTA, increasing the efficiency of energy-consuming technologies, changing energy-use patterns, and shifting to fuels and energy sources that emit less carbon dioxide (CO_2) are among the energy-based options for reducing greenhouse gas (GHG) emissions. OTA noted that because much of the energy infrastructure in developing countries is yet to be built, energy-related improvements in reduction of GHG emissions may be cheaper and relatively greater there. Such improvements would require significant technology transfer, and technical and financial assistance for new construction and retrofitting (1,59). Agriculture-related options for reducing greenhouse gas emissions target methane production in ruminants and $C0_2$ emissions from rice cultivation. Another option for offsetting COZ emissions discussed by OTA is tree planting to increase global carbon storage capacity.

Ozone Depletion

Unlike global warming, stratospheric ozone depletion was not clearly understood nor clearly

[1] The Global Environmental Facility was established in November 1990 to help developing countries to contribute toward solving global environmental problems. Under the supervision of the World Bank, the United Nations Environment Programme, and the United Nations Development Programme, it provides grants for investment programs, technical assistance, and research aimed at protecting the global environment and transferring environmentally benign technologies.

linked with human activity until the latter half of this century (4). Yet, by 1987, international authors of the Montreal Protocol were prescribing a global phaseout of production, consumption, and trade of chlorofluorocarbons (CFCs) and of bromine-containing compounds (halons). *An Analysis of the Montreal Protocol on Substances That Deplete the Ozone Layer* (OTA, 1988) examined the conditions for the agreement's ratification and enforcement; different limits placed on substances; differing transition periods allowed low-CFC-consuming countries versus high-CFC countries; and the Protocol's projected effectiveness at reaching its stated goals under various scenarios. Developing countries, as 1ow-CFC consumers, were permitted by the Protocol to increase CFC production and consumption, within limits, for 10 years, after which they were to reduce production and consumption of some CFCs and cease production and consumption of others. Following discovery of the annual ozone hole over Antarctica and ozone-thinning over the Arctic, the Montreal Protocol was renegotiated and strengthened in 1990 and 1992 to speed the phaseout process and give greater technical and financial assistance to developing countries through a Multilateral Fund (1 ,59).

| Biodiversity Loss and Tropical Deforestation

The Earth's biological diversity—its assortment of ecosystems, species, and genetic material—is being reduced significantly. This suggests, at the very least, the loss of resources that might otherwise improve the quality of human life. In a worst-case scenario, disruption of the basic ecological processes on which civilization is based could result. Maintaining biological diversity will increasingly depend on development and use of specific conservation measures, particularly in areas with highly diverse ecosystems and large numbers of unique species, such as tropical rainforests. How to help foreign assistance agencies respond to tropical forest and biodiversity losses became a key issue in the 1980s. OTA responded with *Technologies To Sustain Tropical Forest Resources (1984)* and *Technologies To Maintain Biological Diversity (1987).* Congressional concern brought funding increases to the U.S. Agency for International Development's (USAID's) programs in these areas. Subsequently, multilateral institutions, other countries' bilateral assistance agencies, some developing countries, and many nongovernmental organizations also became involved in efforts to preserve biologically diverse ecosystems as well as specific species.

Conserving biological diversity can be accomplished through "onsite maintenance" of ecosystems, such as national parks and preserves, and "offsite maintenance" facilities such as zoos, botanical gardens, and seed banks. While the latter approach is more economical and especially efficient for preserving plant varieties for agricultural purposes, the former, the more challenging approach, is considered the best means of maintaining a broad range of biological diversity (35). A combination of these approaches is likely to be needed as pressure on the planet remaining natural areas-about 3.2 percent of world land area—increases. Sustaining tropical forests is of particular importance because they contain the greatest diversity of plant and animal life. Resources from tropical forests are important to agriculture, commerce, and industry in all nations. Technologies that support and contribute to onsite biological conservation include farming systems that combine trees with crops or livestock (agroforestry), improved charcoal production, better wood stoves, genetic improvement of trees, approaches to park design and management, and a variety of forest management systems (35).

Despite conservation efforts, the social, cultural, economic, and political conditions perpetuating destruction of tropical forests and biological diversity have, in most cases, intensified. Although there has been substantial progress in institutional commitments and policies, little progress has been made in the realm of development and extension of technical solutions, suggesting that continued leadership from Congress is needed to sustain the momentum of earlier achievements (17). Specific areas for which OTA provided op-

tions for congressional action were research, technology development, education, and resource planning (17).

Degradation of Marine Environments

The extent of marine and coastal pollution problems facing developing countries has grown, while the institutional capacity and financial resources to address these problems have not. Although developing countries were not cited frequently in OTA's *Wastes in Marine Environments (1987),* this report suggested that, like industrial countries, developing countries need to direct more research toward understanding their marine environments, the specific problems they face, and the relationships between those problems and various land-based activities (33,34). Also needed is the capacity to translate that understanding into policies and actions to correct marine pollution problems.

Development assistance relevant to these needs has taken two broad forms: 1) promotion of developing country government policies that increase research, education, and sound management of marine resources, and 2) programs in coastal management and data collection to improve technical capacity in developing countries (34). Although technologies are available to treat wastewater and improve waste management, their use in developing countries is limited and worldwide increases in settlement of coastal areas already outpace government planning and waste management efforts. As a consequence, "deforestation" of estuaries and coastal wetlands, overfishing, coral harvesting, contamination from agrochemical runoff and erosion, and direct ocean disposal of untreated and partially treated municipal and industrial wastes continue in many areas (3,33,34).

Measuring Global Environmental Changes

Environmental monitoring continues to improve scientists understanding of current and emerging patterns of global environmental change. Satellite remote sensing systems provide the vantage point and coverage necessary to study the Earth as an integrated, interactive, physical and biological system (13). Data from satellite systems can assist in predicting weather patterns and managing land resources; raise awareness of environmental problems; and improve the institutional infrastructure of developing countries (43). For instance, U. S.-supported regional and national centers capable of collecting, processing. and interpreting Landsat data and combining them with other data can be used by developing country governments to plan and monitor forest stands, transportation networks, agricultural production, and hydrology (43). Some developing countries are making efforts to institutionalize management and use of space- and telecommunications-related data and information (table B-2: 43).

Policy discussion regarding distribution of satellite remote sensing data has led to consideration of numerous other issues, including allocation of spectrum resources, sale of sensed data to third parties, commercialization, and general disparities between industrial and developing country telecommunication resources. *The* 1992 *World Administration Radio Conference: Issues for U.S. International Spectrum Policy (1992)* and *The 1992 World Administration Radio Conference: Technology and Policy [replications (1993)* explore the interest of the United Nation's International Telecommunications Union in making telecommunications development and technical assistance to developing countries a more integral part of its mission. Close monitoring of this effort could help U.S. policy makers determine a national policy framework for making telecommunications a more universal resource (20).

Agricultural Technologies and Policies To Support Sustainability

Improving and sustaining agricultural productivity in developing countries has been a long-standing foreign assistance objective. The small-farm agricultural sector of a developing country is often responsible for providing food, fiber, and work to a large part of its population. In addition to meet-

TABLE B–2: Summary of Land Remote Sensing Applications

Agriculture
- Crop Inventory
- Irrigated crop Inventory
- Noxious weeds assessment
- Crop yield prediction
- Grove surveys
- Assessment of flood damage
- Disease/drought monitoring

Forestry and rangeland
- Productivity assessment
- Identification of crops timber, and range
- Forest habitat assessment
- Wildlife range assessment
- Fire potential/damage assessment

Defense
- Mapping, charting, and geodesy
- Terrain analysis
- Limited reconnaissance
- Land cover analysis

Land resource management
- Land cover Inventory
- Comprehensive planning
- Corridor analysis
- Facility siting
- Flood plain delineation
- Lake shore management

Fish and wildlife
- Wildlife habitat Inventory
- Wetlands location, monitoring, and analysis
- Vegetation classiflcation
- Precipitation/snow pack monitoring
- Salt exposure

Environmental Management
- Water quality assessment and planning
- Environmental and pollution analysis
- Coastal zone management
- Surface mine inventory and monitoring
- Wetlands mapping
- Lake water quality
- Shoreline delineation
- Oil and gas lease sales
- Resource inventory
- Dredge and fill permits
- Marsh salinization

Water resources
- Planning and management
- Surface water inventory
- Flood control and damage assessment
- Snow/ice cover monitoring
- Irrigation demand estimates
- Monitor runoff and pollution
- Water circulation, turbidilty, and sediment
- Lake eutrophication survey
- Soil salinity
- Groundwater location

Geological mapping
- Lineament mapping
- Mapping/identification of rock types
- Mineral surveys
- Siting/surveying for public/private facilities
- Radioactive waste storage

Land use and planning
- Growth trends and analysis
- Land-use planning
- Cartography
- Land-capacity assessment
- Solid waste management

SOURCE U S Congress Office of Technology Assessment, *The Future of Remote Sensing from Space Civilian Satellite Systems and Applications*, OTA-ISC-558 (Washington DC U S Government Printing Off Ice, July 1993)

ing farm families' subsistence needs, small-farm production feeds urban populations and contributes to regional and sometimes international trade. According to the Consultative Group on International Agricultural Research (CGIAR), meeting the food needs of the world's projected peak population at current per capita consumption rates will require more than doubling of current staple food crop yields. Yields will have to increase even further to make progress in overcoming malnutrition and poverty in Africa and Southeast Asia (7).

In developing countries, environmental degradation from expanding cultivation seriously undermines potential for sustainable agriculture and development generally. Moreover. staple crop

yields already may be leveling off in areas such as sub- Saharan Africa, and may begin to do the same in Asia (6). Much of the land available to small farmers in developing countries is only marginally suitable for most forms of agricultural production to begin with, and often progressively deteriorates. Poor soils characteristic of many moist tropical forest regions quickly lose their nutrient content, and exposure to wind and rain, often on steep slopes, leads to rapid soil erosion. In arid and semiarid regions, low soil productivity also prevails, and is accompanied by a short growing season, low and erratic rainfall, and higher possibility of drought. Shifting cultivation involves cutting and burning forest, producing crops for a couple of years, abandoning the land for a "fallow" period, and then, at some time later, repeating the cycle. Shifting cultivation has increased in many areas of the world during the last few decades, often penetrating forest areas along logging roads; practitioners generally are using shorter fallow periods than in earlier years (27). Erratic and eventually declining yields are common, and generally are made up for with expanded cultivation or off-farm employment. Catastrophic crop losses, in a climate of chronic food insecurity, has prompted large-scale civil conflict and migration, in parts of Africa over the past two decades.

By some estimates, the equivalent of approximately 15 million hectares of new agricultural lands are needed each year to keep up with population growth and the flagging productivity of currently cultivated lands (6). Urban and rural-area population sprawl competes with agriculture for this land. Although crop production continues to supersede ranching and forestry as a land-use priority, it is increasingly at risk from encroaching urban and industrial development. Pressure on remaining agricultural lands, along with increased cultivation of marginal lands, could spawn numerous unsustainable land-use practices and intensify the fuel wood crisis (6).

Technologies to promote intensification of production on land already in use could help slow agricultural land expansion, thereby reducing deforestation, as well as increasing food production. Potential food production gains from mechanization and intensification of agriculture in developing countries (where most farming is still human powered) is great, but sustainable production and management practices are needed, along with restoration of degraded lands, proper prices for agricultural goods, and long-range landuse planning.

Agricultural Technologies

The goal of agricultural research and technology development generally has been to improve productivity while maintaining reasonable costs of food and fiber. Other interests include soil and water conservation, human nutrition, food quality and safety, and the role of agriculture in international trade and in the economy as a whole. Recently, more concern has been directed to reducing agriculture's adverse environmental impacts using a systems approach. Opportunities to improve agricultural production in the developing world, primarily Africa, have been the focus of a large number of OTA reports.

OTA has examined the status and needs of developing country agriculture; the emergence of appropriate technology and sustainability paradigms; technological advances with potential to improve agricultural efficiency and productivity in industrial countries; and the rise of commercial agricultural biotechnology. OTA has provided Congress with options for strengthening the cost-effectiveness of U.S. participation in international agricultural research, technology development, and assistance. OTA's collected works in these areas address many specific technologies and policy initiatives that could substantially improve food production in developing countries (table B-3).

OTA has concluded in several reports that greater U.S. contributions to domestic, bilateral. and multilateral agricultural assistance will be necessary to increase agricultural production worldwide. Besides monetary assistance, there is a need for a clear plan and renewed effort to: 1) promote U.S. expertise and participation in agricultural research for the benefit of poor populations, and 2) assist developing countries with

TABLE B–3: CGIAR's Challenges and Themes in Agricultural Research and Sustainability

Recognition of links between long-term agricultural productivity and environmental quality led to proposal and discussion of sustainability in agricultural development circles well before it gained a following elsewhere Recently, a special CGIAR Committee on Sustainable Agriculture established four key themes on which to base sustainability research in the CGIAR system

Main challenges to agricultural research

1 Increasing and maintaining global yields to their technical and economic potential
2 Improving productivity in the less-favored areas that have become the last frontier of agricultural expansion (e g , rainforests).
3 Making the production technology gains needed to maintain soil fertility and other vital resources on which production depends.

Key themes on which to base sustainability research

1 Protection of the genetic base of agriculture,
2 Preservation of the natural resource base,
3 Research in less favorable environments.
4 Sustainable agriculture and external inputs,

SOURCE D L Plucknett, ' international Agricultural Research for the Next Century " *BioScience* 43(7) 432-440, 1993

agriculture-related institutional and technology development. For sustainable production increases, farmers need technologies that (31):

- improve the use of local natural resources, including indigenous plants and animals;
- improve soil fertility;
- improve water availability and efficiency of use;
- foster genetic improvement in plants and animals appropriate to local conditions;
- improve integration of animal and cropping systems;
- reduce food losses; and
- enable farmers to modernize as this becomes feasible to them.

Poor farmers need technologies that are low risk, resource conserving, small scale, adaptable to local conditions, and economically affordable. Technologies should also be suited to traditional agriculture methods. Appropriate technologies are those best able to function effectively according to the users' special circumstances. Lack of appropriate technologies and the failure of research systems to develop sustainable technologies that match the perceptions and resources of small-holder African farmers are two of the reasons yields of staple crops have been static in many sub-Saharan countries for the past 10 or more years (6).

Congressional concern over Africa's chronic food problems led to a number of OTA reports on improving agriculture and development assistance in Africa: *A Plague of Locusts (1990); **Enhancing Agriculture in Africa: A Role** for U.S. Development Assistance (1988); Grassroots Development: The African Development Foundation (1988); Continuing the Commitment: Agricultural Development in the Sahel (1986);* **and** *Africa Tomorrow: Issues in Technology, Agriculture, and U.S. Foreign Aid (1984).* Another report with a regional, but non-Africa, focus was *Alternative Coca Reduction Strategies in the Andean Region (1993),* which discussed the potential for agriculture and other renewable resource sectors to displace coca production in the Andes. These reports, in addition to examining specific food and development problems in selected regions, addressed issues central to the role and limits of U.S. assistance more generally.

Other OTA reports deal with generic agricultural issues and technologies. Concern about pesticide-related soil and water contamination, safety of farmers and wildlife, and increased incidence of resistance in target pest populations generated interest in alternative pest-management technologies such as integrated pest management (1PM) (56). For many farmers in developing countries, alternatives to chemical pesticides and fertilizers are a matter of economic necessity as much as environmental awareness. Most 1PM research has focused on U.S. farming conditions and practices. OTA suggested that greater agricultural assistance

for specific developing country research needs and challenges was critical to promoting 1PM internationally (56).[2]

Many factors affecting food supply, such as productivity of soils and chemical fertilizer needs, can be influenced by biological technologies (biotechnologies). New developments in plant and animal genetics were analyzed in OTA's *Commercial Biotechnology: An International Analysis (1984), Biotechnology in the Global Economy (199 1),* and *A New Technological Era for American Agriculture (1992).* In its examination of biotechnology industry research and development, OTA has identified several areas of potential importance to developing countries, including:

- genetic manipulation of plants to improve agricultural production in tropical and arid/semiarid climates (e.g., improvement of nutrient uptake, nitrogen fixation, pest resistance, drought resistance, etc.);
- genetic manipulation of plants to improve nutrition and health benefits (e.g., reduction of the cyanide content in cassava; improvement of protein content of corn);
- human and livestock vaccines engineered to be non-cold chain dependent (see also Human Resource Development); and
- increased production of biomass crops for conversion at local-level factories to help solve the problem of costly petroleum imports (see also Energy Development).

As is the case with 1PM, however, most cutting-edge biotechnology research is conducted in industrialized countries and does not necessarily address developing country needs. Agricultural technologies that are more likely to be accessible and useful to developing country farmers were discussed in *Innovative Biological Technologies for Developing Countries (1985).* These include:

- underexploited native plant and animal species;
- multiple-cropping and intercropping systems;
- green fertilizers;
- zeolite minerals, whose benefits include extending fertilizer efficiency, maintaining soil nitrogen levels, supplementing animal feedstocks, and decontaminating feedlot wastes; and
- beneficial microorganisms such as mycorrhizae, which significantly increase the root's surface area and, therefore, the plant's ability to assimilate soil nutrients.

Information exchange among countries can be valuable to all parties. *Water-Related Technologies for Sustainable Agriculture in Arid/Semiarid Lands: Selected Foreign Experience (1993)* reported on developing country approaches to efficient use of scarce water supplies. This paper provides a useful model for exploring developing country technology relevant to industrial country interests, and demonstrates the potential for more mutually beneficial working and learning exchanges between the United States and developing countries.

Potential mutual benefit also can be gained from U.S. cooperative research on the natural and cultural resources of many developing countries. At least 95 percent of U.S. crops have their origin and centers of genetic diversity outside the United States (56). Thus, opportunities exist for research exchanges and partnerships. Crops, technologies, and farming systems that are indigenous to some developing regions and have demonstrated potential to be practiced sustainably present especially promising areas for cooperative research. In *Plants: The Potentials for Extracting Protein, Medicines, and other Useful Chemicals (1983),* OTA discussed of potential economic uses for indigenous plants. Special consideration was given to the potential for developing countries to generate income, food, or other benefits from these plants.

Some technologies to support agricultural research and food security are found in commu-

[2] An assessment of biological pest control is currently underway at OTA and is scheduled to be completed in June 1995.

nications and data processing systems. *Food Information Systems (1976)* evaluated the information systems of the U.S. Department of Agriculture and the United Nations Food and Agriculture Organisation. *Remote Sensing and the Private Sector (1984), International Cooperation and Competition in Civilian Space Activities (1985),* and *The Future of Remote Sensing from Space: Civilian Satellite Systems and Applications (1993),* while not exclusively concerned with agricultural uses of satellite systems, included updated discussions of these uses with respect to developing countries. Reports that give early warning of adverse weather, pest infestations, natural disasters, and other events that may affect crop availability and demands are a particularly important service.

Critical to the effectiveness of food information, however, is open information sharing within and between countries (58). Inadequate dissemination; neglect of rural and small-holder populations; government resistance to revealing politically, economically, or socially sensitive information; and the inability of many developing countries to gather, receive, and process data pose major constraints to the information flow.

OTA analyzed energy-related agricultural production needs in *Fueling Development: Energy Technologies for Developing Countries (1992).* Agriculture was determined to be responsible for only about 5 to 8 percent of commercial energy use in developing countries, but use of agricultural machinery in developing countries is expected to increase. OTA identified several opportunities for improving the efficiency of commercial energy services in agriculture, particularly for irrigation (e.g., improved pumps, piping, and water delivery systems such as drip irrigation) and traction (e.g., improved nutrition and harness design for draft animals, and more efficient motors for tractors). Other promising energy-efficient measures and technologies can improve:

- industrial energy use to produce farm implements, fertilizers, and chemicals;
- application and plant use of agrichemical;
- postharvest drying and storage;
- conversion of crop residues to energy feedstocks; and
- transport of produce to markets.

Finally, nonagricultural technologies can indirectly improve food production potential by reducing time consumed in collection of firewood and water (e.g., higher-efficiency stoves).

Institutional and Policy Mechanisms

The OTA reports featured in Agricultural Technologies also examined agricultural aid policies and institutional roles; mechanisms by which research and technology are developed and shared with developing countries; and monetary and nonmonetary options for improving the effectiveness of assistance at the institutional level. Agricultural assistance issues were addressed in other reports as well: *An Assessment of the U.S. Food and Agricultural Research System (1981), Grassroots Development: The African Development Foundation (1988), New Opportunities for U.S. Universities in Development Assistance: Agriculture, Natural Resources, and Environment (1991), Science and Technology for Development (1989), Aid to Developing Countries: The Technology/Ecology Fit (1987).*

These reports discussed agriculture-related policy and institutional activity pertaining to:

- research (data collection and management) and technology generation,
- extension and technology transfer,
- education and training, and
- institution- and capacity-building (22).

Research

By most estimates, benefits that accrue from agricultural research greatly out weigh the costs to society, and returns are high relative to many other social investments (16). Research, technology, and extension activities, and appropriate institutional development are major factors contributing to production increases at home and abroad. Research on problems relevant to small-farm pro-

ducers can help identify opportunities for and constraints to developing country agricultural production.

Information and research activities that could contribute to planning and implementing developing country agricultural strategies include:

- country- or region-specific, geological, biological, and agroecological surveys;
- participatory identification of social, economic, and political opportunities and constraints that could affect project outcomes and identification of project-level and national expectations and goals; and
- survey of local infrastructure and human resources (e.g., institutional support, roads, water, agricultural experience, and labor demographics) and information on local crops and farming systems.

Extension and Technology Transfer

Two important conditions for successful transfer of technology, or extension, identified by OTA are:

1. Personal contact, e.g., direct instruction in a technology from the extension agent to the farmer and involvement of parties in technology choice, planning, and implementation; and
2. Adaptation of the technology to the user's local biophysical and socioeconomic conditions. This requires a two-way information transfer such that farmers can inform agents of their needs, problems, and the technologies they use (41 .44).

OTA has suggested lengthening project cycles to allow more time for technology introduction, project monitoring, and mid-project adjustments to deal with problems (2). Such steps could help foster technology adoption and diffusion, and ensure that technologies are ecologically sustainable in specific settings.

Education and Training

Developing countries agricultural research capacity could be improved if U.S. development institutions were to:

1. operate graduate training programs for scientists in their home countries or comparable locations, rather than the United States, to ensure that scientists learned to do research in realistic settings, were able to help solve local problems, and could continue their research after completion of their degrees;
2. provide practical short-term training, by local and foreign experts, for agriculturalists who worked directly with farmers in an advisory capacity;
3. provide literature or grants for preparation and publication of books and bulletins by local scientists to improve access to up-to-date information in countries with inadequate libraries and information resources (22); and
4. sponsor demonstration projects.

The goal of such efforts is to promote the scientific, technical, and management expertise developing countries need to carry on work beyond the life span of individual aid projects, and to ensure that research at the local level can be cooperative, accessible, and relevant. Structures for funding and facilitating coordination and involvement by donors, universities, developing country institutions, and producers in international agricultural work was given extensive analysis in New *Opportunities for U.S. Universities in Development Assistance: Agriculture, Natural Resources, and Environment (199 1).*

Energy Technologies and Policies To Support Sustainable Development

Rapid population growth and structural changes inherent in the development process (e.g., urbanization; building of the commercial, industrial, and transportation infrastructure: substitution of commercial for traditional fuels; and the rise in the demand for consumer goods) are projected to triple developing country commercial energy consumption over the next 30 years (19). Significant financial, operational, and environmental constraints will thwart efforts to increase energy supplies on this scale.

The environmental impacts of rapid expansion of energy supply could be substantial. Production

and use of commercial and traditional fuels contribute to the accelerating rates of environmental degradation within many developing countries. Energy trends in developing countries are also of global environmental concern. Although their per capita energy use is far below that of industrialized countries, developing countries are increasingly important contributors to greenhouse gas emissions from fossil fuels use. They now account for slightly more than one-half of annual global energy-sector carbon dioxide emissions, produce a growing amount of other greenhouse gases, such as methane and nitrogen oxides, and continue to reduce the Earth's carbon storage capacity through deforestation.

While energy production, conversion, and use generally contribute to environmental degradation, energy wisely used can potentially provide several important environmental benefits in developing countries (e.g., higher fuel efficiency, less energy-related air pollution, less need for fuelwood). OTA recently concluded that energy efficiency improvements in developing countries could promote economic development with minimal environmental impact (19).

OTA energy-related studies commonly include information about developing countries, but the reasons for this vary.[3] In both *World Petroleum Availability 1980-2000 (1980)* and *Alternative Energy Futures (1980),* OTA looked at the energy resources and supplies of developing countries as potential fuel sources for the United States. The reports recognized, however, that any increase in developing country energy supplies would likely be offset by growth in local demand and, thus, projected continuing U.S. dependence on the Organization of Petroleum Exporting Countries. OTA determined, however, that changes in U.S. industrial productivity, improved, integrated utility management schemes, and energy efficiency could lower domestic energy use growth rates.

Energy-related technology transfer to developing countries was highlighted in *Technology Transfer to the Middle East (1984)* and *Energy Technology Transfer to China (1985).* In the Middle East report, OTA concluded that the availability of hydrocarbons for power production and the small size of electricity grids limited prospects for transfer of nuclear power technologies in the region. In the China memorandum, OTA also gave special emphasis to nuclear energy technologies because of an impending nuclear cooperation agreement between the two countries that was expected to yield export opportunities for the U.S. nuclear industry. In both studies, OTA observed that U.S. and foreign expectations and interests regarding technology transfers sometimes diverge, with obvious strategic and commercial implications. In the case of nuclear energy in particular, commercial and international security interests have come into conflict. The potential role of nuclear power in nuclear weapons proliferation has been a main point of concern. *Nuclear Power in the Age of Uncertainty* (1984) assessed ways to improve the outlook of the nuclear power industry in the United States, and examined demand growth, costs, regulations, and public acceptance overseas. Human and environmental safety concerns in nuclear powerplants and questions of how to dispose of and prevent accidental release of toxic and radioactive nuclear materials permanently, received attention in *Energy Technology Choices: Shaping Our Future (1991),* and *Fueling Development: Energy Technologies for Developing Countries* (1 ***992).***

Energy efficiencies vary in the developing world but, on average, appear to be much lower than in the industrialized countries. In reasonably standardized operations, such as cooking, steelmaking, and electricity generation, dramatic improvements in technical efficiencies are possible. However, the policy environment that determines

[3] OTA recently produced an overview of past energy reports, and present and future congressional technology and policy interests regarding domestic energy policy, entitled *Energy Technology Choices: Shaping Our Future (1991).*

patterns of incentives and disincentives to energy efficiency is crucial to the adoption of new technologies. In *Fueling Development,* OTA looked" at:

- ways to provide energy services for development through improvements in efficiency;
- established technologies that save energy, diminish adverse environmental impacts, reduce product Iifc-cycle costs to consumers, and lower systemwide capital costs; and
- the institutional and policy mechanisms that determine their rate of adoption.

Energy Technologies

Low technical efficiencies with respect to energy production. conversion, and use in developing countries could be improved through adoption of proven technologies. On the demand side, these include efficient 1ights, stoves, refrigerators, cars and trucks, industrial boilers, electric motors, and a variety of new manufacturing processes for energy- intensive industries such as steel and cement. Energy-efficient pumps, fertilizers, and mechanical traction can improve agricultural productivity. Technology also could boost efficiency, quality, and productivity of traditional small-scale industry. which accounts for one-half to three-quarters of manufacturing employment in many developing countries and is an important source of income for rural and urban poor. Numerous technologies at various stages of development and commercialization also could enhance the efficiency of delivering energy services (1 9).

Widespread adoption of improved energy use and delivery technologies could save substantial energy in the course of development. Capturing energy savings could benefit the environment and ease the import burden for many developing countries.

Various opportunities and constraints exist with regard to improving the efficiency of developing coal, oil, gas, and biomass resources. Alternative, non-combustion-based energy supply projects, such as hydro, solar, nuclear, and wind also carry a number of financial, technical, and environmental 1imitations (table B-4). However, important benefits have been provided by new energy supply technologies in several areas. Characteristics identified by OTA that made these technologies suitable to developing country needs included:

- ***Modular, small scale, and short lead times.*** Energy supply technologies that are small and modular can match demand growth more closely than conventional ones. Shorter lead times and small projects lower costs and reduce risk.
- ***Reliability and performance.*** Technologies that improve plant reliability and performance reduce problems related to blackouts. brownouts, and sharp power surges, which often plague developing country systems. Many consumers are obliged to invest in back-up equipment in order to minimize the impact of disrupted supplies.
- ***Rural Access.*** Most populations of dc~'eloping countries live in rural areas, the great majority in poverty and without access to the services that could improve their standard of 1iving. Smaller scale technologies (modern biomass energy and decentralized renewable) that can bring high-quality energy sources to rural areas help promote rural development and employment.
- ***Environmental benefits.*** OTA's analysis suggested that among fossil fueled systems. natural gas generally has the fewest adverse environmental impacts. Increased emphasis on natural gas could reduce the negative impacts and human health hazards associated with coal, and avoid some of the problems of' large hydro- and nuclear power. Modern biomass systems also would reduce environmental impacts compared with coal or other conventional fuels. Finally, decentralized renewable resources were found to generate less air pollution and other environmental problems associated with large-scale energy projects.
- ***Foreign exchange savings. New*** technologies that develop local energy resources can reduce energy imports—which currently account for at least 50 percent of export earnings in several of the poorest countries.

TABLE B-4: Development- and Environment-Related Tradeoffs of Energy Resources

Energy resource	Advantages	Disadvantages
Biomass	Used widely—in Africa is two-thirds of total, in Asia one-third, and Latin America one-fourth Some developing countries are wholly dependent on it. Current use is Important to traditional rural economies and employment for poor Potential resource base is extensive, Countries with sufficient land resources could save foreign exchange dollars for reinvestment. Produced Indigenously, could reduce energy import dependence and stimulate rural development. If produced sustainably, would not add to net greenhouse gas (GHG) emss.ions, if substituted for fossil fuels, could actually decrease GHG emissions, also could improve local environments by reducing sulfur dioxide and nitrogen oxides (acid rain precursors) emissions Of different sources *Agricultural and industrial (e.g.,* forest products industry) *residues* Could be used more extensively and efficiently than they are presently (e.g., dung could be processed in a biogas digester); densified residues have high energy content per volume, reducing transport costs, *Natural forest-derived wood and charcoal,* Used widely—meet 90 percent of energy needs in Ethiopia, Nepal, and Bangladesh—m households and businesses Careful management and use could provide additional energy supplies, many subsistence populations depend on them for their livelihood, are integral to ecosystem maintenance and global environmental quality, e g , for carbon storage, numerous techniques exist to minimize damage from wood collection but are undermined by agricultural expansion, immigratlon, and livestock rather than by fuelwood gatherers Efficiency of charcoal kilns and fuelwood stoves continues to improve and technologies continue to be made more widely available, as do tree-planting programs (Field, 1993) *High-yleld field crops* Research and development have greatly improved feasibility *Woody biomass* Able to be bred for fast growth, high density (heat value per unit of volume), robustness, nitrogen fixing, and coppicing potential	Requires significant amounts of land, and significant amounts of energy for planning, harvesting, drying, and-if done-conversion. Not likely to be supplied at competitive price on a sustainable basis Requires well-developed transportation Infrastructure to be relied on regionally, In many developing countries, energy plantations might compete with food crops, Any diversion of land could adversely affect the poor, by denying access to food and previously "free" fuel, fodder, fiber, and fertilizer, Long-term environmental Impacts of sylvan monoculture and high-yield crops are unknown, but could involve risks to soil and water quality and availability, Most current research and development does not reflect developing country needs and conditions, Of different sources: *Agricultural and industrial residues:* Raises issue of "determining when a waste is really a waste, " e.g., current biomass is already heavily used and may have Important uses other than fuel, e g , livestock feed, fiber, and fertilizer, is also plowed under to fertilize fields, needs careful management so as not to result in soil degradation and erosion *Natural forest-derived firewood and charcoal* High demand and subsequent high prices likely would leave fuelwood needs of many unmet, aggravating shortages (Field, 1993) Techniques to minimize damage from wood collection are undermined by agriculture expansion, immigration, and livestock (Hosier, 1993) *High-yield field crops.* Species very site-speclflc—not a suitable characteristic for developing countries, require long-term sustained efforts, i.e. , could not occur independent of larger development context. *Woody biomass* Forest management notoriously difficult Monoculture short rotation forests are susceptible to devastating effects from poor soil, harsh microclimates, pests, fires, weeds, and diseases

(continued)

TABLE B-4 (cont'd.): Development- and Environment-Related Tradeoffs of Energy Resources

Energy resource	Advantages	Disadvantages
coal	Largest single source of fossil fuels in developing countries though developed and used mostly in China and India Cheaper per unit of heat value than 011 and, usually, gas Is a long-established technology Mining capital costs are low	Difficult to handle and transport Less versatile than 011 Frequently of poor quality Underground mining Involves hazardous work conditions Disturbs surface lands and waters May contaminate underground or surface waters if excavated material is not properly managed Surface mining causes significant land loss Dust and emissions from mining and preparation can contribute to local air pollution, e g adds sulfur dioxide ($S0_2$) suspended particulates, carbon monoxide (CO), nitrogen oxides (NO_x), and carbon dioxide ($C0_2$) emissions leading to acid rain, urban smog, respiratory infections and, potentially, global warming Has highest per unit energy $C0_2$ content –25 kilograms of carbon per Gigajoule (GJ, or 204 million Btu) Produces large amounts of solid waste
Geothermal	Uses Indigenous resources Low land requirement Depending on the technology used (binary vs. direct steam single-flash or dual-flash) can have a short construction lead time Site-speclf!c environmental problems (see Disadvantages) can be controlled	Resources can only be quantified using expensive drilling (e g , by one estimate, geothermal drilling costs in Kenya are roughly $250,' foot) Resource extraction requires technical expertise and can be costly Depending on the technology used (see Advantages), can cause emissions of $C0_2$ and hydrogen sulfide and can require large amounts of water Small binary plants however, can use air-cooled condensers Site-specific environmental problems Include subsidence of land overlying wells contamination of water supplies by saline (and sometimes toxic) geothermal fluids and reinjected water and the generation of surplus high-temperature liquid effluent containing metals and dissolved solids

(continued)

TABLE B-4 (cont'd.): Development- and Environment-Related Tradeoffs of Energy Resources

Energy resource	Advantages	Disadvantages
Natural gas	Many (i.e. , at least 52) developing countries—including several poor, sub-Saharan African countries— have significant reserves, and more are being discovered. Releases fewer GHGs and produces less localized pollution than other fossil fuels. Has lowest per unit energy $C0_2$ content—produces 13.6 kilograms of carbon per gigajoule (compare with coal and 011, under Disadvantages) High quality, "modern" liquid and gas fuels offer many benefits—reduced time, labor, and reduced air pollution (compared with crude biomass fuels) in provision of residential and commercial energy services (e g , cooking, water heating)	There is little exploration for gas—reserves discoveries often are a by-product of oil exploration Markets are not developed and local (developing country) markets wiII not generate adequate foreign exchange to repatriate profits to foreign Investors Production and transport can lead to land disturbance and water contamination Combustion contributes to air pollution, e g , adds $S0_2$, suspended particulates, CO, NO_x, and $C0_2$ emissions, leading to acid rain, urban smog, respiratory infections, and, potentially, global warming, though less so than coal or oil.
Oil	Mainstay of most developing country commercial energy supplies (two-thirds of total) Easy to transport Easily used m all sectors at all scales of operation. Developing countries with reserves could potentially attract small field development, though Investment incentives traditionally are biased in favor of large, low-cost rather than small, higher-cost fields among major (foreign) 011 companies, to this end, multilateral development banks are now assisting countries with investment challenges. Is most common substitute for wood-based fuels (firewood and charcoal) (Field, 1993)	Not found in large amounts or under good production conditions in most developing countries-current reserves in most developing countries wiII exhaust sooner than worldwide reserves/production ratio Domestic 011 resource development in developing countries projected to stabilize or decline and import dependence is expected to increase Imports already consume a significant part of developing country foreign exchange budgets. Production and transport can lead to land disturbance and water contamination Combustion contributes to air pollution, e g , adds $S0_2$, suspended particulates, CO, NO_x, and $C0_2$ emissions leading to acid rain, urban smog, respiratory infections, and, potentially, global warming Has 19 kilograms of carbon per gigajoule. At user -level, kerosene is more expensive and supply is often unreliable

(continued)

TABLE B-4 (cont'd.): Development- and Environment-Related Tradeoffs of Energy Resources

Energy resource	Advantages	Disadvantages
Large-scale hydro	Uses Indigenous resources Proponents say most environmental costs can be prevented, particularly as adverse environmental Impacts become a more routine consideration in project designs (Goodland, et al , 1992)	Has become increasingly controversial as concern about its adverse social and environmental impacts has come to the fore Very capital-Intenswe and construction time can be long, consulting a major drain on developing country economies Can flood large tracts of land, uprooting people and leading to loss of forests and wildlife habitat, can disrupt the natural flow of rivers and contribute to the increased incidence of debilitating diseases such as schistosomiasis Depending on the extent of flooding, type of landscape flooded (e.g. , physical, chemical, and biological features), and mode of power generation, can emit significant amounts of GHGs (Rudd, et al , 1993)
Small-scale hydro	Less likely than larger projects to flood large tracts of land, uproot people, cause significant loss of forests and wildlife habitat, disrupt the natural flow of rivers, or contribute to the Increased incidence of debilitating diseases such as schistosomiasis Less likely than larger projects to emit significant amounts of GHGs (Rudd, et. al , 1993) If matched to and operated according to local community needs, and constructed using local materials and labor, can achieve considerable savings over designs based on large projects. However, centralized organization still likely to be needed to provide effective maintenance and repair services (Foley, 1992) *Water turbines.* Have been successfully substituted for traditional water mills for milling gram also have been equipped with generators to provide lighting (Foley, 1992)	Study in India found small hydro to be nine times more expensive, per kilowatt hour than larger projects Small projects based on large project designs tend to suffer from diseconomy of scale large overhead for construction, access roads, and site establishment. Hydro projects generally face significant technical, financial, and managerial problems (e.g , lack of water, site instability) (Foley, 1992).
Nuclear	Releases little air pollution Proponents say small, modular, safer units under development could offer high performance and safety at reasonable costs However, data on costs and performance are not yet available, and risk averse potential nuclear power users with limited capital may choose to wait until these are operated commercially and have demonstrated these claims	Has potential to release toxic and radioactive materials wastes require careful handling and long-term disposal strategies High capital costs are likely to limit potential for development in developing countries, historically nuclear power systems have cost more and operated at lower capacity factors than anticipated Nuclear technology requires technically skilled personnel Developing countries, at least Initially, would be dependent on other countries for equipment and operation of powerplants Poses problems of weapons proliferation

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TABLE B-4 (cont'd.): Development- and Environment-Related Tradeoffs of Energy Resources

Energy resource	Advantages	Disadvantages
Solar	*Small photovoltaics kits.* Used to power water pumps suitable for drinking supplies, and electricity generation for solar refrigerators, lighting, and small electronic equipment (e.g., radios, cassette players, small TVs). Useful for decentralized applications, as in remote areas (Foley, 1992) *Flat-plate solar collectors:* Sold commercially *in* the United States. Main potential in developing countries is in urban areas (Foley, 1992).	*Small photovoltaics kits,* Historically plagued by failures of solar cells and ancillary equipment in harsh developing country operating conditions, shortage of spare parts and suitably skilled technicians has constrained life span in some countries. Appears to require considerable subsidizing—voluntary or spontaneous adoption and dissemination has been negligible. Power output is not suitable for operation of many domestic appliances (e. g., irons, sewing machines, hot plates, much less commercial enterprises), thus potential for expanded electricity use is hindered (Foley, 1992). *Centralized power stations:* Extremely unreliable and expensive to maintain-dependent upon services of expert technicians from manufacturing companies in donor countries for repairs (Foley, 1992). *F/at-p/are solar collectors:* Cost and technical complexity preclude use in remote areas (Foley, 1992). *Solar dryers and solar cookers,* Have proved expensive, awkward, and generally impractical (Foley, 1992).
Wind	Has proven competitive with traditional electricity generation technologies in some applications in the United States. A 1987 World Bank report identified 16 developing countries that would be appropriate for grid-connected wind turbines (i.e., exhibiting a sufficient wind resource within 50 kilometers of an existing electricity grid),	Major constraints to wind turbines are wind resource limits and backup requirements. Land requirements for wind turbines can be large, however, crop production and cattle raising can still be done on this land. Design and manufacture of wind turbines is somewhat complex and may not be readily done in many developing countries, although some manufacturing and most assembly of components can be done within the user country,

SOURCES U S Congress, Office of Technology Assessment, Fueling Development Energy Technologies for Developing Countries, OTA-E-516 (Washington, DC: U S Government Printing Off Ice, April 1992), unless otherwise indicated Also T Field, "Wood -Starved and Footsore, " American Forests, 99(July-August) 49-52, 1993, G Foley, "Renewable Energy in Third World Development Assistance Learning from Experience" Energy Policy 20(April) 355-364,1992, R Goodland, A Juras, and R Pachauri, "Can Hydroreservoirs in Tropical Moist Forests Be Made Environmentally Acceptable?" Energy Policy 20(June) 507-515, 1992, R H Hosier, "Charcoal ProductIon and Environmental Degradation. Environmental History, Selective Harvesting, and Post-Harvest Management, " Energy Policy 21 (May) 491-509, 1993, J W M Rudd, et al , "Are Hydroelectric Reservoirs Significant Sources of Greenhouse Gases?" AMBIO 22(4) 246-248, 1993

Employment. Decentralized renewable need installation and servicing that could create local jobs. Production of biomass energy can also create rural employment.

However, adoption of new energy technologies depends on not only the intrinsic superiority of the technology itself but also on whether financial and institutional factors favor adoption. Finally, little experience with large-scale use of decentralized technologies exists to serve as a basis for firm decisionmaking (19).

| Institutional and Policy Mechanisms

Institutional and procedural impediments exist to energy efficiency in developing countries. Examples from the energy supply sector include: official interference in day-to-day management of utilities, overstaffing, inadequately trained staff and management, poor system integration and planning, poor maintenance, deficient financial monitoring, lack of standardization of equipment, distorted pricing structures, corruption, shortages of foreign exchange to buy spare parts, and regulatory frameworks that discourage competition. These problems raise questions about the potential for energy supplies to expand rapidly even if financial resources were available.

OTA found that when all costs are accounted for, energy-efficient equipment usually can provide energy services at a lower installed capital cost than less efficient equipment. In the electric sector, for example, capital could be saved because higher initial costs of efficient end-use equipment usually are outweighed by savings realized from building fewer powerplants. Opportunities to install energy-efficient equipment are particularly important in developing countries because of the rapid growth in stocks of energy-using equipment and the high share of total investment budgets devoted to increasing energy supplies.

To achieve substantial capital savings through energy efficiency, institutional changes are needed to enable decisionmaking on a system-wide basis, and to focus financial resources on adoption of efficient end-use equipment. A powerful tool for achieving such a systems approach is Integrated Resource Planning, in which energy-efficiency investments are explicitly included as an alternative to capacity expansion (box B-1).

Utilities in developing countries also must build up and maintain competent technical staffs. This will require a long-term institutional commitment to training in support of environmental planning and regulatory functions (19).

Technical transfer policies that could help overcome constraints to adoption of energy -efficient technologies include:

- increased attention to technology adaptation;
- increased training in energy-efficient end use or improved supply technologies;
- energy pricing policies that reflect the full costs of supplying energy:
- taxation of consumers;
- financial incentives (e.g., tax relief or low-cost loans) to encourage production or purchase of energy efficient equipment: and
- efficiency standards.

Developing countries seeking alternative ways to meet the demand for energy are giving increased attention to politically sensitive questions such as energy price reform, improved management, and operations' efficiency in state-owned energy supply industries. Several developing countries have taken steps to encourage private investment, and many countries have developed capable resource and policy institutions. Progress also has been made in energy-related environmental protection.

Bilateral and multilateral donor institutions also are beginning to incorporate environmental planning and energy conservation into their projects and to encourage a larger role for the private sector. Congress has directed USAID to encourage energy pricing reform, end-use energy efficiency, integrated resource planning (termed *least cost planning),* and renewable energy; and to increase the number and expertise of personnel devoted to these areas. USAID has also been directed to include global warming considerations in its energy assistance activities. In particular, Congress requested USAID to identify those de-

BOX B–1: Integrated Resource Planning[1]

Conceptually, Integrated resource planning[2] (IRP) is straightforward. Planners rank by cost all the different energy supply and energy end-use technologies that might be used to provide an energy service, and implement them beginning with the lowest cost opportunities. Thus, various electricity supply technologies such as conventional coal plants, steam-injected gas turbines, and combined-cycle plants are compared with each other and with end-use technologies such as compact fluorescent lights, adjustable--speed electronic drives for motors, and increased insulation in buildings to reduce air-conditioning loads. Of all the different possibilities, the lowest cost options are chosen for investment

The manner in which energy institutions are organized, however, has not encouraged the implementation of Integrated resource planning Under the traditional regulatory framework found in most countries, utilities are in the business of selling energy supplies, not energy services Each kilowatt-hour sold by an electric utility increases gross earnings, no matter how much it costs to generate; conversely, each kilowatt-hour saved by using an energy-efficient technology decreases earnings, no matter how little it costs to Implement [3] Similarly, displacing utility-generated power with purchases of power from nonutility sources such as industrial cogeneration usually reduces utility earnings These considerations often hold even where electricity costs are heavily subsidized—the state simply replenishes utility funds while utility managers and workers are rewarded in terms of job security, increased salaries or staffs, and so forth for the amount of electricity generated, irrespective of its cost and usefulness.

in contrast, Integrated Resource Planning changes the regulatory framework in order to encourage utilities and other to Implement the least-cost demand and supply options. Among other changes, regulators allow utilities to earn income based on the net benefits from investments m energy-efficiency Improvements This focuses the financial, managerial, and technical skills of the utility on some of the market failures on the demand side and helps realize some of the most important policy responses, especially the capital cost-related ones

Factors that should be considered in IRP programs include: providing appropriate financial rewards for utilities to support efficiency Improvements as well as supply-decoupling utility profits from the number of kilowatt-hours sold—m order to minimize the overall cost of supplying energy services, ensuring that the startup costs of the IRP program and the administrative complexity and overheads are kept to a minimum, developing adequate methods for "measuring" savings (also known as scorekeeping), and avoiding the "free-rider" problem.

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[1] Sources and further reading David Moskovitz, ' Profits and Progress Through Least-Cost Planning, " National Association of Regulatory Utility Commissioners, Washington, DC, November, 1989, Jonathan Koomey, Arthur H Rosenfeld, and Ashok Gadgil, "Conservation Screening Curves To Compare Efficiency Investments to Power Plants, " *Energy Policy*, October 1990, pp 774-782, Thomas B Johansson, Birgit Bodlund, and Robert H Williams, *Electricity Efficient End-Use and New Generation Technologies and Their Planning Implications* (Lund, Sweden Lund University Press, 1989), Howard S Geller, *Efficient Electricity Use A Development Strategy for Brazil*, contractor report for the Off Ice of Technology Assessment (Washington, DC American Council for an Energy Efficient Economy, 1991), *Proceedings 5th National Demand -Side Management Conference,* Electric Power Research Institute, Palo Alto, CA, report CU-7394, 1991, P Herman, et al , "End-Use Technical Assessment Guide, volume4 Fundamentals and Methods, " Electric Power Research Institute, EPRI CU-7222, VOI 4, April 1991, Palo Alto, CA; Linda Berry and Eric Hirst, "The U.S DOE Least-Cost Utility Planning Program, " Energy 15(12) 1107-1117, 1990, Glenn Zorpette, "Utilities Get Serious About Efficiency, " *IEEE Spectrum*. May 1991, pp 42-43

[2] Other names associated with integrated resource planning include/east *cost planning* and *demand side management* Least Cost Planning has sometimes been taken to mean only comparisons of energy supply options, with no comparisons with end use options, with no comparisons with energy supply options

3 Adapted from David Moskovitz, Op cit , footnote [1]

veloping countries where changes in energy and forestry policies might significant y reduce greenhouse gas emissions.

Given the relatively small scale of U.S. bilateral assistance for energy development,[4] aid attention should focus on:

- promoting technical assistance and institution building for technology transfer and diffusion;
- introducing energy efficiency and related environmental considerations into broader international policy discussions where the U.S. voice carries considerable weight;
- bringing influence to bear on the activities of the multilateral development banks whose expenditures represent a major force in developing country energy decisionmaking; and
- developing cooperative approaches with other bilateral donors and lending agencies, and the private sectors in the United States and developing countries.

Regulatory and Trade Policies To Support Sustainable Development

Discussions of developing country industrialization needs have become more common as issues such as international trade agreements, multinational enterprises, "aid for trade," and "greener" production have entered the domestic and international policy dialog. Helping developing countries reduce the adverse environmental impacts of urbanization and industrial growth can, in some instances, help U.S. producers of environmental technologies.

However, U.S. manufacturers have long expressed concern about the cost of complying with U.S. environmental regulations. In most developing countries, compliance costs are lower and, in some cases, negligible. OTA generally has found that environmental regulation has little overall effect on U.S. trade performance. Market access, wages, and labor standards are much more important to siting facilities differences. Environmental regulation and enforcement have greater impact in U.S. sectors with higher compliance costs and regulatory burdens than their foreign competitors (29). Various domestic and foreign policy responses to unequal levels of environmental regulation are possible, such as negotiations with other countries for higher standards, changes in the U.S. regulatory system, and incentives to U.S. industries to adopt pollution prevention and other innovative, more cost-effective environmental approaches. Environmental agreements with other countries could be combined with U.S. technical assistance to help countries develop and implement appropriate environmental standards. U.S. policy efforts aimed at making business elsewhere adhere to industrialized country standards would be controversial, but could yield long-term benefits for the environment and for public receptiveness to trade liberalization in the United States. However, developing country officials may fear losing multinational investments if their environmental standards are raised above those of neighboring countries.

The issue of unequal environmental standards was addressed in *Copper: Technology and Competitiveness* (1988). U.S. copper producers claimed that extensive environmental regulations significantly added to the costs of domestic production and adversely affected their competitiveness. In developing countries, environmental regulations on copper producers had considerably less impact. OTA suggested that the United States could apply pressure for environmental control through its participation in international financing of foreign copper projects (World Bank), or through taxes on imported copper. Pressure on Mexico and Canada, in particular, could be tied to treaties related to border issues. In the end, however, the U.S. copper industry's concerns about environmental regulations, labor costs, and ore quality were offset by their advantages with re-

[4] According to OTA estimates of 1991 aid, total U.S. bilateral assistance for environmental technologies. including energy, is second only to Japan (OTA, 1993).

spect to transportation costs, technology, supporting infrastructure, and workforce capabilities.

OTA described potential conflicts between environmental protection and trade in *Trade and Environment: Conflicts and Opportunities (1992).* Options for addressing these conflicts in for the General Agreement on Tariffs and Trade (GATT) and North American Free Trade Agreement (NAFTA) negotiations were offered in *Industry, Technology, and the Environment: Competitive Challenges and Business Opportunities (1994).*

In *U.S. -Mexico Trade: Pulling Together or Pulling Apart? (1992),* OTA evaluated the effects of one trade agreement, the NAFTA with Mexico, on U.S. jobs and economic opportunities. Although analysis centered on U.S. industries (automobiles and parts, electronics, apparel, and agriculture), discussion of potential repercussions on both sides of the border was offered. For instance, open trade could increase prosperity and raise standards of living in both countries, or it could drive down wages and living standards in the United States without accelerating development in Mexico. Mexico's environmental laws, though comprehensive, do not appear to be well enforced and funding for pollution control, cleanup, and inspection is scarce. In OTA's estimation, the agreement Integrated Plan for the Mexican-U.S. Border Area was only a small step toward improving the border environment. It was feared that the plan lacked concrete goals and financial commitments, and called for more information exchanges and studies than actions. Nevertheless, programs are now underway to improve Mexico's economic opportunities and workplace health and safety standards, and to institute social and environmental improvements, including:

- product standards, e.g., environmental health and safety standards for exported goods;
- sanitary and phytosanitary measures, e.g., specific pesticide residue limits for agricultural and food products;
- restrictions on trade, e.g., prohibition of products containing or generating CFCs;
- dispute settlement, e.g., opening up the process to public involvement, in contrast to GATT's "closed forum" process; and
- establishment of the North American Development Bank.

Environmental and Industrial Technologies To Support Sustainability

In accordance with growing environmental awareness worldwide, OTA recently looked at environmental protection issues in terms of the economic and industrial opportunities they may present (9, 11). Environmental awareness, liberalization of trade, and the presence of multinational firms is leading to more environmental technology imports in some developing countries.

Developing countries are not equally advanced in their economic and regulatory capacities or environmental equipment needs. For most developing countries, provision of basic water, sewer, and refuse disposal services are major environmental priorities and the areas where most spending on environmental technologies occurs. Technologies such as improved cookstoves, forest management, and agricultural practices are the primary needs in some countries. Potential buyers of environmental equipment in developing countries are the electric power, chemical, petroleum refining, steel, pulp and paper, food, textile, and other process industries.

Provision of even basic environmental public works involves heavy capital expenditures, long lead times in planning and construction, and high fixed costs. Developing countries will need more systems suited to rural areas, as well as systems that reach the urban poor. A few of the environmental public works technologies discussed in *Delivering the Goods: Public Works Technologies, Management, and Finance (1991)* are appropriate for rural and low-income users (52).

Multilateral institutions and bilateral donors will play the principal role in building environmental infrastructure in developing countries. Thus, environmental product and service provid-

ers look to foreign aid and private and public investment as major clients. Linking development assistance with promotion of environmental exports may benefit business as well as bring needed environmental technology to developing countries. Some fear this could result in transfer of technologies that do not meet the recipient's developmental or environmental needs. Potential for transfer of inappropriate technologies could be reduced through safeguards to keep export promotion efforts consistent with developmental and environmental objectives (9).

The industrial sector consumes 40 to 60 percent of total commercial fossil energy used in developing countries and also uses biomass fuels heavily. Lack of efficient conversion technologies and reliable supplies contributes to the overall inefficiency of energy use and promotes adverse economic and environmental impacts. Certain technologies that lead to more efficient use of energy and materials can be applied to many industries. In rapidly industrializing countries where very large investments in new production systems are occurring, the application of cleaner production and energy-efficient technologies can provide long-term environmental and economic benefits.

Approaches to industrial development that prevent pollution often are more cost-effective than end-of-pipe water treatment technologies, Several OTA reports, beginning with *Serious Reduction of Hazardous Waste* and culminating most recently in *Industry, Technology, and the Environment (1994),* have discussed the potential for industrial pollution prevention. As noted in *Development Assistance, Export Promotion, and Environmental Technologies (* 1993), pollution prevention would be a logical candidate for more attention from bilateral and multilateral aid agencies.

Primary barriers to improve industrial efficiency in developing countries are: typical small scale needed (i.e., inability to take advantage of economy of scale), inadequate infrastructure. use of low quality or obsolete technology, and the high initial costs for installing improved technologies or constructing new facilities with improved technologies *(52).*

OTA suggested the following options with potential direct benefits to developing countries and the United States:

- provide developing countries with information and technical advice on environmental products. approaches, and available technologies;
- make cleaner production and pollution prevention priorities in multilateral aid;
- fund USAID-Department of Energy programs for transfer of innovative energy and environmental technologies to developing countries;
- increase the U.S. Trade and Development Agency's funding for capital project feasibility studies; and
- encourage U.S. firms to emphasize training in equipment and service contracts in their international activities.

The role of U.S. development assistance in strengthening developing country economies remains controversial. On the one hand, U.S. assistance programs are to promote sound economic development and policy choices, and improve developing countries' conditions for private investment and foreign exchange earnings. On the other hand, these activities are not to create competition for U.S. industry nor export U.S. jobs. A discussion of the pros and cons of using development assistance to promote trade and U.S. economic growth is provided in OTA's *Development Assistance, Export Promotion and the Environment (1993).*

Human Resources To Support Sustainability

Aid for development at the project level often aims to meet a given need within a host population, and to improve that population's potential to identify and address its own institutional and technical needs after direct assistance has ended. The latter requires attention to human capital and institutional support. Within many developing countries, the institutions needed for sustainable development are not broadly available outside of major urban areas, or to the poor in general.

Several OTA reports focus on issues of human resource development in recipient nations and domestic communities, including assessments of international telecommunications policy, tropical disease research, and local development.

Communications and Information Technologies

Facilitating communication among industrial and developing countries will be fundamental to many aspects of sustainable development. The expansion of personal computer networks and associated communication applications (e.g., Internet, Telnet) seems to portend a communication explosion. However, widespread investment will be needed to increase availability and accessibility of even the most basic communications technologies in developing countries. First, the basic telecommunications infrastructure must be expanded and upgraded. Secondary objectives are:

- ***Improve availability and accessibility to cellular radio technology.*** Remote areas in developing countries have been particularly marginalized in terms of access to information. Cellular technology, although expensive, could be appropriate in these areas where environmental constraints mitigate against traditional communications infrastructure.
- ***Promote availability and use of computerized applications.*** Increasing access to a wide variety of electronic information could assist professionals and decisionmakers to address a variety of problems from diagnosing diseases, determining what crops to plant based on international markets, or identifying potential technical experts for specific sustainable development projects. Making such information easily available in developing countries where many facilities are constrained by small budgets could significantly improve their operability.
- ***Improve and expand international communications.*** A variety of electronic technologies (e.g., Internet, electronic mail, and facsimile) have revolutionized information exchange. The expansion of electronic mail and facsimile has been dramatic and allows easy communication around much of the world, irrespective of time-zone differences that can make telephone access problematic. One- to two-day turnarounds on information is possible. Although costs vary, they seem to be decreasing, making international electronic communication more accessible. For example, many nongovernmental organizations in developing countries use computer-based communication systems to gather and disseminate information internationally.

Several organizations are working toward improved global communications. The United Nations Sustainable Development Network is assisting less developed countries develop and maintain data on domestic development activities with an ultimate goal of compiling a global network. Similarly, US AID is improving its Management Information System as a programmatic tracking mechanism. Both of these sources could contain valuable information for developing country professionals and decisionmakers. Coordination of information suppliers could generate greater benefits.

Unfortunately, developing countries are significantly disadvantaged in international telecommunications. Most developing countries lack even basic infrastructure such as sound (audio) satellite and TV broadcasting and cellular data. Sound satellite services, capable of delivering educational, health information, disaster warning, news, and entertainment services, currently reach only 30 percent of Africa's territories (5). Ninety percent of the allocated radio spectrum already is utilized by industrial countries, and many of the services sought by developing countries use parts of the spectrum desired or already occupied by industrialized countries. Furthermore, the developing country representatives responsible for choosing and lobbying for services and technologies often must do so without adequate resources or understanding of technical issues, and at tremendous economic risk. Developing countries have, therefore, had little choice but to attempt to pool their resources and develop a unified position

in international negotiations. Identification of common, regional interests and problems regarding spectrum access and use can overcome some financial and human resource constraints, but industrial country cooperation is necessary.

Agreement and support from the United States is necessary if spectrum resource inequities are to be reduced. Technical and financial assistance and cooperation from the United States could help developing countries make informed technology choices in support of development (5).

Tropical Disease-Related Biomedical Technologies

In broadest measurements, human health has improved in all developing regions over the past few decades (e.g., life expectancy at birth, mortality of children age 5 and below). Nevertheless, of total deaths in 1985 in developing countries, nearly one-half were caused by infectious and parasitic diseases. Of these, 37 percent were children under 5 (versus 3 percent in developed countries) (61).

Vectorborne, tropical diseases remain pervasive problems in the developing world:

1. Malaria is on an upward trend due to insecticide-resistant mosquitoes and resistance of the parasite to antimalarial drugs; a 7-percent increase was noted between 1985 and 1990.
2. Schistosomiasis is endemic in 76 countries; 200,000 people die of this each year; 200 million are infected and 600 million are at risk.
3. Filariasis affects 76 countries; 90 million people are infected and 900 million are at risk.
4. Onchocerciasis is endemic in 26 African, two eastern Mediterranean, and six Latin American countries: 17.6 million to 17.8 million people are infected and 85 million to 90 million are at risk (61).

U.S.-supported tropical medicine research is carried out by several multinational programs, government agencies, universities, and private research foundations and corporations, Two OTA documents about tropical disease emerged in response to congressional uncertainty over whether to continue funding the Gorgas Memorial Laboratory in the Republic of Panama: *Quality and Relevance of Research and Related Activities at the Gorgas Memorial Laboratory (1983)* and *Status of Biomedical Research and Related Technology for Tropical Diseases (1985).* OTA identified the now-defunct Gorgas Memorial Laboratory as one of the few high-quality, broadly relevant, tropical research institutions located in a tropical country. OTA suggested such institutions were needed in the Tropics to: 1) provide field information on the occurrence, natural history, and transmission of diseases; and 2) test research results+. g., drugs, vaccines, vector control programs—where diseases occur. It was also pointed out that research institutions in developing countries can serve as training facilities and can help developing countries retain professionals who otherwise would likely seek positions in industrialized countries.

International health research centers along the lines of the international agricultural research centers could make a large contribution to improving the health care/maintenance systems in developing countries. Such centers could identify and analyze the sources of health problems as well as conduct local research on design and delivery of health maintenance systems. Developments in basic and applied biomedical research hold promise for more specific disease control measures (38). *Status of Biomedical Research and Related Technology for Tropical Diseases {1985),* included an overview of the major U.S. tropical R&D supporters (e.g., National Institutes of Health, Center for Disease Control, U.S. Department of Defense, and U.S. Agency for International Development); policies concerning medical technology development, research funding, and congressional oversight; and assessment of biomedical laboratory research. Some field research pertaining to selected tropical diseases also was discussed.

Local Development

Many developing countries are still at a stage where increased investment in sanitation and clean water would bring tremendous benefits. Small and regional wastewater, drinking water,

and municipal solid waste systems used in U.S. rural areas, which might have uses in developing countries, were discussed along with metropolitan public works in *Delivering the Goods: Public Works Technologies, Management, and Finance (1991).*

Construction, operation, and maintenance of public service facilities (e.g., environmental public works and transportation) in developing countries, particularly their rural areas, impose high costs. Without these services, however, neglected populations in rural and urban areas suffer higher incidence of infectious diseases, and may be forced to invest considerable time and energy in securing water; furthermore, rural economic development options are severely limited.

An Assessment of Technologies for Local Development (198 1) assessed the potential for reducing the costs of community services using appropriate technology. Case studies were conducted of community-based projects for: resource-efficient residential architecture, solar greenhouses, small farm systems, farmers markets, resource recovery from municipal solid waste, wastewater treatment, energy generation, and health- care- systems. Critical to all the projects was public interest; availability of technical information and expertise; material, capital, and financial resources; and various types of financing (e.g., grants, cost-sharing, contracts, subsidies, conventional financing).

Appropriate technology may not be readily transferable. Because appropriate technology is tailored to special conditions and available resources at the community level, a similar outcome is not guaranteed elsewhere. Transfer of appropriate technologies in overseas projects depends on reliable information on the design, cost, and performance of the technologies themselves; and on removal of institutional barriers (e.g., opposition from commercial interests and reluctance of donors to accept innovative project designs).

Improved human capital is a precondition to transfer of technical and productive knowledge, and eventual production of new knowledge. Practicing sustainable development will depend on broad understanding of the interdependence of the Earth's social, economic, and environmental resources and the costs and benefits of adopting sustainable practices.

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C List of Abbreviations

ADF	African Development Foundation
ATI	Appropriate Technology, International
CDIE	Center for Development Information and Evaluation (USAID)
CGIAR	Consultative Group on International Agricultural Research
DAC	Development Assistance Committee (OECD)
DFA	Development Fund for Africa, U.S. Agency for International Development
EDF	European Development Fund (EU)
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
GEF	Global Environment Fund (World Bank)
IAF	InterAmerican Foundation
IARC	International Agricultural Research Centre
IDB	InterAmerican Development Bank
IIED	International Institute for Environment and Development
IMF	International Monetary Fund
NGO	Nongovernmental organization
NIC	Newly Industrialized Country
ODA	Overseas Development Administration (Great Britain)
ODA	official development assistance
ODI	Overseas Development Institute (London. UK)
OECD	Organisation for Economic Cooperation and Development
PL-480	Agricultural Adjustment Act of 1954 as Amended, ● 'Food aid"
PVO	Private voluntary organization
SD	Sustainable Development
SDI	sustainable development index
SDN	Sustainable Development Network. UNDP
STOR	sustainable terms of reference
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNIDO	United Nations Organization for Industrial Development
USAID	U.S. Agency for International Development
WB	World Bank (the International Bank for Reconstruction and Development, the International Development Agency, and the International Finance Corporation comprise the World Bank)
WCS	World Conservation Strategy

Appendix D: Principal Reviewers

D

James Adriance
InterAmerican Foundation
Arlington, VA

Nancy Alexander
Bread for the World
Silver Spring, MD

Mark Baird
World Bank
Washington, DC

David Bathrick
Chemonics, International
Washington, DC

Joseph D. Ben-Dak
Technology Group
United Nations Development Programme
New York, NY

Richard Bissell
Overseas Development Council
Washington, DC

Vary Coates
Office of Technology Assessment
Telecommunications and Computing Technologies Program

Robert Coppock
The 2050 Project
Washington, DC

Kathy Cox
Office of Technology Assessment
Environment Program

Mike Crosswell
U.S. Agency for International Development
Washington, DC

Diana Crowley
Environment and Natural Resources Policy and Training Project
Arlington, VA

Peter Donaldson
Population Reference Bureau
Washington, DC

Kevin Dopart
Office of Technology Assessment
Energy, Transportation, and Infrastructure Program

Joy Dunkerly
Office of Technology Assessment
Energy, Transportation, and Infrastructure Program

Laura Effros
U.S. Agency for International Development
Washington, DC

Frank Fender
U.S. Department of Agriculture
Office of International Cooperation and Development
Washington, DC

Donald Ferguson
U.S. Department of Agriculture
Office of International Cooperation and Development
Washington, DC

Wendell Fletcher
Office of Technology Assessment
Industry, Trade, and Employment Program

Linda Garcia
Office of Technology Assessment
Telecommunications and Computing Technologies Program

Hellen Gelband
Office of Technology Assessment
Health Program

Robert Goodland
World Bank
Washington, DC

Julie Gorte
Office of Technology Assessment
Industry, Trade, and Employment Program

Hans Gregerson
University of Minnesota
College of Natural Resources
St. Paul, MN

Charles Hall
State University of New York
College of Environmental Science and Forestry
Syracuse, NY

Jim Hester
U.S. Agency for International Development
Washington, DC

John E. Ikerd
University of Missouri
Center for Sustainable Agriculture Systems
Columbia, MO

Gary Jahn
Office of Technology Assessment
Environment Program

David Jensen
Office of Technology Assessment
Energy, Transportation, and Infrastructure Program

Inge Kaul
Human Development Report Office
United Nations Development Programme
New York, NY

David C. Korten
PCDForum
New York, NY

Robert Lester
US. Agency for International Development
Washington, DC

David Lewis
Cornell University
City and Regional Planning Department
Ithaca, NY

Arnold Lowenstein
Charles River & Associates
Boston, MA

George Mahaffey
Environment Programs
U.S. Peace Corps
Washington, DC

Sandra Nichols
Nichols Productions, Inc.
Oakland, CA

Walter Parham
China Tropical Lands Project
Vienna. VA

Ross Pomfrey
U.S. Agency for International Development
Washington, DC

Mark Powell
U.S. Agency for International Development
Washington, DC

Vernon Ruttan
Department of Agricultural and Applied Economics
University of Minnesota
St. Paul. MN

Rodney Sobin
Office of Technology Assessment
Industry, Trade, and Employment Program

William Stewart
Global Environment Program
Pacific Institute
Oakland, CA

John Stovall
Hubert Humphrey Institute of Public Affairs
University of Minnesota
Alexandria, VA

Ann Thrupp
World Resources Institute
Center for International Development and Environment
Washington, DC

Phyllis Windle
Office of Technology Assessment
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