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)

Innovative Blological Technologles for Developing Countries—Workshop Proceedings, OTA-BP-F-29 (July 1985)

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)

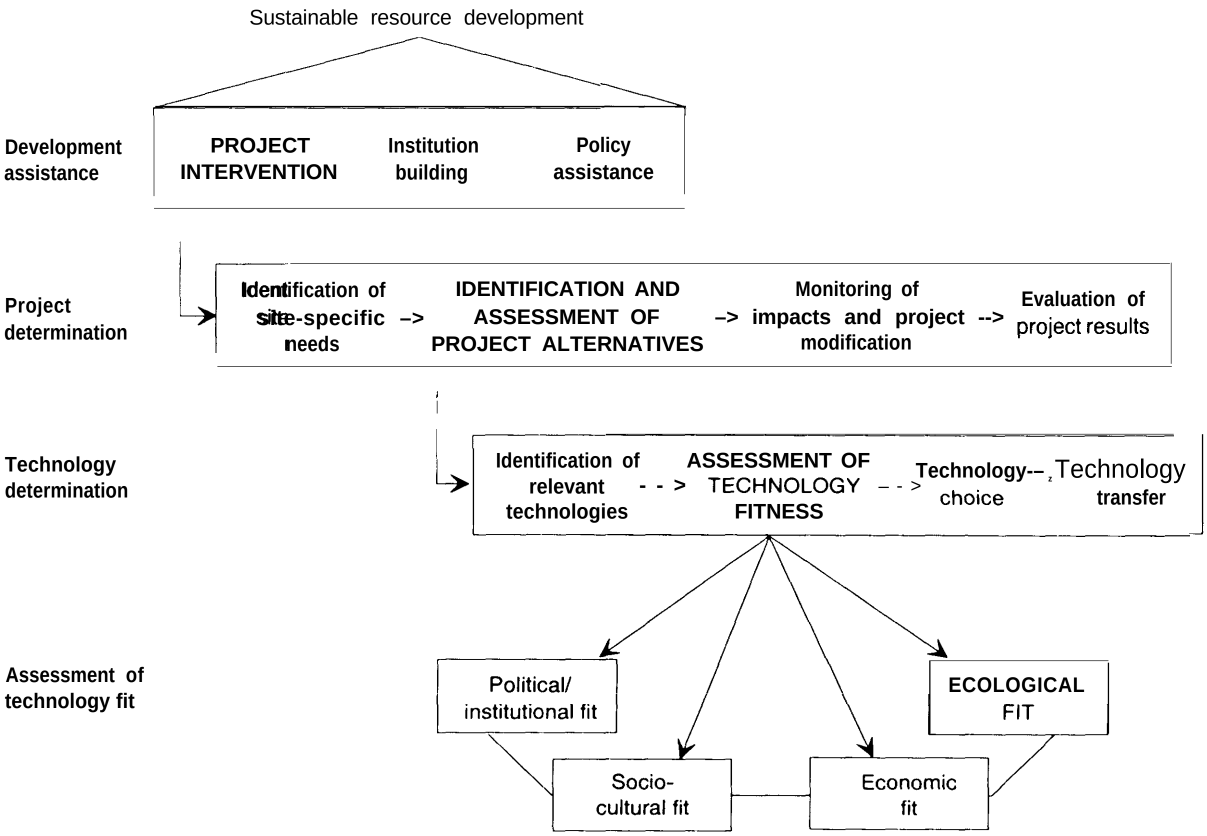
Exploratory Program

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

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 Environmental 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 options 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 classification
- 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 producers 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 enerU)’- 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 Iivestock 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 Iikely 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 Iikely 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 Iong-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 (SO_2) suspended particulates, carbon monoxide (CO), nitrogen oxides (NO_x), and carbon dioxide (CO_2) emissions Ieading to acid rain, urban smog, respiratory infections and, potentially, global warming Has highest per unit energy CO_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 CO_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 CO_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 will 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 SO_2, suspended particulates, CO, NO_x, and CO_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 will 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 SO_2, suspended particulates, CO, NO_x, and CO_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-lntenswe 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 Iikely 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 Iittle 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 Iimited 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 Iikely to Iimit 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 Productlon 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 systemwide 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 providers 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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